(Preliminary)

Unilateral vs. Cross Licensing
: A theory and new evidence on the firm-level determinants

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Abstract

This paper examines the firm level determinants of the incidence of cross-licensing. It develops a simple stochastic theory explaining such incidence, and confirms its implications based on new dataset of licensing contracts by Japanese firms. Among major findings are:

(1) Licensing probability has an almost linear relationship with the size of a potential licensor.

(2) Cross-licensing is more prevalent between large and symmetric firms.

(3) A licensing contract with only patents is more likely to involve cross-licensing than that with only trade secret.

(4) A licensor is on the average larger than a licensee.

Key words: cross-licensing, licensing contracts, patent
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1 Introduction

Technology licensing plays a very important role in innovations. It is an important mechanism for knowledge dissemination, and simultaneously it enhances the ex-ante incentive for R&D[i]. It can also affect the division of labor in innovations by allowing an entry of a firm specialized in R&D (see Arora and Gambardella (2001)). Whether stronger IPRs promote or harm innovation may depend critically on whether stronger IPRs promote licensing or not[ii]. Given this importance, licensing has attracted increasing research attentions in recent years. However, while there are many theoretical studies on licensing[iii], empirical work, especially those which have strong theoretical underpinnings, is still very scarce[iv]. As a result, some of the basic structure of licensing contracts are still not well accounted for.

This study aims at analyzing the firm level determinants of the incidence of a cross-license. In particular, it analyzes how it is related to firm size and the types of IPRs covered by a contract. It also inquires why a licensor tends to be larger than a licensee in observed licensing contracts. Existing theoretical literature tends to analyze unilateral licensing and cross-licensing separately and does not provide a guide for analyzing these basic questions. Existing empirical literature focuses mainly on inter-industry differences in the incidence of cross-licensing (See Anand and Khanna (2000) and Arora, Fosfuri and Gambardella (2001)), so that it has not systematically investigated how its variation within industry is determined.

In this paper we will develop a simple stochastic theory explaining the incidence of cross licensing. We focus entirely on ex-post licensing behaviors. The theory is based on a simple assumption that the probability that a firm will seek a license of a specific external technology is very small and that such probability is independent with each other across available external technologies. Although a very simple model, we can extract the following testable implications: (1) cross-licensing is more prevalent between large and symmetric firms, (2) a licensing contract with patents is more likely to involve cross-licensing than that with trade secrets, and (3) a licensor is on the average larger than a licensee.

In order to test these implications, we need to have a database of licensing contracts matched with corporate information on both licensors and licensees. We have developed such database based on the corporate reports filed by the Japanese manufacturing firms in 1999FY under the Security Exchange Law. A substantial number of Japanese firms disclosed the existing licensing contracts that their management regarded to be important, complying with this legal requirement. We have found econometric evidence strongly supportive of the above implications, based on these dataset.

The rest of the paper consists of the following. Section 2 provides the definitions and explanations of the database of licensing contracts which we have developed as well as the descriptive statistics. Section 3 presents a theoretical framework and testable implications. Section 4 presents the estimation results and discussions. Section 5 concludes.

2. Licensing contracts database

Our sample is comprised of 1,144 licensing contracts, which were disclosed by 268 Japanese manufacturing firms in their financial and corporate reports for 1998FY and for which the employment data of both licensor and licensee was available[v]. These Japanese manufacturing firms were listed on the first section of the Tokyo Stock

Exchange. The Security Exchange Law requires a publicly traded company to disclose important contracts for its business, which has encouraged many firms to disclose licensing contracts, although the coverage of the licensing contracts is far from being comprehensive. We have consolidated contracts reported by both a licensor and a licensee.

Table 1 shows the number of contracts and their composition by six industry sectors. It also shows the same set of information with respect to the sub-sample, for which the R&D data of both licensor and licensee are available. Industrial classification follows that of a reporting firm in the Tokyo Stock Exchange. We consolidate the industrial classification into the following five categories: chemicals (*che*), pharmaceuticals (*pha*), materials (*mat*), general machinery and transportation machinery (*mac*), electronics and electrical machinery (*ele*) and the other industries (*oth*). These six categories of industries are broadly defined based on technology characteristics[vi]. The average incidence of cross-licensing is 8.5% for the entire sample, and it is 14.1% for the sub-sample with R&D data. The incidence of cross-licensing is higher for the sub-sample, primarily because R&D data is less available for the firms in developing countries and cross-licensing by a Japanese firm is much less frequent with these firms. Cross licensing is most extensive in electronics and electrical industry.

(Table1)

Table 2 shows the composition of licensing contracts by the relationship between the licensing partners, by the IPRs specified in a contract and by the nationality of the licensing partner. In this Table, we distinguish a licensing partner to be either independent from the reporting firm, its subsidiary, a related firm which is short of subsidiary[vii] or its parent. We introduce four categories in the nationalities of the licensing partners of Japanese firms: Japan, the USA, the other high-income OECD economies (HIO)[viii], and the rest of the countries. According to the Table, cross-licensing is most prevalent between independent firms. It is significantly more prevalent when a licensing contract covers only patents, although there exist cross licensing contracts with only know-how. Finally, it is most frequent in the licensing contracts with the US firms.

(Table2)

3. Theory and estimation framework

3.1 Theory and testable implications

We assume that licensing is entirely ex-post. Firm j has n_j technologies. For simplicity, we assume that the probability that firm k will seek a license with respect to an external technology in the industry ($\alpha(n_k)$) is so small that the following condition is satisfied:

$$\alpha(n_k)n_j << 1 \qquad (1)$$

In addition, such probability is assumed to be identical and independent across all technologies existing outside of firm k. Given these assumptions, the probability that firm k will seek a license from firm j with n_j technologies is proportional to n_j and is given by

$$p(k \leftarrow j)_{license} = \alpha(n_k)n_j \qquad (2)$$

, since we can ignore the higher order terms. The function $\alpha(n_k)$ may or may not increase with n_k. On the one hand a firm with a larger technology portfolio is more likely to have a technology substituting external technologies, but it would have larger scope of business on the other, which would in turn increase the necessity of using the technologies of the other firms.

Cross-licensing between firm *j* and *k* is going to take place only when each firm decides to use the technologies of the other firm. Assuming that the probability of a firm to use the technologies of another is independent, the probability that cross-licensing will take place between firm *j* and *k* is given by

$$p(j,k)_{cr} = \alpha(n_k)\alpha(n_j)n_j n_k \tag{3}$$

Licensing (either unilateral license or cross-license) will take place when one or both of the firms would decide to use the technologies of the other. Such probability is given by

$$p(j,k)_{license} = \alpha(n_k)n_j + \alpha(n_j)n_k - \alpha(n_k)\alpha(n_j)n_j n_k \tag{4}$$

Given equations (3) and (4), the probability of cross-licensing conditional upon licensing is equal to the following:

$$p(j,k;licensing)_{cr} = \alpha(n_k)\alpha(n_j)n_j n_k / \{\alpha(n_k)n_j + \alpha(n_j)n_k - \alpha(n_k)\alpha(n_j)n_j n_k\} \tag{5}$$

Note that the above conditional probability is unaffected even if contracts are reported by either or both of the firms only with some probability (φ), as long as such probability is common between a cross-license and a unilateral license. It is convenient to rewrite equation (5) in the following manner:

$$p(j,k;licensing)_{cr} = 1/[1/\{\alpha(n_k)n_j\} + 1/\{\alpha(n_j)n_k\} - 1] \tag{6}$$

We can derive the following four propositions for empirical analysis, based on equations (5) and (6).

If we double the level of *α*, the probability of cross-licensing quadruples as shown by equation (3), while that of licensing as a whole increases but short of doubling as shown by equation (4). Thus, we have the following proposition:

Proposition 1

The higher the probability of patent infringement for a given number of technologies, the higher is the conditional probability of cross-licensing.

Proof: This is evident from equation (6), given that higher probability of patent infringement implies higher α.

Thus, the more complementary the innovations of different firms are either in research or in the use of new technology, the more prevalent is cross-licensing. In addition, the expansion of the scope of patent protection would increase the conditional probability of cross-licensing. Furthermore, it also implies that trade secret results in less cross-licensing than patents, since trade secret does not provide an exclusive right to a firm owing it. That is, the use of an independently discovered technology does not result in the infringement in the case of trade secret, but it does in the case of a patent, although a firm may still wish to cross-license trade secret, in order to avoid duplication of research.

Similarly, the conditional probability of cross-licensing would increase with firm size when α is non-decreasing with firm size.

Proposition 2

If $\alpha(n_k)$ is non-decreasing with n_k, increasing the firm size of either a licensor or a licensee would increase the conditional probability of cross-licensing.

Proof: When such condition is satisfied, increasing the size of a firm would increase either or both of $\alpha(n_k)n_j$ and $\alpha(n_j)n_k$. Then, equation (6) provides the result.

In the case of constant α, the probability of cross-license is larger when the firms are more symmetric. This is because we have

$$p(j,k;licen\sin g)_{cr} = \alpha n_j n_k /(n_j + n_k - \alpha n_j n_k) \qquad (7)$$

and $$n_j n_k = \{(n_j + n_k)^2 - (n_j - n_k)^2\}/2.$$

A simple arithmetic example clarifies the logic of why the more symmetric the firm sizes are, the more prevalent is cross-licensing. If both firms find the probability of seeking a license from another firm to be 10%, the conditional probability of cross-licensing among such pair of firms is equal to 5%. However, if one of the firms finds the probability of seeking a license to be 19% and the other to be 1%, the conditional probability of cross-licensing is equal to only 1%. Thus, the asymmetry of the size of the firms reduces the probability of cross-licensing. More generally, we have the following proposition, including the case where the α function is not constant.

Proposition 3

Any small deviation from symmetry in firm size reduces the conditional probability of cross-licensing.

Proof: See appendix 2

In the following, we assume that $\alpha(n_k)$ has a linear relation with n_k, so that

$$p(k \leftarrow j)_{license} = \alpha_0(1+\theta n_k)n_j \qquad (8),$$

where θ is a parameter. In this case, the probability of a license from a potential licensor j to a potential licensee k depends on the size of a potential licensor j and on the multiple of the sizes of the two firms. Since the size of a licensee affects the probability of licensing only through the cross-term with the size of a licensor, we have the following proposition.

Proposition 4

The expected size of a licensor is larger than that of a licensee in unilateral licensing contracts, if equation (8) holds.

Proof: For any pair of firm *j* and *k*, the expected size of a licensor (a licensee) is respectively given by

$$Size_{licensor} = \{\alpha(1+\theta n_k)n_j - p(j,k)_{cr}\}n_j + \{\alpha(1+\theta n_j)n_k - p(j,k)_{cr}\}n_k,$$

and

$$Size_{licensee} = \{\alpha(1+\theta n_k)n_j - p(j,k)_{cr}\}n_k + \{\alpha(1+\theta n_j)n_k - p(j,k)_{cr}\}n_j$$

The above equations immediately suggest that the expected size of a licensor is larger than that of a licensee for any pair of firms, since

$$Size_{licensor} - Size_{licensee} = \alpha(n_j - n_k)^2 \geq 0 \qquad (9)$$

Thus, generally, the expected size of a licensor is larger than that of a licensee in unilateral licensing contracts. (QED)

Note that the above inequality is reversed if the probability of a license from a licensor j to a licensee k is proportional to the size of a licensee k rather than to the size of a licensor j (that is, if we have $p(k \leftarrow j)^{Al}_{license} = \alpha_0(1+\theta n_j)n_k$). Consequently, the above proposition provides a test discriminating the assumption (8) from the above alternative assumption. Such test is important, since the two assumptions are observationally equivalent in determining the conditional probability of cross-licensing (i.e. implying the identical equation (5)), even though the alternative assumption does not have a good theoretical basis.

For the purpose of providing a tractable analytical framework for directly estimating the determinants of conditional probability, we further assume that,

$$\left|\theta n_k\right| << 1 \qquad (10).$$

It says that the size of a licensee does not significantly affect the probability that it receives a license[ix]. Given the assumptions of (1), (8) and (10), equations (5) can be approximated by the following manner:

$$p(j,k;licen\sin g)_{cr} \cong \alpha_0 n_k n_j/(n_j+n_k) + \alpha_0\theta\{n_k n_j/(n_j+n_k)\}\{(n_k{}^2+n_j{}^2)/(n_j+n_k)\} \quad (11).$$

This equation can be used to provide estimates of α_0 and θ of equation (8).

3.2 Framework of estimation

In order to test the above theoretical propositions we estimate the following two equations for the conditional probability of cross-licensing. First, we estimate directly equation (11):

$$\begin{aligned} p(j,k;licen\sin g)_{cr} &= \beta_0 + \beta_1 A_{k,j} + \beta_2 B_{k,j} + \beta_3(related) + \beta_4(opat) \\ &+ \beta_5(both) + controls_{industry} + controls_{region} \end{aligned} \qquad (12)$$

, where $A_{k,j} = n_k n_j/(n_j+n_k)$ and $\mathrm{B_{k,j}} = \mathrm{A_{k,j}}(n_k{}^2+n_j{}^2)/(n_j+n_k)$. We estimate this linear probability model by OLS, using heteroskedasticity-robust standard errors. The coefficients of $A_{k,j}$ and $B_{k,j}$ in equation (12) give the estimates of the parameters of *α* function: $\beta_1 = \alpha_0$ and $\beta_2 = \alpha_0\theta$. We expect that β_1 is positive, but β_2 can be either positive or negative. Since equation (12) depends on the linear approximation of equation (5), we also estimate the Probit model with the following latent variable. This specification incorporates the implications of the propositions 2 and 3 into independent variables: cross-licensing is more prevalent between large and symmetric firms,

$$\begin{aligned} latent\,(j,k;licensing)_{cr} &= \delta_0 + \delta_1 mn_{k,j} + \delta_2 arn_{k,j} + \delta_3(related) \\ &+ \delta_4(opat) + \delta_5(both) + controls_{industry} + controls_{region} \end{aligned} \tag{13}$$

In equation (13), $mn_{k,j} = \ln\{(n_k + n_j)/2\}$ gives the logarithm of the average firm size and $arn_{k,j} = |\ln(n_k / n_j)|$ gives the absolute value of the logarithm of the relative firm size. We expect a positive δ_1 and a negative δ_2, from propositions 2 and 3. We measure the size of firms (n_k, n_j) both in terms of employment (*eml,* the unit of which is 10,000) and R&D (*rd,* the unit of which is 1 Billion US$). Thus, $A_{k,j}$ in equation (12) ($mn_{k,j}$ in equation (13)) is respectively given by $Aeml_{k,j} = eml_k eml_j /(eml_j + eml_k)$ ($meml_{k,j} = \ln\{(eml_k + eml_j)/2\}$).

The rest of the variables are common for equation (12) and (13). The dummy variable *related* indicates whether the licensing relation involves a related firm, covering three cases (a licensee is a subsidiary, a related firm short of subsidiary or a parent firm of a licensor). Although not directly implied by the above theory, it seems to be reasonable to expect that cross-license is less prevalent for the licensing relationship with a related firm. This is because the efficient coordination of R&D within the group of related firms would result in the allocation of R&D tasks in such a manner that the R&D tasks with higher interdependency would be internalized within a single firm, while the R&D tasks with only unilateral dependency could be divided between different firms within a group. Thus, cross-licensing would be rare in licensing contracts involving a related firm, since the R&D coordination within a firm would make (ex-post) cross-licensing unnecessary. The dummy variable *opat* indicates whether the licensing contract covers only patents or not. The dummy variable *both* indicates whether the contract covers both patents and know-how. Thus, the base of estimation is a contract with only know-how. Proposition 1 would imply that the incidence of cross-licensing would be higher for a contract with only patents than that with only know-how: *opat* has a positive sign. Thus, the theoretical predictions are that: $\beta_3\,(\delta_3)$ are negative and $\beta_4\,(\delta_4)$ are positive.

As for control variables, we introduce five industry dummies and four regional variables (including three dummies). The function $\alpha(\mathrm{n_k})$ would depend significantly upon the nature of technology. Such probability would be high in those industries where technological interdependency among firms in either production or research is high. We capture such effects by industry dummies with electrical and electronics industry as the base. We use the following five dummies: *che* for chemical industry, *pha* for pharmaceutical industry, *mat* for material industry, *mac* for machinery industry and *oth* for the other industry. We expect negative coefficients for these dummies, since past studies suggest that technological interdependency among firms is the highest in electrical and electronics industry (See Anand and Khanna (2000)).

The regional variables control the regional variations in the relationship between the proxy of firm size (employment size and R&D expenditure) and the number of technologies (n). For a given level of n, firm size would vary, depending on the difference in the degree of vertical integration, factor prices, the composition of R&D and the other unaccounted-for factors across nations. We control these differences by the GNP per capita of a country with that of Japan as the basis (*gnpgap,* the unit of which is 10,000 US$) in which a licensing partner exists, and three regional dummies: *jusa* for a licensing with a US firm, jhio for a licensing with a firm in high-income OECD countries excluding Japan and the USA, and a dummy *joth* for a licensing with a firm in the other countries. Thus the base of estimation is a domestic licenses. See Appendix 3 for a summary statistics of the variables.

Let us turn to Proposition 4 on the relative size of a licensor in unilateral licensing. It suggests the following equation for the size of a licensor relative to that of a licensee.

$$\begin{aligned}\ln(n_j / n_k) = \beta_0 + \beta_1(lsorpar) + \beta_2(lsorsub) + \beta_3(\mathrm{Re}\ gion_{licensor}) \\ + \beta_4(\mathrm{Re}\ gion_{licensee})\end{aligned} \qquad (14)$$

The dependent variable is the logarithm of the size of employment or research expenditure of a licensor divided by that of a licensee ($\ln(n_j / n_k)$ = *rem* or *rrd*). As for the independent variables, *lsorpar* is a dummy for the contract in which a licensor is a parent company and the licensee is either a subsidiary or a related firm short of a subsidiary. *Lsorsub,* on the other hand, indicates a situation where a licensee is a parent company and the licensor is a subsidiary firm. A subsidiary is often smaller than a parent firm, since the parent firm provides managerial and supporting services to a subsidiary. Thus, we expect that *lsorpar (lsorsub)* has a positive (negative) coefficient. Regional variables control the regional difference of firm sizes, reflecting the difference in the degree of vertical integration, factor prices and the others. We use the same set of regional dummies as above for both a licensor and a licensee. Proposition 4 suggests that we have a significantly positive estimate for β_0, since $\beta_0 = 0$ implies that the licensor has the same size as the licensee on the average.

4 Estimation results

4.1 Conditional probability of cross-licensing

Table 3 provides four estimation results when we measure the size of a firm by its employment. The first and second estimations are based on the linear probability model (12) and the rest are based on the latent variable model (13). While the first and the third estimation use the variable (*related*) as an independent variable, the second and fourth estimations use the IPR variables (*opat* and *both*) as independent variables. Since only half of the sample firms report IPR information, the size of the sample is significantly reduced for these estimations. We cannot use the two set of variables simultaneously, since there are no cross-licensing contracts with a related firm in the smaller sample with information on IPR. Thus, estimation 2 and 4 use only the contracts between independent firms as the sample.

(Table 3)

Estimation results provide strong supports to the theoretical model in the above section. Almost all estimated coefficients have expected signs and most of them are highly statistically significant, although the explanatory power of the equations is not very high (R^2 is 0.18 for estimation 1 and 0.28 for estimation 3). The coefficients of *Aeml* in equation 1 and 2, which provide the estimate of α_0, are statistically significant at 1%. They imply that the probability of a firm seeking a license from another firm is 5.5% (or 5.9%) when the latter is of the employment size of 10,000 persons. On the other hand, the coefficient estimates of *Beml* are statistically insignificant, so that we cannot reject the hypothesis that θ is zero. According to the estimate (see the last row of Table 3), 10,000 increase of the employment size reduces such probability only by 1.7% (or 2.1%). Thus, a licensing probability has an almost linear relationship with the size of a potential licensor. Estimations 3 and 4 clearly show that cross-licensing is more prevalent between large and symmetric firms in employment size, fully consistent with the above results from estimations 1 and 2. The average size of the firms (*meml*) has a highly significant positive coefficient, and the relative size of the firms in the absolute terms (*areml*) has a highly significant negative coefficient in both equations, each at 1% level.

Turning to the effects of the variables *rel*, *opat* and *both*, estimation 1 shows that the dummy for a subsidiary and related firm (*rel*) has a highly significant negative coefficient, consistent with a theoretical consideration, although the coefficient is not significant in estimation 3. The dummy for a contract with only patent (*opat*) has a significant positive coefficient in estimation, consistent with our theoretical prediction. It has a positive but insignificant coefficient in estimation 4. The dummy for a contract with both patent and know-how (*both*) has a negative coefficient, although not significant.

Let us turn to control variables. All industry dummies, except for that of the other industries (*oth*), have negative coefficients, showing that cross-licensing is most prevalent in electrical and electronics industry. The negative coefficients are large and highly significant for pharmaceutical industry and material industry in all estimations. In these two industries innovations of firms are much less interdependent among firms than in electrical and electronics industry. As for regional variables, the dummy for the licensing contract with the firms in the USA has a highly significant positive coefficient in all estimations, while the other dummies are not significant. The gap of GNP per capita from that of Japan (*gnpgap*) has an insignificant coefficient. Since its coefficient is small and the GNP per capita gap between Japan and the USA is small (0.3 in favor of

Japan), the estimation results, including those of estimation 1 and 3 with a positive coefficient for *gnpgap*, shows that the interdependency of innovations is more significant between Japanese and US firms than between Japanese firms in terms of the incidence of cross-licensing[x].

Table 4 provides the results of estimation when we measure the size of firm by R&D (*rd*). They are based on a more limited sample of the firms, for which R&D data is available, and use the same models as for Table 3. The results are highly consistent with those in Table 3. The coefficients of *Ard* in equation 1 and 2, which provide the estimate of α_0 , are statistically significant at 1%. They indicate that the probability of licensing-in by a firm with a potential licensor with 100 M$ R&D budget is 5.6%. The coefficient estimates of *Brd* are statistically insignificant, as before. Thus, a licensing probability has an almost linear relationship with the size of a licensor. Estimations 3 and 4 show that cross-licensing is clearly more prevalent between large and symmetric firms in terms of R&D. The patent variable (*opat*), an industry dummy (*pha*) and the regional dummy *(jusa*) have significant coefficients either at 1% or 5%[xi], except for jusa in estimation 4.

(Table 4)

4.2 The size of a licensor relative to that of a licensee in unilateral contracts

Table 5 shows the estimation results for equation (14), with and without regional control dummies. The first and second estimations use the logarithm of employment (*eml*) to measure the size of a firm, while the third and fourth estimations use the logarithm of R&D (*rd*) to measure the size of a firm. As shown as estimation 1, the average relative size of a licensor adjusting the parent and subsidiary relationship is 1.29 in the logarithmic term (or 3.65 in the absolute term) and is significantly larger than zero at

1% level. As expected, the parent dummy (*lsorpar*) for a licensor has a significant and positive sign (i.e. the parent firm is significantly larger than a subsidiary). Similarly, the subsidiary & related firm dummy (*lsorsub*) for a licensor has a significant and negative coefficient.

(Table 5)

Estimation 2 adds regional dummies to control international differences in the degree of vertical integration, relative factor prices and other non-accounted-for factors. The parent dummy (*lsorpar*) for a licensor has a significant and positive sign and the subsidiary & related firm dummy (*lsorsub*) for a licensor has a significant and negative coefficient, as in estimation 1. The estimated average size of a licensor relative to that of a licensee for domestic licensing between independent firms is again positive and highly significant. It is 3.00 in the absolute terms. The dummy representing high income OECD countries (excluding the USA) has a positive and significant coefficient when it refers to a licensor status (*lsorhio*), and a negative coefficient when it refers to a licensee status (*lseehio*). On the other hand, the GNP per capita variable has a negative and significant coefficient when it refers to a licensor status (*lsorgnpgap*), and a positive coefficient when it refers to a licensor status (*lsorgnpgap*). The coefficients of these variables indicate that a Japanese firm, both as a licensor and as a licensee, is smaller than a firm in the other high income OECD countries[xii]. The dummy representing the other countries has a negative and significant coefficient when it refers to a licensor status (*lsoroth*), and a positive and significant coefficient when it refers to a licensee status (*lseeoth*). The coefficients of these variables indicate that the firms in lower in come countries tend to be smaller in size than a Japanese firm. The estimation 3 and 4, which are based on R&D, provide the results largely consistent with these results. The estimated average size of a licensor relative to that of a licensee for domestic licensing between independent firms is 4.2 according to estimation 3 (and 3.7 according to estimation 4) in the absolute term.

5. Conclusions

This paper has examined how firm size and the IPRs specified in the contracts can explain the incidence of cross licensing. We have developed a simple stochastic theory explaining the conditional probability of cross license, and derived implications on the incidence of cross-license as well as on the relative size of a licensor. We have tested these implications, based on newly collected dataset of licensing contracts by Japanese firms.

The major findings are the following:

(1) Licensing probability has an almost linear relationship with the size of a potential licensor (employment or R&D). The size of a potential licensee does not affect such probability (negatively if any).

(2) A theory suggests that the conditional probability of cross-licensing increases with the sizes of a licensor and a licensee as well as with their symmetry, given that cross-licensing depends on the matching of double wants. The empirical evidence strongly supports this implication.

(3) A theory suggests that the incidence of cross-licensing is higher for a contract with a patent right than that with trade secret, since patent is an exclusive right unlike trade secret. We found evidence strongly supportive of this implication: a licensing contract covering only patents is found to involve cross-licensing significantly more frequently.

(4) We also found that the incidence of cross-licensing is larger for a licensing between

Japanese and US firms than that among Japanese firms. It suggests that innovations are more interdependent between Japanese and US firms than among Japanese firms.

(5) A licensor is on the average significantly larger than a licensee in terms of employment and R&D, which supports our theoretical assumption that the size of a potential licensor is the primary determinant of the licensing probability.

Appendix 1 (Data sources)

The employment and R&D data of the Japanese firms located in Japan are drawn from NEEDS (Nikkei Economic Electronic Database System). The employment of Japanese firms is based on a consolidated account, so as to improve the international comparability of data. The employment and R&D data of foreign firms are collected from the World Scope database. All of these data belong to 1998FY. In order to obtain R&D data in a common base in US $, we converted the national currency data by PPP exchange rate in 1998CY as reported by the World Development Indicators (2000) of the World Bank. The employment data of the foreign subsidiaries and related firms of the Japanese firms are from Kaigai Shinshutsu Kigyo Soran (Japanese Overseas Investment) of Toyo-Keizai.

Appendix 2 (Proof of proposition 3)

Consider the following deviation from a symmetric firm size: $n_j = n(1+\Delta)$ and $n_k = n(1-\Delta)$. In this case, we have

$$p(j,k)_{cr} = \{\alpha(n) + \alpha' n\Delta\}\{\alpha(n) - \alpha' n\Delta n\}(n + n\Delta)(n - n\Delta)$$

$$= \{\alpha^2 - (\alpha')^2 n^2 \Delta^2\}(n^2 - n^2\Delta^2) \cong \alpha^2 n^2 [1 - \{(\alpha' n/\alpha)^2 + 1\}\Delta^2]$$

$$p(j,k)_{license} + p(j,k)_{cr} = \alpha(n_k)n_j + \alpha(n_j)n_k = (\alpha - \alpha' n\Delta)(n + n\Delta) + (\alpha + \alpha' n\Delta)(n - n\Delta)$$

$$\cong 2\alpha n\{1 - (\alpha' n/\alpha)\Delta^2\}$$

Thus, we have

$$p(j,k;licensing)_{cr} \cong \alpha n/2[1 - \{(\alpha' n/\alpha)^2 - \alpha' n/\alpha + 1\}\Delta^2]$$

Since the bracketed term in front of Δ^2 is positive, the conditional probability of cross licensing declines as Δ increases in the absolute term.

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[i] Licensing may also be used strategically to lower the incentive of a competitor to invent around the initial innovation (see Gallini and Winter (1985)).

[ii] See Gallini and Scotchmer (2002) and Besen and Maskin (2000) in the domestic context. See Helpman (1993) and Yang and Maskus (2001) in the international context.

[iii] See Gallini and Winter (1985, 1990), Katz and Shapiro (1985, 1986), Kamien and Tauman (1986), Fershtman and Kamien (1992), Eswaran (1993), and Shapiro (2000).

[iv] There are not many empirical studies of licensing. Exceptions are Taylor and Silberston (1973), Caves, Crookell and Killing (1983), Anand and Khanna (2000) and Arora and Gambardella (2001).

[v] See the appendix 1 for the sources of employment and R&D data.

[vi] We have chosen to classify industries in the following manner. The chemical industry (*che*) in this paper covers not only a narrowly defined chemical industry, but also petroleum, pulp & paper and textile industries. Since licensing contracts by the textile industry often involves licensing of chemical process, we have chosen to consolidate textile industry and chemical industry. On the other hand, we analyze pharmaceutical industry independently, since product technology is much more important in this industry. Material industry (*mat*) covers glass & stone, steel, non-ferrous metal and metal products industries. Machinery industry (*mac*) covers general machinery and transportation machinery industries. Electronics and electrical machinery industry (*ele*) covers a narrowly defined electronics and electrical machinery industry as well as precision machinery industry.

[vii] Typically, a (licensor) firm has more than 50% of the ownership stake on the licensee in the case of subsidiary, and it has less than or equal to 50% of the ownership stake but more than or equal to 20% of the stake in the case of a related firm.

[viii] High-income OECD economies are those in which 1998 GNP per capita was $9,361 or more, and are the members of the OECD. Our classification of development level follows that of World Development Indicators (2000).

[ix] This assumption may be justified by the fact that the size of a licensee has two effects on the licensing probability which are offsetting each other. We will see whether the empirical findings are consistent with such assumption.

[x] One interpretation of such pattern is that a US firm plays a hub as a supplier of the basic technology for Japanese firms and it also requires a grant-back condition in its licensing to the latter.

[xi] The variable (*rel*) is dropped in estimation 2 and 4 in Table 4, since there are no cross-licensing contracts with subsidiary or related firms in the sub-sample with R&D data, as in the case of Table 3.

[xii] The average *gnpgap* is -0.83 for high-income OECD countries and -2.73 for the other countries. Thus, the licensor belonging to high-income OECD countries is larger than a Japanese licensor by 1.43 (=0.88-0.66*(-0.83)), and the licensee belonging to high-income OECD countries is larger than

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a Japanese licensee by 0.64 (=0.65+0.013*(-0.83)).

Table1 Number and composition of licensing contracts by Sectors

Industry	Number of Japanese firms	Number of licensing contracts	Cross licensing, %
Chemicals (*che*)	68(46)	294(111)	3.4(7.2)
Pharmaceuticals (*pha*)	22(20)	108(87)	1.9(2.3)
Materials (*mat*)	34(19)	139(50)	2.9(6.0)
General and transportation machinery (*mac*)	55(27)	183(57)	3.3(8.8)
Electrical and electronics (*ele*)	72(53)	371(244)	19.1(24.6)
Other (*oth*)	17(8)	49(19)	8.2(10.5)
Total	268(173)	1144(568)	8.5(14.1)

Note: The figures in parentheses represent the number and the composition of licensing contracts by R&D expenditures.

Table2 Number and composition of licensing contracts by firm relation/IPR/nationality

Licensing	by firm relation				by IPR			by nation of partners			
	Independent firm	Subsidiary firm	Not subsidiary but related	Parent Firm	Only Patent	Patent and knowhow	Only knowhow	Japan-Japan	Japan-USA	Japan-HIO	Japan-Other
Number of licensing contracts	848	210	62	11	391	109	108	263	378	174	329
Cross licensing	96	1	0	0	75	2	6	16	67	10	4
Cross licensing, %	11.32%	0.48%	0.00%	0.00%	19.18%	1.83%	5.56%	6.08%	17.72%	5.75%	1.22%

Table 3. Estimates of conditional probablity of cross-licensing based on employment

	OLS estimation of linear probability model							Probit estimation of the latent variable model					
	Estimation 1			Estimation 2				Estimation 3			Estimation 4		
	Number of obs = 1131 F(12, 1118) = 10.25 R-squared = 0.1764 Root MSE = 0.2556			Number of obs = 608 F(12, 595) = 8.02 R-squared = 0.1889 Root MSE = 0.31283				Number of obs = 1131 LR chi2(12) = 185.23 Log likelihood = -238.35 Pseudo R2 = 0.2798			Number of obs = 608 LR chi2(12) = 128.63 Log likelihood = -178.02 Pseudo R2 = 0.2654		
chioce	Coef.	Robust Std. Err.		Coef.	Robust Std. Err.		choice	Coef.	Std. Err.		Coef.	Std. Err.	
Aeml	0.0553	0.0179	***	0.0585	0.0208	***	meml	0.2568	0.0624	***	0.2813	0.0838	***
Beml	-0.0009	0.0007		-0.0012	0.0008		areml	-0.1793	0.0429	***	-0.1938	0.0517	***
rel	-0.0355	0.0107	***				rel	-0.6769	0.4142				
opat				0.0981	0.0394	**	opat				0.2949	0.2688	
both				-0.0229	0.0324		both				-0.8007	0.4393	*
che	-0.0643	0.0230	***	-0.0452	0.0336		che	-0.3253	0.2032		-0.0836	0.2751	
pha	-0.1047	0.0242	***	-0.1281	0.0326	***	pha	-0.9488	0.3401	***	-1.0052	0.4663	**
mat	-0.0824	0.0234	***	-0.0953	0.0356	***	mat	-0.6353	0.2742	**	-0.6817	0.3467	**
mac	-0.0813	0.0248	***	-0.0547	0.0463		mac	-0.5633	0.2367	**	-0.2209	0.3435	
oth	-0.0321	0.0446		0.0679	0.0773		oth	-0.0530	0.3093		0.5230	0.3768	
jusa	0.0967	0.0245	***	0.1435	0.0346	***	jusa	0.6491	0.1889	***	0.6051	0.2475	**
jhio	0.0006	0.0247		-0.0082	0.0343		jhio	0.0890	0.3021		-0.2727	0.4593	
joth	0.0251	0.0282		0.0430	0.0581		joth	0.6475	0.7808		-0.2444	1.3246	
gnpgap	0.0029	0.0071		-0.0131	0.0123		gnpgap	0.2922	0.3089		-0.2500	0.5056	
cons	0.0677	0.0229	***	-0.0162	0.0448		cons	-1.2126	0.1889	***	-1.5237	0.3136	***

θ	-0.0169			-0.0212		

Note: *** significant at 1% level, **significant at 5% level and *significant at 10% level

Table 4. Estimates of conditional probablity of cross-licensing based on R&D expenditures

	OLS estimation of linear probability model							Probit estimation of the latent variable model					
	Estimation 1			Estimation 2				Estimation 3			Estimation 4		
	Number of obs = 567 F(12, 554) = 12.27 R-squared = 0.2275 Root MSE = 0 .3095			Number of obs = 376 F(13, 362) = 9.60 R-squared = 0.2564 Root MSE = 0.3402				Number of obs = 555 LR chi2(10) = 98.48 Log likelihood = -179.65 Pseudo R2 = 0.2151			Number of obs = 375 LR chi2(12) = 102.68 Log likelihood = -127.69 Pseudo R2 = 0.2868		
chioce	Coef.	Robust Std. Err.		Coef.	Robust Std. Err.		choice	Coef.	Std. Err.		Coef.	Std. Err.	
Ard	0.5629	0.1863	***	0.5575	0.1973	***	mrd	0.1765	0.0541	***	0.1457	0.0748	*
Brd	-0.0295	0.0550		-0.0428	0.0584		arrd	-0.1512	0.0406	***	-0.1973	0.0501	***
rel	-0.0231	0.0197					rel						
opat				0.1393	0.0626	**	opat				0.8297	0.3967	**
both				0.0156	0.0723		both				-0.1523	0.5256	
che	-0.0563	0.0362		-0.0506	0.0462		che	-0.3436	0.2323		-0.5396	0.3618	
pha	-0.1444	0.0289	***	-0.1528	0.0362	***	pha	-1.2982	0.3443	***	-1.4990	0.4788	***
mat	-0.0681	0.0415	*	-0.0657	0.0563		mat	-0.6789	0.3342	**	-0.6963	0.3695	*
mac	-0.0750	0.0448	*	0.0701	0.1044		mac	-0.6014	0.2801	**	0.0941	0.4148	
oth	-0.0247	0.0721		0.0884	0.0992		oth	-0.2789	0.4318		0.1156	0.5208	
jusa	0.1317	0.0395	***	0.1457	0.0460	***	jusa	1.0412	0.2555	***	-0.2547	0.5665	
jhio	0.0025	0.0567		-0.0447	0.0385		jhio	0.4400	0.4049		-3.0024	1.3919	**
joth	0.0092	0.1898		-0.0767	0.1436		joth						
gnpgap	0.0114	0.0779		-0.0669	0.0566		gnpgap	0.3422	0.4645		-4.2079	1.6622	**
cons	0.0629	0.0275	**	-0.0516	0.0578		cons	-0.8323	0.2169	***	-1.4300	0.4406	***
θ													
θ	-0.0523			-0.0767									

Note: *** significant at 1% level, **significant at 5% level and *significant at 10% level

Table 5. Estimation results for the size of a licensor relative to a licensee in unilateral licensing

	Table5-A Based on Employment							Table5-B Based on R&D expenditures					
	Estimation 1			Estimation 2				Estimation 3			Estimation 4		
	Number of obs = 1047 F(2, 1044) = 652.54 R-squared = 0.1378 Root MSE = 2.4327			Number of obs = 1047 F(10, 1036) = 25.68 R-squared = 0.1986 Root MSE = 2.3544				Number of obs = 488 F(1, 486) = 0.07 R-squared = 0.0002 Root MSE = 3.1673			Number of obs = 488 F(8, 479) = 65.31 R-squared = 0.3347 Root MSE = 2.6025		
reml	Coef.	Robust Std. Err.		Coef.	Robust Std. Err.		rrd	Coef.	Robust Std. Err.		Coef.	Robust Std. Err.	
lsopar	2.082	0.129	***	1.818	0.188	***	lsopar	-0.638	2.383		1.618	0.907	*
lsorsub	-3.609	0.166	***	-4.136	0.366	***	lsorsub						
lsorusa				-0.455	0.283		lsorusa				0.501	0.428	
lsorhio				0.877	0.279	***	lsorhio				2.747	0.688	***
lsoroth				-4.549	0.752	***	lsoroth						
lsorgnpgap				-0.657	0.309	**	lsorgnpgap				-0.340	0.931	
lseeusa				-0.440	0.305		lseeusa				-2.607	0.441	***
lseehio				-0.654	0.399	*	lseehio				-4.167	0.368	***
lseeoth				0.912	0.384	**	lseeoth				-2.130	0.765	***
lseegnpgap				-0.013	0.120		lseegnpgap				0.076	0.295	
cons	1.294	0.097	***	1.099	0.162	***	cons	1.441	0.144	***	1.298	0.201	***
exp(cons)	3.649			3.001				4.224			3.664		

Note: * significant at 1% level, **significant at 5% level and *significant at 10% level**

Appendix 3. Summary statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Dependent Variables					
choice	1144	0.0848	0.2787	0	1
reml	1047	1.7899	2.6174	-7.3752	9.8686
rrd	488	1.4381	3.1643	-7.5609	9.3859
Independent Variables					
Aeml	1144	1.0225	2.1704	0.0002	16.7037
Beml	1144	16.8987	53.2348	0.0000	558.3663
Ard	568	0.1378	0.2543	0.0001	1.4030
Brd	568	0.3482	0.8427	0.0000	5.4274
meml	1144	0.3241	1.7010	-5.1413	3.5091
areml	1144	2.5530	1.7427	0.0066	9.8686
mrd	568	-1.0646	1.7618	-6.9861	3.0460
arrd	568	2.8142	1.9461	0.0186	9.3859
rel	1131	0.2502	0.4333	0	1
opat	608	0.6431	0.4795	0	1
both	608	0.1776	0.3825	0	1
jj	1144	0.2299	0.4209	0	1
jusa	1144	0.3304	0.4706	0	1
jhio	1144	0.1521	0.3593	0	1
joth	1144	0.2876	0.4528	0	1
gnpgap	1144	-0.9352	1.1271	-3.2000	0.7630
ele	1144	0.3243	0.4683	0	1
che	1144	0.2570	0.4372	0	1
pha	1144	0.0944	0.2925	0	1
mat	1144	0.1215	0.3269	0	1
mac	1144	0.1600	0.3667	0	1
oth	1144	0.0428	0.2026	0	1
lsorpar	1047	0.2512	0.4339	0	1
lsorsub	1047	0.0076	0.0871	0	1
lsorusa	1047	0.1767	0.3816	0	1
lsorhio	1047	0.0898	0.2860	0	1
lsoroth	1047	0.0010	0.0309	0	1
lsorgnpgap	1047	-0.1150	0.2368	-2.3750	0.7630
lseeusa	1047	0.1203	0.3255	0	1
lseehio	1047	0.0669	0.2499	0	1
lseeoth	1047	0.3095	0.4625	0	1
lseegnpgap	1047	-0.8719	1.2168	-3.2000	0.7630