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Acquisitions and Use of Patents: A Theory and New Evidence from the Japanese Firm Level Data

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: A theory and new evidence from the Japanese firm level data†

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Summary
A significant part of the patents held by a firm are not used. We show that, given the uncertainty of invention quality at the patent application stage and the sunk cost incurred for obtaining and developing a patent, the patent (internal) utilization rate declines with the (anticipated) size of complementary assets, licensing opportunity, and invention quality uncertainty while it increases with the average quality of an invention. We find empirical evidence supportive of these theoretical predictions. Moreover, a firm with larger price cost margin does not have a lower rate of patent utilization, which does not support the view of preemptive R&D and patenting as a primary explanation of unused patents. Finally, a firm with more diversified patent portfolio tends to have more patents but its utilization rate tends to be lower, suggesting that such diversification facilitates appropriation.

Key words: patent; unused patents; uncertainty; complementary assets
JEL Classification: O31, L20
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1. Introduction

While a large R&D intensive firm has many patents reaching thousands in number, their significant fraction is not used either for production or for licensing. In addition, there exist significant variations in the utilization rate across firms and industries. For an example, it declines with firm size, and it is very low in drugs and medicine. In particular, a large firm uses considerably less of its patents (see Figure 1 in section 3). Such variations have obvious and important implications on the measures of R&D productivity based on the patent counts. Furthermore, the variation of the utilization rate could provide important clues on the effects of a firm's R&D strategy such as preemption and diversification, which would be difficult to be identified based only on the information on the number of patents acquired. Despite of the importance of the issue, its theoretical and empirical studies are scarce.

Existing literature suggests the following two causes of unused patents. First, a patent has an option value, even if currently unused (see Pakes (1986)). As long as this option value exceeds the cost of the patent renewal, a patent is maintained, even if it is not in use. This view suggests that a firm which faces greater uncertainty in the values of a patent has more unused patents[1], but it cannot explain the negative relationship between firm size and patent utilization rate. Second, a firm may choose not to use a patent but still wants to keep it, in order to make it more difficult for a competitor to invent-around its core technology in use. This view, however, does not immediately explain why a large firm has *proportionately more* of such patents. Such tendency may appear if a firm with market power engages in preemptive R&D and patenting so as to deter the entry of a competitor (see Gilbert and Newbery (1982) and Newbery (1987)). However, there is a question how pervasive such preemptive R&D is, since successful preemption requires that inventing-around is difficult and that the incumbent has the first mover advantage in R&D.

We would like to add the following explanation, which is driven by the uncertainty over the quality of an invention which exists at the patent application stage but is resolved by its commercialization stage, and the sunk cost incurred for obtaining and developing a patent. The sources of such uncertainty include the availability of complementary or substitute technologies and the regulatory uncertainty. We show that, given such uncertainty, a firm with more complementary assets has more unused patents[2], since such firm gains more from implementing a patented invention so that it has a higher propensity to apply for a patent. As formally shown in the analytical section, such behavior tends to cause a lower rate of utilizing patents, since such firm seeks a patent for a relatively low quality invention. The effect would be similar to that of a lower standard of patentability or a lower cost of patenting for such firm. This view would help explain why a large firm tends to have lower rate of patent utilization.

As for empirical literature, there was only one large-scale published survey on the utilization of patents until recently, to the best of our knowledge[3]. This survey was done in 1957 with respect to the US patents. The sample covered randomly 2% of the patents issued in three years[4]. According to the survey results, the percentage of use either currently or in the past was over 55% for all patents. It was higher for small companies and more than 71%. Patent utilization is closely related to patent renewal, since the fact that a patent is not renewed within a relatively short period is likely to indicate that it has not been used. According to Schankerman and Pakes (1986), only about half of all patents in European countries is renewed within ten years. In addition, it is also found that the fraction of non-renewed patent is larger in France and U.K. than in Germany, in which the renewal cost is the most expensive and the patentability standard seems to be the highest. These studies, however, have not analyzed how the patent utilization rate depends on the firm-level determinants, such as the appropriability advantage of a firm.

Based on the newly available extensive firm-level database on the use of the patents by the Japanese firms, we attempt to assess how the firm level characteristics, with a particular focus on the appropriability advantage, uncertainty, and invention quality, can account for the pattern of patent acquisition and utilization across Japanese firms. We use the extensive survey data (the Survey of Intellectual Property-Related Activities; hereafter, the *SIPRA* data) of the Japanese firms prepared by the Japan Patent Office (*JPO*), matched with the corporate and the other information of the firms listed on the Japanese stock exchanges. Although the *SIPRA* is not a compulsory survey, a significant proportion of the Japanese firms responded to it. Thus, we have a pretty comprehensive data on the major Japanese corporations[5].

The remainder of this paper is organized as follows. Section 2 represents a theoretical framework and the main hypotheses we test. In section 3, we discuss the data set and summarize basic facts about patent utilization by Japanese firms. Section 4 presents an estimation framework as well as the construction of variables in our estimation. In section 5, we provide the results of estimation, and section 6 concludes.

2. Theoretical Framework

We consider the following simple model to explain the unused patents, which take into accounts the difference between the *ex ante* (expected) value of an invention in the patent application stage (or the stage of requesting a patent examination) and its *ex post* value at the commercialization stage, as well as the sunk cost such as patent examination fee and the cost of developing the patented invention to be incurred between the two stages. We adopt the framework of two-stage (application stage and commercialization stage) analysis. We assume that the cost of maintaining a patent in the second stage is zero, so that once a patent is granted in the first stage it is maintained in the second stage even if it is not used. We assume that the patent application by a firm (or its request for patent examination) always results in the patent grant for simplicity. We denote the value of an invention at the commercialization stage by v and its expected value at the patent application stage by v_{app}. We denote the number of inventions a firm produces by *inv*, the number of its granted patents by *pat*, and its R&D investment by *rd.* Larger expenditure of R&D of a firm increases the number of its inventions but may reduce the mean quality of inventions (q_m) due to a diminishing return.

We consider the patent acquisition and use decision of a firm with respect to an exogenous single invention, which has only a marginal effect on the profit of a firm, based on the following model. Initially we assume that a firm uses its invention only internally. The firm gains the following maximized profit π out of the production and sales of quantity s for the constant marginal cost of mc and price p.

$$\pi = (p - mc)s \qquad (1),$$

We assume that the willingness to pay of the consumers toward the product of a firm increases with the technological quality ϕ of the product produced by the firm, only if such improvement is protected by a patent[6]. Given the profit maximizing choice of p (or s), the marginal increase of the willingness to pay of the consumers enhances the profit of the firm by

$$\partial\pi / \partial\phi = (\partial p / \partial\phi)s \qquad (2),$$

due to the envelope theorem. If an invention improves the product quality by $d\phi$, patenting such invention has the following (expected) value:

$$v = s(\partial p / \partial\phi)d\phi = sQ \qquad (3)$$

Here $Q = (\partial p / \partial\phi)d\phi$ gives the quality of a patented invention in terms of economic value, which represents the expected increase of the willingness to pay of the marginal consumer for the product of a firm, due to the patented invention[7]. We can consider s to indicate the size of the complementary assets, for which a firm can apply the invention within a firm. This is because a firm has the production and marketing capacity which supports the sales of quantity s. Thus, the (marginal) value of a patented invention depends positively on its quality (Q) as well as on the size of its complementary assets (s). A firm with a larger size of complementary assets can gain more from the invention of the same quality, since it can apply the technology more widely.

In the following analysis, we take the size of the complementary assets as a deterministic parameter and focus on the uncertainty of the invention quality for the ease of exposition[8]. We assume that the quality of an invention consists of the following two random components:

$$Q = q + \varepsilon$$

Here q is invention quality as recognized by the firm at the patent application stage and it is a random variable, reflecting the uncertainty in invention process. ε is the remaining quality uncertainty resolved only through further development of an invention after the patent application. The sources of the uncertainty in term of ε include the extent by which complementary or substitute technologies are available. ε

has a zero mean for any q since it is an expectation error. We further assume that they are independent.

Given these assumptions, the value of the patented invention at the commercialization stage is given by the following specification.

$$v = s(q + \varepsilon) \qquad (4)$$

A firm seeks a patent examination if the expected value of patenting the invention exceeds its patenting and development cost k, which will become sunk in the second stage of commercializing a patent, knowing the level of q[9]. Given that we use a two-stage model, such condition is given by

$$v_{app} = E(s(q + \varepsilon) \mid q) = sq > k$$

Thus, the non-conditional probability that an invention is patented (that is, patenting propensity) is given by the following:

$$\textit{Patenting propensity} = \Pr(q > q_{thre} = k/s) = \int_{q_{thr}}^{\infty} f(q; q_m)\,dq \qquad (5)$$

Where $f(q;\, q_m)$ is the probability distribution of q and q_m is the mean of the distribution. This relationship implies that a firm with the capability of generating high quality invention (large q_m) or a firm with larger complementary assets (small q_{thre}) has a higher patenting propensity. In particular, a firm with larger complementary assets applies for more patents for a given statistical distribution of invention quality. Since the number of inventions increases with the R&D investment rd, if we denote the mean of the distribution of the invention quality by q_m, we have the following patenting equation:

$$pat = f(s/k, q_m, rd) \qquad (6.1),$$

$$\partial f / \partial (s/k) > 0, \partial f / \partial q_m > 0, \text{ and } \partial f / \partial rd > 0 \qquad (6.2).$$

A firm uses the granted patent only if the value at the stage of commercialization is positive, ignoring the sunk investment in patent application and in its development (k). Thus, the probability that a firm uses the granted patent is given by the following conditional probability:

$$\textit{Probability of use} = \Pr(s(q+\varepsilon) > 0 \mid v_{app} > k) = \Pr(\varepsilon > -q \mid q > k/s)$$

$$= \int_{q_{thre}}^{\infty} g(-q) f(q;q_m) dq \Big/ \int_{q_{thre}}^{\infty} f(q;q_m) dq \quad (7)$$

where g(*) is the cumulative probability function for ε, which is independent of q by assumption. This probability increases with $q_{thre} = k/s$, since, when q_{thre} is large, a patent is applied only for a high quality invention which is more likely to be used even if a negative shock in terms of ε occurs. Thus, a firm with larger complementary assets has a lower conditional probability of using a granted patent. The conditional probability of patent use decreases with the size of uncertainty (the variance of ε when the distribution can be approximated by normal distribution), since lower quality patent can be unused while higher quality patent is always used. It also increases with the mean of the invention distribution q_m for a given distribution of q, since an *ex ante* high quality invention is likely to remain as a high quality invention *ex post*. Thus, we have the following three testable propositions.

Proposition 1 (Complementary assets and the sunk cost of patenting and developing an invention)

A larger (anticipated) size of complementary assets increases the patenting propensity of a firm and reduces the rate of utilizing the granted patents, when quality uncertainty of an invention and the sunk cost for obtaining and developing a patent is important.

Larger sunk cost reduces the patenting propensity and increases the utilization rate of the granted patents.

(See the appendix for a formal proof)

Proposition 2 (Quality of invention)

A firm with high quality portfolio of inventions (high q_m) has both a high patenting propensity and a high rate of utilizing the granted patents.

(See the appendix for a formal proof)

Proposition 3 (Uncertainty in the development stage)

A firm which faces higher uncertainty in developing the patented technology for commercial use has a lower rate of utilization.

(See the appendix for a formal proof)

Let us extend the model to cover the case where a firm has licensing opportunities. A firm may unilaterally license its patented technology to the other firms or may use it as a bargaining chip in cross-license to reduce the payment for accessing the technology of the other firms. The value of such external use of a patented invention depends on the size of the complementary assets of the other firms (s^*) which potentially use the invention. Considering a license to a non-competing firm, we have

$$v = s(q + \varepsilon) + a^* s^* (q + \varepsilon^*) \qquad (8)$$

where a^* indicates the proportion of the value which the licensor can appropriate and ε^* represents uncertainty which exists on the part of a licensee. A firm applies for a patent examination if the expected value of the patented invention exceeds the patenting and development cost (k):

$$v_{app} = (s + a^* s^*) q > k \quad \text{or} \quad q > k/(s + a^* s^*) \qquad (9)$$

This equation shows that a firm which can license its patented technology has higher incentive to patent its invention. A firm, however, uses the granted patent internally only if the value at the stage of commercialization is positive, so that the probability that a firm internally uses the granted patent is given by

$$\Pr((s + a^* s^*)(q + \varepsilon) > 0 \mid v_{app} > k) = \Pr(\varepsilon > -q \mid q > k/(s + a^* s^*)) \qquad (10)$$

This probability decrease with s^*. In summary, we have the following proposition.

Proposition 4 (Effect of licensing possibility)

A firm which can license its technology has a higher propensity to patent its invention and a lower rate of internally utilizing the granted patents.

The last potential cause of unused patents which we discuss is the strategic motivation to acquire the patent only for preventing a competitor from using that invention to produce a product substitute to its own product. A firm with such an invention would keep its patent even if it is not used internally. Such invention may become especially important if a firm has a significant market power, since such firm may engage in preemptive R&D and patenting while keeping the granted patents unused due to its concern over the cannibalization of the profit of existing products (see Gilbert and Newbery (1982) and Newbery (1987)).

Proposition 5 (Effect of preemptive R&D and patenting)

A firm with stronger market power would have a lower rate of utilizing the granted patents, if it successfully pursues the strategy of preemptive R&D and patenting.

3. Data

The dataset we use is based on the first and the second surveys by the Japan Patent Office on the intellectual property-related activities of Japanese firms. It covers 81 % of the R&D expenditures by Japanese firms and 62% of the patent applications in Japan (see Table A1-1and A1-2 in the Appendix).We use the following firm level information on the acquisitions and use of patents in this section: the number of patent stocks owned by firms and the number of patents used internally[10]. The utilization rate of patents is given by their ratio.

As is shown in Figure 1, the internal utilization rate of granted patents declines monotonically with firm size for both domestic and foreign patents. A firm with employment size between 20 and 299 uses internally more than 70% of its domestic patents and more than 80% of its foreign patents. On the other hand a firm with employment size being equal to 3,000 or more uses only 39% of its domestic patents and 42% of the foreign patents. The negative correlation between firm size and patent utilization is consistent with Proposition 1. In addition, the utilization rate of the patents is higher for foreign patents than for domestic patents for all class of firm sizes. Higher utilization rate of foreign patents is also consistent with Proposition 1 for the following two reasons. A firm tends to have more complementary assets in the domestic market than abroad, and the patenting expense is considerably larger for a foreign patent than for a domestic patent due to the translation fees.

(Figure 1)

Figure 2 shows that these patterns hold in most industrial sectors. A large firm has a lower patent utilization rate than a small and medium size firm, except for ceramics industry. In addition, the domestic utilization rate is higher than the foreign utilization rate in most sectors (exceptions are petroleum and coal products, electricity & gas and the other utilities, food, and drugs and medicines). The patent utilization rate of pharmaceutical industry is one of the lowest in both domestic and foreign patents, which could be explained by Proposition 3. A firm in the pharmaceutical industry needs a long time from invention to commercialization and there exist significant uncertainty between the two stages which has to be resolved, including the regulatory approval (thus, the variance of ε is large).

(Figure 2)

Figure 3 shows the patent utilization rates, according to different average length of time which elapsed between applications and grants. A firm which spends longer time until a patent grant tends to have a lower rate of exploiting the patents. A firm was able to postpone a request for patent examination by up to 7 years for the patents applied by September 2001 under the Japanese patent law. Thus, a firm facing significant uncertainty as to the value of its invention could wait for a significant period of time without losing the patenting option. Thus, what Figure 3 suggests is consistent with Proposition 3: a firm facing larger uncertainty has a lower rate of patent utilization,

(Figure 3)

4. Empirical Estimation

4.1 Framework of empirical estimation

In this paper, we estimate a patent acquisition function and a patent (internal) use function. Proposition 1 of section 2 implies that *ex ante* appropriability advantage (or *anticipated* size of complementary assets) has a positive impact on patent acquisition but a negative effect on patent utilization rate. On the other hand, Proposition 2 implies that higher quality of the invention portfolio of a firm has a positive impact both on the size of patent stocks granted and on the patent utilization rate. Thus, the estimation of the two equations helps us identify whether a particular factor enhancing the patent acquisition by a firm affects patent acquisitions from appropriability side or from invention quality side.

In the patent acquisition function, the dependent variable is the patent stock owned by firm *i* as of the end of 2001 fiscal year (generally, March 31st in 2002), or the average of those for 2001 and 2002 fiscal years, using the common sample. Although the theory developed in section 2 refers to the patenting and utilization of a marginal invention, we use the stock data of the patents owned and their utilization, due to the limitation of data availability. The patent acquisition function combines the invention production function and the patent propensity function, corresponding to equation (6.1). We assume that it follows a negative binominal model (NBREG).

$$E[pat_i \mid \mathbf{X_i}] = \ln \lambda_i = \exp(\mathbf{X_i}\boldsymbol{\alpha} + ind.dummies + \mu_i)$$

$$\Leftrightarrow$$

$$\begin{aligned}\ln(pat_i) = {} & \alpha_1 \ln(emp95_i) + \alpha_2 \ln(tfa95_i / emp95_i) + \begin{cases}\alpha_3 \ln(success_i) \\ \alpha_3' \ln(citation_i)\end{cases} + \alpha_4 \ln(aveyear_i) \\ & + \alpha_5 license_i + \alpha_6 \ln(pcm95_i) + \alpha_7 \ln(rdemp_i) + \alpha_8 \ln(div_i) \\ & + \alpha_9 grsales01\_95_i + \alpha_{10} \ln(age_i) + ind.dummies + \mu_i\end{aligned}$$

In the patent use function, the proportion of the patents used internally in the total patents of a firm is a dependent variable, corresponding to the conditional probability specified by equation (7). We estimate this by OLS method.

$$\ln(jisha_i / pat_i) = \beta_1 \ln(emp95_i) + \beta_2 \ln(tfa95_i / emp95_i) + \begin{cases} \beta_3 \ln(success_i) \\ \beta_3' \ln(citation_i) \end{cases}$$
$$+\beta_4 \ln(aveyear_i) + \beta_5 license_i + \beta_6 \ln(pcm95_i) + \beta_7 \ln(div_i)$$
$$+\beta_8 grsales01\_95_i + \beta_9 \ln(age_i) + ind.dummies + \mu_i'$$

4.2 Sample and Variables

We have the following four sources of firm level data matched by the tickers of the publicly traded companies. The information on the patent stocks granted and the proportion of the patents used internally is from the *SIPRA* data (Survey of Intellectual Property-Related Activities) by the Japan Patent Office[11]. The information on the business and financial status of firms is from NEEDS database (Nikkei Electronic Economic Database Systems) which mainly uses the annual reports by the firms submitted to the financial regulatory authority of Japan. The other patent information is from the Patent Quarterly Journal and Corporate Patent & Financial Statistics Yearbook compiled by IPB (Intellectual Property Bank Corporation) the US Patent Citations Data prepared by Bronwyn Hall[12].

We constructed the variables for estimation in the following way. See Table 1 for a summary of the definitions and the expected signs of the explanatory variables in estimations:

(Table 1)

(1) Dependent variables

We use the total number of patents owned by a firm (*pat*) as of the end of 2001FY (generally, March 31st in 2002) in the patent acquisition function, and the proportion of the patents used internally in the total patents (*jishar*(=*jisha/pat*)) in that fiscal year (usually, between April 1st in 2001 and March 31st in 2002) in the patent (internal) use function[13]. We also use the average of these variables in 2001FY and 2002FY with respect to the common sample.

(2) Explanatory variables

Complementary assets

(a) Employment size of a firm (*emp90*)

We use the employment size of a firm in 1990FY (FY: Fiscal Year) as the indicator of the overall size of complementary asset useful for commercializing patented inventions of the firm (we use the intensity variable for the size of fixed asset, see the following paragraph). Since patented technology would affect firm size only with some lag, employment size in 1990FY would be significantly exogenous with respect to the stock of patents granted as of 2001FY. Proposition 1 suggests that the expected sign of this variable should be positive in the patent acquisition function and negative in the patent use function.

(b) Tangible fixed assets / Size of employment of the firm (*tfa90/emp90*)

The fixed asset and employment ratio in 1990FY represents the relative importance of fixed asset with respect to employment as complementary assets, controlling for the overall size of complementary assets by employment size. According to Proposition 1, the expected sign of this variable is also positive in the patent acquisition function and it is negative in the patent use function, if fixed asset is important as a complementary asset.

Quality of inventions

We use the following two variables. As indicated by Proposition 2, we expect that the signs of these variables are positive in both the patent acquisition function and the patent use function.

(c) Average success rate of passing patent examination (*success*)

One indicator of the average quality of the inventions of a firm which we use is the weighted average success rate of a firm in passing patent examinations between 1997 and 1999 in terms of the year of examination request. The weights we use are 0.870 for 1997, 0.953 for 1998, 1.0 for 1999, reflecting the degree of the completion of the requested examinations. The success rate is lower for the patents examination of which are more recently requested, due to higher degree of incompletion of examinations. We use higher weight for more recent years to correct this bias.

(d) Forward citations of the patents granted (*citation*)

We use the number of forward citations (median) until 2002 for the US patents granted between 1988 and 1997 to a firm. Those firms whose patents are cited more would have inventions with higher quality on the average. Since the number of forward citations varies with patent application year and technological field, we adjust this measure divided by the average number of forward citations for each application year and each IPC subclass code.

Uncertainty in the development stage

(e) Average time necessary for the patents granted (*aveyear*)

In Japan as in Europe, the Patent Office examines the patent application only if it is requested by an applicant. In the period of the sample of this study a firm could defer the examination request by up to seven years. As a result, a firm facing large invention quality uncertainty can spend more time before requesting patent examinations so as to screen out low quality inventions. We use the average time which elapsed between the applications and the grants for the patents granted between 1997 and 1999 as an indicator of the degree of uncertainty in the development stage. We expect that a firm with longer *aveyear* would have a smaller number of patents. In addition, such firm would have a lower utilization rate of its patents since such firm faces higher risk between patent application and commercialization (according to Proposition 3).

Effect of licensing possibility

(f) Whether or not a firm has at least one patent licensed out (*license*)

We use a dummy indicating whether or not a firm has licensed out at least one patent during 2001FY to test Proposition 4. This variable would have a positive effect on the patent stocks owned in patent acquisition function, while it has a negative effect in the patent use function, according to Proposition 4.

Effect of the price cost margin of a firm

(g) Price cost margin of a firm (*pcm90*)

We use price cost margin (*pcm*) which is defined as the ratio between the excess of the sales value over the cost of goods sold and the sales value in 1990FY, to represent the profitability of the complementary assets of a firm. If the combination of preemptive R&D and sleeping patents is important as a determinant of unused patents, we expect that the price cost margin (*pcm*) has a negative sign on the rate of utilizing the patents (see Proposition 5). On the other hand, if the preemptive R&D is not important, it may even have a positive sign to the extent that it represents the quality of an invention (see

Proposition 2). In either case it would have positive coefficients in the patent acquisition function.

(3) Other Variables

(h) Size of R&D (*rdemp*)

We use R&D personnel as of the end of 2001FY to represent size of R&D in the patent acquisition function. Since the R&D expenditure data of NEEDS database is not comprehensive in firm coverage, we use the R&D personnel data reported in SIPRA, although it has only recent data. We expect that it has a positive coefficient since a firm with more investment in R&D has more inventions to be patented.

(i) Degree of the diversification of R&D (*div*)

The degree of diversification of a firm may affect the research productivity as well as the appropriability of research. If it enhances either or both of them, it would have a positive coefficient in the patent acquisition function. On the other hand, the diversification of a firm would negatively affect the patent utilization rate if its main effect is to enhance the appropriability of an invention, but it would positively affect the utilization of patents if it results in the improvement of invention quality. We measure the degree of diversification of a firm by using the HHI index of the patent portfolio of each firm among 12 technology fields in 2001FY (*div=1-HHI*).

(j) Growth rate of the sales of a firm (*grsales01_90*)

We take growth rate of sales from 1990FY to 2001FY as a control variable. It would control the effects that a rapidly-growing firm tends to have smaller number of patents for a given level of recent R&D. Thus, it would have a negative coefficient in patent acquisition function. It would also represent the unanticipated effects of growth in complementary assets. In this case, it would have a positive effect on the patent utilization.

(k) Age of a firm (*age*)

Age of a firm (*age*) is the difference between 2002 and the establishment year of the firm. Since a firm would have a larger number of patents the longer it undertakes R&D for a given size of R&D, *age* of a firm would have a positive coefficient in patent acquisition function. It may also represent the experience in R&D and patenting and the stock of know-how, implying a positive coefficient. In addition, *age* of a firm would have a positive coefficient in patent use function, if it represents the capability of a firm to generate high quality inventions.

(l) Industry dummy (*ind.dummys*)

We use detailed industry dummies (*ind.dummies)* to control the other missing variables, including the differences of the level of the number of patents per R&D in the patent acquisition function. They are defined at six-digit industry level.

For *emp90*, *tfa90/emp90*, *success*, *citation*, *aveyear*, *pcm90*, *div* (plus one), *rdemp*, and *age*, we use log transformation in all samples. Our sample is cross-sectional data, consisting of 685 firms, with 106 industries in total. It covers about 35% of R&D expenditures of the Japanese firms, and 31% of the patent applications in Japan (see

Table A1-1 and A1-2 in the Appendix).The summary statistics in details are shown in the Appendix Tables (see Table A2-1 and A2-2 in the Appendix).

5. Estimation results and discussions

Table 2 shows the results of estimation. We use three samples depending on the scope of the independent variables used. In sample 1, we use only the NEEDS database for explanatory variables, so that we do not use the variables on the invention quality and the average length for the patents to be granted. We add the variables dependent on the records of patent examinations (*success* and *aveyear*) in sample 2, and add (forward) citation index from the US Patent Citations Data in sample 3. The estimation results for the patent acquisition function are listed on the left side of the table and those for the patent use function on the right side.

(Table 2)

First, let us see whether we can find evidence supporting Proposition 1. The estimation results for the patent acquisition function (estimations (1) ~ (6)) show that the size of the employment (*emp90*) affect the patent stocks of a firm (*pat*) positively and highly significantly, even controlling for the effects of R&D. Moreover, the coefficient size of the employment is larger than that of R&D, indicating the importance of the complementary asset as a determinant of the patent acquisition decision, which is consistent with the finding by Hall and Ziedonis (2001). The ratio between intangible fixed assets and the employment of a firm (*tfa90/emp90*) is also significant in estimations (1) and (2), although the size of coefficient is one third or less than that of employment. Thus, the patent stocks granted increases with the size of complementary assets of the firm in terms of both employment and fixed assets, even after controlling for the effect of the size of R&D (*rdemp*), which is also highly significant. This result is consistent with Proposition 1. The coefficient of the size of complementary assets of a firm in terms of the size of the employment (*emp90*) is negative and highly significant in the patent use function. This result that patent utilization rate is lower for a firm with larger employment is also consistent with Proposition 1. A firm with large size of complementary assets has high patenting propensity, since such firm can afford to seek a patent for even low–quality invention, but lower quality invention has higher probability of not being used *ex post*, due to technological obsolescence for an example. The ratio of tangible fixed assets relative to the employment of the firm (*tfa90/emp90*), however, does not have a significant coefficient, although the coefficient is negative.

Secondly, estimations (3) to (6) in Table 2 show that both the average success rate of passing patent examination (*success*) and forward citations (*citation*) have significantly positive effects on the patent acquisition, which support Proposition 2. However, we find a significant effect of these invention quality variables in the patent utilization function in only one case (estimation (12)), although they have positive coefficients (see estimations (9) to (12)). Thus, we can find only weak evidence supporting Proposition 2 as for the effect of invention quality on patent use. This may be due to the limitations of these two measures of invention quality. In particular, they may not adequately reflect the degree of complementarity between the invention and the business assets of a firm.

Thirdly, as shown in estimations (9) to (12), the average time necessary for the patents to be granted (*aveyear*) has a negative and significant coefficient in patent utilization rate (although only at 10% level), consistent with Proposition 3. A firm facing higher uncertainty has lower patent utilization rate. In addition, estimations (3) to

(6) show that the coefficient of this variable is negative in the patent acquisition. This result is not surprising, since a firm which takes more time for requesting patent examination would have a smaller number of patents granted for a given number of inventions.

Fourthly, the coefficient of the licensing dummy has a positive coefficient in the patent acquisition function (significant in estimations (2)), while it has a negative and significant coefficient in the patent use function (see estimation(8)) . That is, a firm which licenses its technology has a higher propensity to patent its invention and a lower rate of internally utilizing the granted patents. This finding supports Proposition 4.

Fifthly, price cost margin (*pcm90*) has a positive coefficient in the patent acquisition function. At the same time, it has a positive and significant coefficient in all estimations for the patent use function. A positive sign of this variable indicates that a firm with higher profitability is likely to have a higher rate of utilizing the patents granted. Thus, our finding tends to reject the view that the primary cause for unused patents is that a firm with high market power chooses to pursue preemptive R&D and patenting.

Finally, let us take a look at the coefficients of the rest of the variables: the degree of R&D diversification of the firm (*div*), the sales growth between 1990 and 2001 (*grsales90_01*) and the age of a firm (*age*). The degree of R&D diversification of a firm has a positive effect on the number of patents acquired. As a result, the patent stocks granted increases not only with the size of R&D personnel (*rdemp*), but also with the R&D diversification (*div*). On the other hand, the degree of R&D diversification of a firm (*div*) has a negative and significant impact on the utilization rate of the patents. These results indicate that R&D diversification facilitates the appropriability of research more than enhancing invention quality. The sales growth does not have a significant coefficient in patent acquisition function nor in the patent use function. This finding suggests that this variable may represent partially the unanticipated improvement of the availability of complementary assets. That is, when the availability of complementary assets improves unexpectedly, patents are more used, given the quality of inventions, which supports Proposition 1.The coefficient of the age of a firm (*age*) has positive and weakly significant coefficients in both functions. It suggests that this factor may help to represent the capability of a firm to generate high quality inventions.

Let us turn to the robustness check of our findings. There may exist potentially large reporting errors in the number of internally used patents, since such assessment would involve substantially subjective elements. We constructed the dataset that uses only the sample of the firms which responded to the surveys in two consecutive years in a consistent manner with respect to the number of internally used patents[14]. We use the average numbers of the patents granted and the patent utilization rates for 2001FY and 2002FY. This reduces the number of observations significantly (by 30%) but we may be able to reduce the errors in reporting significantly. Table 3 reports the estimation results. They are very similar to those in Table 2.

(Table 3)

In addition, we implemented the following estimation for the purpose of robustness check against outliers. We constructed the dataset which excluded the observations with the patent utilization rate of less than 5% or of more than 95%. Some firms may report extreme values in order to avoid the work of assessing the number of patents internally used. Such trimming of the sample, however, introduces downward bias in estimations, if firms do report honestly. Table 4 reports the estimation results, which are qualitatively similar to those in Table 2. The major differences are that the invention quality and uncertainty variables (*success, citation, aveyear*), the license variable (*license*) and the R&D diversity variable (*div*) become less significant in patent use function, although the signs of these variables remain the same.

(Table 4)

6. Conclusions

This paper has examined the firm-level determinants of unused patents both theoretically and empirically. We have developed a simple model to explain unused patents, which take into accounts the difference between the *ex ante* (expected) quality of an invention in the patent application stage (or the stage of requesting a patent examination) and its *ex post* quality at the commercialization stage, as well as the sunk cost to be incurred between the patent application stage and its commercialization stage. We show that such model implies that the patent (internal) utilization rate decreases with the (anticipated) size of complementary assets, the licensing opportunities and the uncertainty in the development stage, while it increases with the average quality of inventions.

We find empirical evidence supportive of these theoretical predictions, which are based on the large scale database of Japanese firms. Specifically, a firm with large complementary assets is more likely to acquire patents, controlling for the effects of R&D, while such firm has a lower patent utilization rate. A firm which licenses its patents has more patents but a lower (internal) patent utilization rate. A firm which spends more time from a patent application to a patent grant, which is likely to indicate the amount of uncertainty which a firm faces between these two stages, has a lower patent utilization rate. A firm with high quality inventions has more patents granted as well as a higher patent utilization rate (although the evidence for the latter effect is not strong).

We also find that a firm with larger price cost price margin tends to have a higher patent utilization rate, which does not support the view of preemptive R&D and patenting for entry deterrence as a primary explanation of unused patents. Finally, we find that a firm with more diversified patent portfolio has more patents but lower patent utilization rate, suggesting a possibility that such diversification enhances appropriability rather than efficiency of R&D. It is important to note that the last result may well depend on the level of technology classification.

There are several important issues for further research. Although we have introduced the major determinants of patent acquisition and its use, including industry dummies at 6 digit levels in our econometric analysis, we may not fully control the potential biases due to missing variables. Although a panel data with significant time span are not currently available, its expected availability in the future would help us to implement fixed effect estimation. Our analysis suggests that diversification defined at a broad level of technology classification affects the R&D performance through appropriability than through efficiency. However, we do not differentiate R&D diversification and business diversification in our analysis. We clearly need further work to identify the effects of these two different aspects of diversification.

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Appendix (Mathematical and data appendixes)

Appendix 1 (Proofs of propositions 1, 2 and 3)

Let us denote the probability distribution of q by $f(q;\ q_m)$, and the cumulative probability that ε is more than α by $g(\alpha)$. That is, denoting the probability distribution function of ε by $t(\varepsilon)$, we have

$$g(\alpha) = \int_{\alpha}^{\infty} t(\varepsilon) d\varepsilon \qquad \text{(a.1)}$$

Here we assume that ε and q are independent. The conditional probability that a granted patent is used is given by

$$\Pr(v > 0 \mid v_{app} > k) = \Pr\{q + \varepsilon > 0 \mid q > q_{thre} = k/s\}$$

$$= \Pr\{\varepsilon > -q, q > q_{thre}\} / \Pr(q > q_{thre})$$

$$= \int_{q_{thre}}^{\infty} g(-q) f(q;q_m) dq \Big/ \int_{q_{thre}}^{\infty} f(q;q_m) dq \qquad \text{(a.2)}$$

(1) Effects of the size of complementary asset and the sunk cost of applying a patent and its development

If we take the derivative of (a.2) with respect to $q_{thre} = k/s$, we have

$$\partial \Pr(v > 0 \mid v_{app} > k) / \partial q_{thre} = [f(q_{thre};q_m) / \{\int_{q_{trhe}}^{\infty} f(q;q_m) dq\}^2] \times$$

$$[-g(q_{thre}) \int_{q_{thre}}^{\infty} f(q;q_m) dq\} + 1] > 0 \qquad \text{(a.3)}$$

, given that both $g(q_{thre})$ and $\int_{q_{thre}}^{\infty} f(q;q_m) dq$ is less than one. Thus, generally, the conditional probability increases with $q_{thre} = k/s$.

(2) Effect of the mean quality of a patented invention

Let us then consider the effect of the change of the q_m which is the mean of the statistical distribution of q. We assume that the distribution function has a single peak at q_m.

$f(q;q_m) = h(q - q_m)$ with $h' > 0$ for $q<q_m$ and $h' < 0$ for $q>q_m$, and $h'' \leq 0$ (a.4)

Let us define $w(q\text{-}q_m)$ as the following variable.

$$w(q - q_m) = -h'(q - q_m) \int_{q_{trhe}}^{\infty} h(x - q_m) dx + h(q - q_m) \int_{q_{thre}}^{\infty} h'(q - q_m) dq \qquad \text{(a.5)}$$

Then, we have

$$\int_{q_{trhe}}^{\infty} w(x-q_m)dq=0 \qquad \text{(a.6)}$$

Given $h'' \leq 0$, and noting that $\int_{q_{thre}}^{\infty} h'(x-q_m)dx=-h(q_{thre}-q_m)<0$, we have

$$w(q-q_m)<0 \text{ for } q<q_m \text{ and } w'(q-q_m)>0 \text{ for } q>q_m. \qquad \text{(a.7)}$$

Thus, there exist q_z (>q_m), such that $w(q-q_m)$ has a negative value for $q<q_z$ and a positive value for $q>q_z$.

By taking the derivative of equation (a.1) with respect to q_m, we have

$$\partial \Pr(v>f \mid v_{app}>k+f)/\partial q_m = [1/\{\int_{q_{trhe}}^{\infty} h(q-q_m)dq\}^2]\times$$

$$\{\int_{q_{thre}}^{\infty} g(f/(sq))w(q-q_m)dq\} \geq 0 \qquad \text{(a.8)}$$

, since $g(f/(sq))$ (>0) increases with q.

(3) Effect of uncertainty

If the distribution $t(\varepsilon)$ can be approximated by normal distribution ($tn(\varepsilon;\sigma)$ with standard deviation σ), the variable ε can be normalized by standard deviation (σ). Thus,

$$g(-q)=\int_{-q}^{\infty} tn(\varepsilon;\sigma)d\varepsilon=\int_{-q/\sigma}^{\infty} tn(\eta;1)d\eta \qquad \text{(a.9)}$$

Given that $q>(k+f)/s>f/s$, it is clear that a larger standard deviation reduces *g(-q)*, thus the above conditional probability. For a general case, the increase of uncertainty in terms of the expansion of the tails of the distribution of $t(\varepsilon)$ reduces *g(-q)* and the conditional probability.

Appendix 2 Survey of Intellectual Property-Related Activities

The objective of the Survey of Intellectual Property-Related Activities (*SIPRA*), first conducted in 2002 October, is to obtain information on (1) the trends of industrial property rights applications and registrations (2) the usage of IPRs (3) information on the IPR management at the firm, and (4) trends of industrial property right infringement disputes in Japan. The *SIPRA* data for the 2001st fiscal year covers firms, individuals, and public organizations which submit more than three patent applications in 2000 (16,136 organizations and individuals). It also covers randomly the firms, individuals, and public organizations which submit less than three patent applications in 2000, amounting to 516 entities of these organizations and individuals in total. The survey was conducted in October, 2002, and its response rate was 41.1%. The number of valid response is 6,616 organizations and individuals. Appendix Table A1-1 provides the coverage of the above survey with respect to the data of the Survey of Research and Development by Statistics Bureau, Management and Coordination Agency Government of Japan, which is a compulsory survey. The coverage ratio of this survey in terms of R&D activities is very high. Appendix A1-2 shows the coverage of the patents by this survey in the Japanese patent applications and grants as reported by the Japan Patent Office Annual Report 2002. We estimate that this survey captures more than 60% of the patent applications and examination requests in Japan.

[1]Even if there is no uncertainty, the lag between an invention and its exploitation can cause unused patents. New patents will be unused until the firm completes the complementary investment to make ready for commercialization. Thus, a firm with a longer gestation period from an invention and its exploitation has more unused patents, just as a firm with longer production process has a larger work-in-progress.

[2] In this paper, we define complementary assets as the firm's assets or capabilities which can be used to commercialize patented technologies. See section 2 for a rigorous definition.

[3] However, there is a recent large scale patent-level survey on the utilization of patents in Europe (see Gambardella (2004)).

[4] 1938, 1948 and 1952.

[5] For the details of the data coverage of the SIPRA, see section 3.

[6] A quite parallel analysis holds for the case of cost-reducing innovation.

[7] The technological quality here is defined by its capability to generate income, combined with the complementary assets of a firm. Thus, a basic invention with a high degree of scientific component can have low quality if it cannot be readily commercialized.

[8] It is easy to see that unexpected growth of complementary assets increases the patent utilization rate. This effect is taken into account in the empirical analysis.

[9] Non-sunk cost for commercializing a patent does not affect the basic results, as long as it is small relative to the value of the patent.

[10] In the *SIPRA*, "use" of patents is defined as follows: either the use of patented products or the use of patent for production.

[11] For some details, please see appendix 2 of this paper.

[12] It is an extension of the NBER database described by Hall, Jaffe and Trajtenberg (2001), and available from her home page.

[13] We do not have structural information concerning patents stocks in terms of application years and technological fields.

[14] We use the observations only if the reported internal utilization rates for 2001FY and 2002FY differ less than or equal to 0.2 from each other.

Figure 1 Firm size and patent internal utilization rate

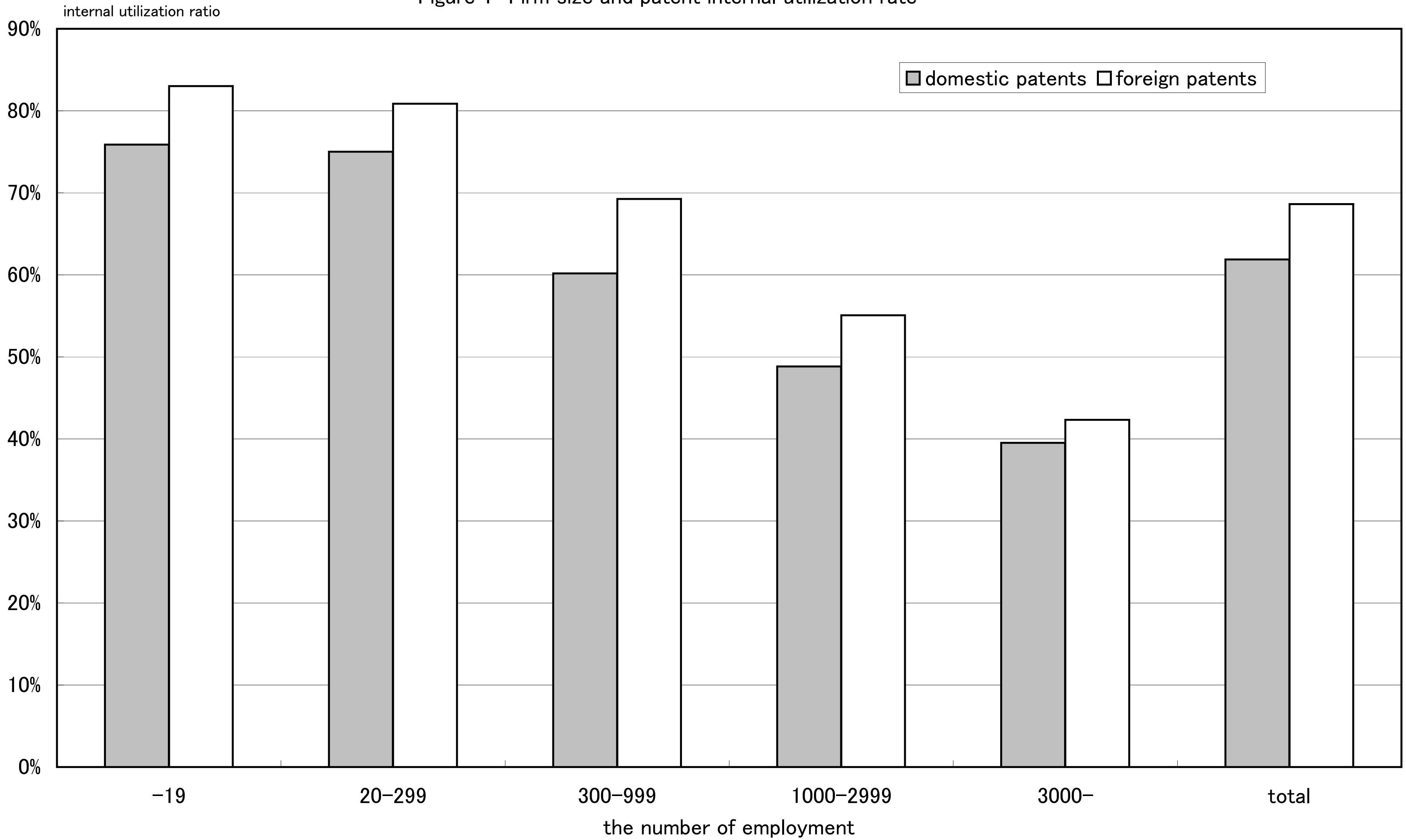

Figure 2 Patent internal utilzation rate by sectors

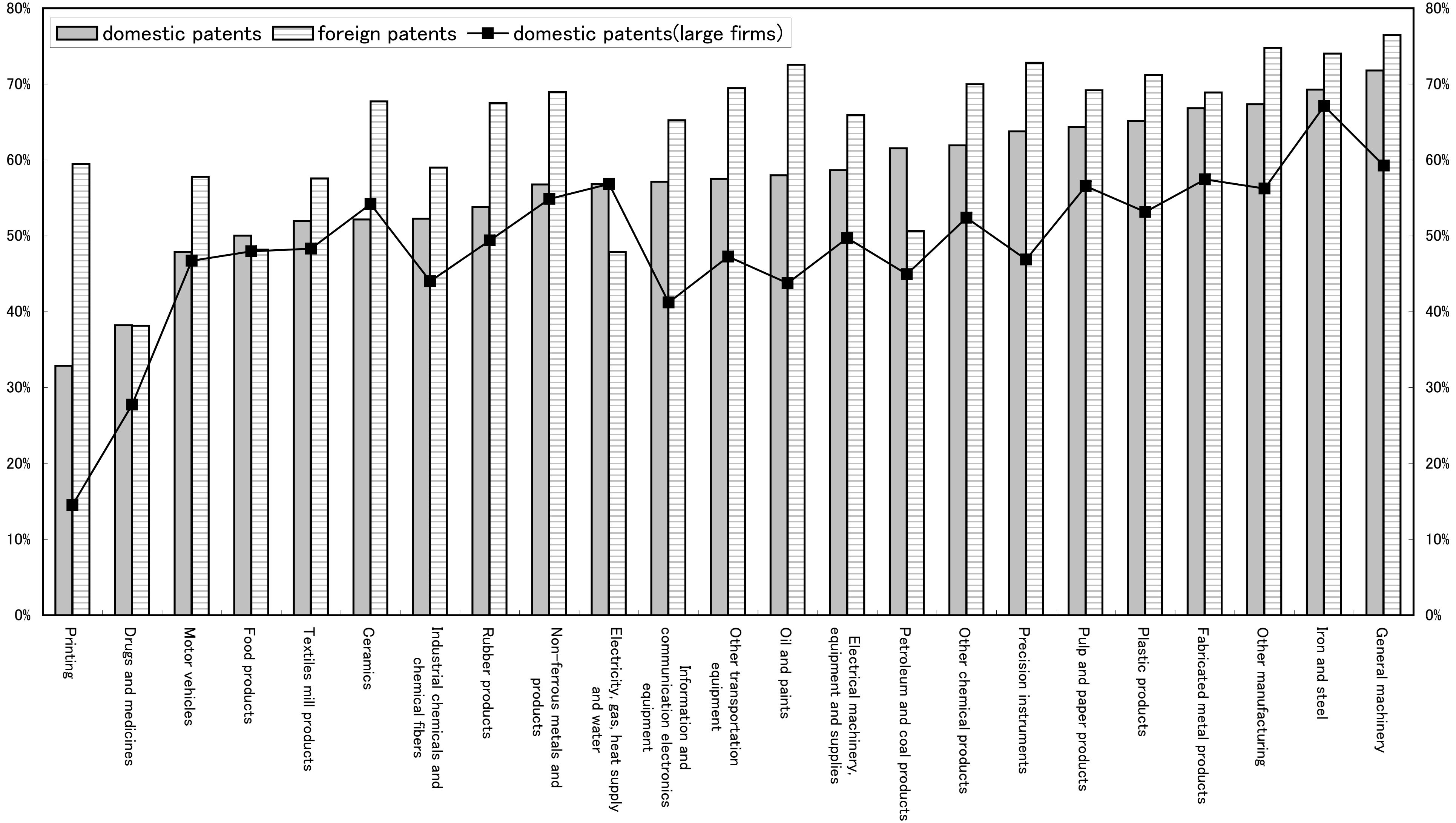

Figure 3 Lengh from patent application to grant and patent utilization

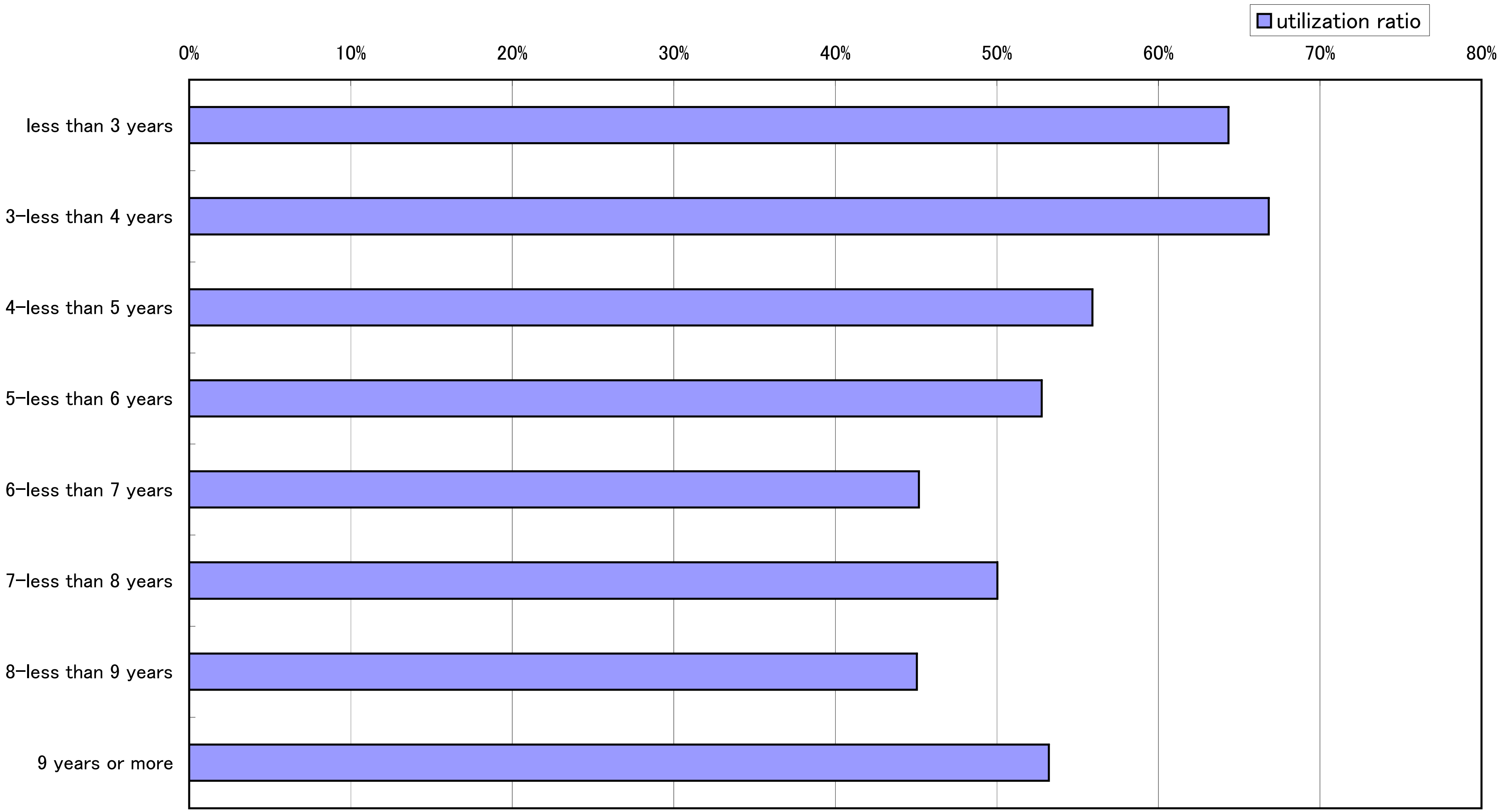

Table 1

Variable	Definition	Data Source	Expected Sign: Patent Acquisition Function	Expected Sign: Patent Use Function
pat	the number of total patents owned as of the end of 2001fiscal year or 2002 fiscal year, or their average	SIPRA		
jishar	the proportion of the patents used internally in the total patents owned during 2001fiscal year or 2002 fiscal year, or the average	SIPRA		
emp90	the size of employment of a firm in 1990FY	NEEDS	+	−
tfa90/emp90	tangible fixed assets in 1990FY over size of employment of the firm in 1990FY	NEEDS	+	−
success	the weighted average success rate of a firm in passing patent examination between 1997 and 1999 in terms of the year of examination request	IPB	+	+
citation	the number of forward citations (median) until 2002 for patents granted between 1988 and 1997.	NBER	+	+
aveyear	the average time necessary for the patents granted to the firm between 1997 and 1999.	IPB	−	−
license	whether or not a firm has licensed out at least one patent during 2001fiscal year (usually, between April 1st in 2001 and March 31st in 2002)	SIPRA	+	−
pcm90	the price cost margin of a firm in 1990FY. Price cost margin=(Sales-Cost of Goods Sold)/Sales	NEEDS	+	+/−
rdemp	the number of R&D personnel as of the end of 2001fiscal year (generally, March 31st in 2002) or the average.	SIPRA	+	
div	the degree of the diversification of research of a firm measured by 1 − the HHI index of the patent application portfolio among 12 technology fields in 2001 or the average.	SIPRA	+	−
grsales01_90	the growth rate of sales in 2001FY to that in 1990FY. That is, (sales in 2001FY-sales in 1990FY)/sales in	NEEDS	−	+
age	the age of a firm as of the end of 2001fiscal year (generally, March 31st in 2002). That is, 2002-foundation year.	SIPRA	+	+
ind.dummys	industry dummy variables (6 digits)	NEEDS		

Note) SIPRA stands for Survey of Intellectual Property-Related Actvities.

Table 2 Determinants of patent acquisition and use (based on 2001FY data, full observations)

Full Sample Estimation	Patent Acquisition Function (NBREG)						Patent Use Function (OLS)					
	Sample1	Sample1	Sample2	Sample2	Sample3	Sample3	Sample1	Sample1	Sample2	Sample2	Sample3	Sample3
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Dependent Variable	pat	pat	pat	pat	pat	pat	jishar	jishar	jishar	jishar	jishar	jishar
ln(emp90)	0.454***	0.435***	0.519***	0.514***	0.677***	0.669***	−0.070***	−0.059***	−0.052***	−0.045***	−0.058***	−0.050***
	[0.057]	[0.057]	[0.060]	[0.060]	[0.061]	[0.062]	[0.012]	[0.012]	[0.013]	[0.014]	[0.014]	[0.015]
ln(tfa90/emp90)	0.179***	0.146**	0.121	0.109	0.076	0.06	−0.028	−0.021	−0.032	−0.026	−0.026	−0.019
	[0.069]	[0.069]	[0.076]	[0.077]	[0.076]	[0.078]	[0.019]	[0.019]	[0.023]	[0.023]	[0.025]	[0.025]
ln(success)			0.520***	0.506***					0.002	0.003		
			[0.193]	[0.194]					[0.058]	[0.058]		
ln(citation)					0.530***	0.530***					0.09	0.094*
					[0.159]	[0.158]					[0.056]	[0.056]
ln(aveyear)			−0.181	−0.197	−0.121	−0.131			−0.094*	−0.088*	−0.097*	−0.090*
			[0.159]	[0.160]	[0.157]	[0.157]			[0.051]	[0.051]	[0.054]	[0.054]
license		0.264***		0.067		0.077		−0.064***		−0.042*		−0.045*
		[0.075]		[0.075]		[0.074]		[0.023]		[0.025]		[0.027]
ln(pcm90)	0.137	0.145	0.134	0.139	0.108	0.111	0.061**	0.060**	0.059*	0.059*	0.068**	0.067*
	[0.099]	[0.097]	[0.100]	[0.100]	[0.097]	[0.097]	[0.028]	[0.028]	[0.033]	[0.033]	[0.034]	[0.034]
ln(rdemp)	0.542***	0.518***	0.436***	0.433***	0.353***	0.349***						
	[0.043]	[0.044]	[0.044]	[0.044]	[0.044]	[0.044]						
ln(div+1)	0.459***	0.451***	0.141	0.134	0.065	0.058	−0.166***	−0.158***	−0.129**	−0.129**	−0.129**	−0.128**
	[0.175]	[0.174]	[0.175]	[0.176]	[0.170]	[0.171]	[0.052]	[0.052]	[0.058]	[0.058]	[0.061]	[0.061]
grsales01_90	−0.016	−0.011	0	0	0.055	0.053	0.001	0.002	−0.004	−0.003	−0.005	−0.003
	[0.044]	[0.043]	[0.058]	[0.058]	[0.054]	[0.054]	[0.012]	[0.012]	[0.017]	[0.017]	[0.017]	[0.017]
ln(age)	0	0.02	0.066	0.073	0.182*	0.192*	0.067**	0.063*	0.066*	0.064*	0.068*	0.065
	[0.108]	[0.108]	[0.105]	[0.106]	[0.108]	[0.109]	[0.033]	[0.033]	[0.036]	[0.036]	[0.040]	[0.040]
ind.dummies	106industries	106industries	90industries	90industries	83industries	83industries	106industries	106industries	90industries	90industries	83industries	83industries
Constant	−2.362***	−2.105***	−1.104	−1.019	−2.645***	−2.550***	1.279***	1.203***	1.461***	1.396***	1.477***	1.399***
	[0.764]	[0.762]	[0.847]	[0.851]	[0.841]	[0.846]	[0.231]	[0.231]	[0.285]	[0.287]	[0.298]	[0.301]
Observations	638	638	454	454	393	393	638	638	454	454	393	393
Log likelihood	−3855.906	−3849.708	−2942.74	−2942.345	−2570.551	−2570.019						
Adjusted R2	0.137	0.139	0.137	0.137	0.146	0.146	0.193	0.203	0.205	0.209	0.251	0.256

Standard errors in brackets

* significant at 10%; ** significant at 5%; *** significant at 1%

In case of negative binominal regression, Pseudo R2 is shown instead of Adjusted R2.

Table 3 Determinants of patent acquisition and use (based on the common sample of 2001FY and 2002 FY)

Estimation Results	Patent Acquisition Function(NBREG)						Patent Use Function(OLS)					
	Sample1	Sample1	Sample2	Sample2	Sample3	Sample3	Sample1	Sample1	Sample2	Sample2	Sample3	Sample3
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Dependent	pat	pat	pat	pat	pat	pat	jishar	jishar	jishar	jishar	jishar	jishar
ln(emp90)	0.395***	0.389***	0.463***	0.463***	0.576***	0.570***	−0.059***	−0.044***	−0.037***	−0.030**	−0.044***	−0.035**
	[0.073]	[0.072]	[0.073]	[0.073]	[0.073]	[0.073]	[0.015]	[0.015]	[0.014]	[0.015]	[0.015]	[0.016]
ln(tfa90/emp90)	0.219***	0.206**	0.150*	0.150*	0.145*	0.143*	−0.019	−0.011	−0.005	−0.002	0.005	0.007
	[0.085]	[0.085]	[0.087]	[0.088]	[0.084]	[0.084]	[0.026]	[0.025]	[0.025]	[0.025]	[0.025]	[0.025]
ln(success)			0.643***	0.643***					0.017	0.021		
			[0.200]	[0.201]					[0.058]	[0.058]		
ln(citation)					0.355**	0.350**					0.105*	0.111*
					[0.174]	[0.174]					[0.059]	[0.058]
ln(aveyear)			−0.15	−0.15	−0.107	−0.105			−0.105*	−0.107*	−0.116*	−0.121**
			[0.193]	[0.193]	[0.190]	[0.190]			[0.059]	[0.059]	[0.059]	[0.059]
license		0.198**		−0.001		0.066		−0.088***		−0.051*		−0.051*
		[0.087]		[0.089]		[0.089]		[0.029]		[0.028]		[0.029]
ln(pcm90)	0.287***	0.311***	0.254**	0.254**	0.165	0.178*	0.033	0.023	0.043	0.037	0.062*	0.055
	[0.107]	[0.107]	[0.107]	[0.108]	[0.105]	[0.106]	[0.035]	[0.035]	[0.035]	[0.035]	[0.035]	[0.035]
ln(rdemp)	0.588***	0.563***	0.491***	0.491***	0.426***	0.420***						
	[0.060]	[0.061]	[0.060]	[0.060]	[0.058]	[0.058]						
ln(div+1)	0.550**	0.525**	0.355	0.355	0.254	0.246	−0.131*	−0.114	−0.125*	−0.121*	−0.141**	−0.131*
	[0.216]	[0.215]	[0.217]	[0.217]	[0.209]	[0.209]	[0.071]	[0.070]	[0.068]	[0.068]	[0.069]	[0.068]
grsales01_90	−0.091	−0.094	−0.083	−0.083	−0.077	−0.079	0.001	0.007	−0.005	−0.003	0.001	0.003
	[0.064]	[0.064]	[0.061]	[0.061]	[0.055]	[0.056]	[0.019]	[0.019]	[0.017]	[0.017]	[0.017]	[0.017]
ln(age)	0.133	0.161	0.029	0.029	0.198	0.206	0.05	0.047	0.024	0.024	0.005	0.001
	[0.145]	[0.146]	[0.145]	[0.145]	[0.140]	[0.141]	[0.050]	[0.050]	[0.049]	[0.048]	[0.049]	[0.049]
ind.dummies	86industries	86industries	75industries	75industries	71industries	71industries	86industries	86industries	75industries	75industries	71industries	71industries
Constant	−3.305***	−3.392***	−0.742	−0.743	−2.425***	−2.379***	1.007***	0.986***	1.468***	1.402***	1.601***	1.541***
	[0.916]	[0.915]	[0.933]	[0.935]	[0.920]	[0.923]	[0.300]	[0.296]	[0.300]	[0.301]	[0.303]	[0.303]
Observations	389	389	310	310	282	282	389	389	310	310	282	282
Log likelihood	−2425.895	−2423.358	−2021.228	−2021.228	−1842.651	−1842.378						
Pseudo R2	0.145	0.146	0.144	0.144	0.152	0.152	0.198	0.22	0.276	0.283	0.334	0.34

Standard errors in brackets

* significant at 10%; ** significant at 5%; *** significant at 1%

In case of negative binominal regression, Pseudo R−squared is shown instead of Adjusted R−squared.

Table 4 Determinants of patent acquisition and use (based on 2001FY data, 5%-95% in patent use)

Estimation Results	Patent Acquisition Function (NBREG)						Patent Use Function (OLS)					
	sample1		sample2		sample3		sample1		sample2		sample3	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	pat	pat	pat	pat	pat	pat	jishar	jishar	jishar	jishar	jishar	jishar
ln(emp90)	0.457***	0.441***	0.525***	0.519***	0.691***	0.683***	−0.038***	−0.035***	−0.036***	−0.031**	−0.047***	−0.041***
	[0.060]	[0.060]	[0.063]	[0.063]	[0.063]	[0.064]	[0.010]	[0.011]	[0.012]	[0.013]	[0.013]	[0.013]
ln(tfa90/emp90)	0.153**	0.131*	0.129*	0.116	0.098	0.084	−0.014	−0.013	−0.018	−0.014	−0.005	0
	[0.071]	[0.071]	[0.078]	[0.079]	[0.079]	[0.080]	[0.017]	[0.017]	[0.020]	[0.021]	[0.022]	[0.023]
ln(success)			0.582***	0.570***					0.003	0.003		
			[0.201]	[0.201]					[0.052]	[0.052]		
ln(citation)					0.568***	0.569***					0.067	0.069
					[0.165]	[0.164]					[0.050]	[0.050]
ln(aveyear)			−0.21	−0.23	−0.162	−0.17			−0.059	−0.055	−0.053	−0.049
			[0.172]	[0.173]	[0.169]	[0.169]			[0.048]	[0.048]	[0.050]	[0.050]
license		0.203***		0.078		0.068		−0.019		−0.03		−0.032
		[0.077]		[0.078]		[0.077]		[0.020]		[0.023]		[0.024]
ln(pcm90)	0.207**	0.208**	0.187*	0.193*	0.14	0.142	0.070***	0.070***	0.066**	0.066**	0.081***	0.081***
	[0.102]	[0.101]	[0.103]	[0.103]	[0.100]	[0.100]	[0.025]	[0.025]	[0.030]	[0.030]	[0.031]	[0.031]
ln(rdemp)	0.529***	0.514***	0.446***	0.443***	0.357***	0.356***						
	[0.045]	[0.046]	[0.047]	[0.047]	[0.047]	[0.047]						
ln(div+1)	0.151	0.145	0.003	−0.005	−0.067	−0.073	−0.055	−0.054	−0.055	−0.055	−0.065	−0.064
	[0.179]	[0.179]	[0.182]	[0.182]	[0.176]	[0.176]	[0.046]	[0.046]	[0.052]	[0.052]	[0.054]	[0.054]
grsales01_90	−0.014	−0.009	−0.005	−0.005	0.061	0.058	0.004	0.004	−0.001	−0.001	−0.005	−0.004
	[0.043]	[0.043]	[0.058]	[0.058]	[0.055]	[0.055]	[0.010]	[0.010]	[0.015]	[0.015]	[0.015]	[0.015]
ln(age)	0.004	0.019	0.071	0.077	0.18	0.187*	0.049*	0.047	0.045	0.044	0.051	0.049
	[0.111]	[0.111]	[0.109]	[0.109]	[0.112]	[0.112]	[0.029]	[0.029]	[0.032]	[0.032]	[0.036]	[0.036]
ind.dummies	103industries	103industries	88industries	88industries	81industries	81industries	103industries	103industries	88industries	88industries	81industries	81industries
Constant	−2.906***	−2.737***	0.177	0.226	−1.643*	−1.603*	1.001***	0.982***	0.951***	0.928***	0.968***	0.940***
	[0.908]	[0.907]	[0.873]	[0.873]	[0.881]	[0.882]	[0.231]	[0.232]	[0.261]	[0.261]	[0.275]	[0.275]
Observations	562	562	421	421	365	365	562	562	421	421	365	365
Log likelihood	−3473.537	−3470.05	−2750.784	−2750.294	−2402.952	−2402.556						
Adjusted R-square	0.137	0.138	0.136	0.137	0.146	0.146	0.143	0.143	0.156	0.157	0.219	0.222

Standard errors in brackets

* significant at 10%; ** significant at 5%; *** significant at 1%

In case of negative binominal regression, Pseudo R-squared is shown instead of Adjusted R-squared.

Appendix Table A2-1

Variable	sample1					sample2					sample3				
	Obs	Mean	Std. Dev.	Min	Max	Obs	Mean	Std. Dev.	Min	Max	Obs	Mean	Std. Dev.	Min	Max
pat	638	601.603	3157.413	1	72028	454	814.738	3718.383	5	72028	393	922.155	3986.057	5	72028
jishar	638	0.503	0.265	0.002	1	454	0.453	0.242	0.002	1	393	0.447	0.239	0.002	1
emp90	638	2722.936	5956.492	36	70841	454	3498.689	6888.746	87	70841	393	3789.756	7297.496	133	70841
tfa90/emp9	638	15.046	34.297	0.424	702.372	454	14.986	23.037	0.544	223.696	393	15.028	21.516	0.701	223.696
success	x	x	x	x	x	454	0.648	0.117	0.095	0.941	x	x	x	x	x
citation	x	x	x	x	x	x	x	x	x	x	393	0.784	0.428	0	3.25
aveyear	x	x	x	x	x	454	6.744	1.512	2.217	10.697	393	6.861	1.454	2.217	10.697
license	638	0.514	0.500	0	1	454	0.615	0.487	0	1	393	0.634	0.482	0	1
pcm90	638	0.237	0.122	0.036	0.808	454	0.233	0.117	0.036	0.808	393	0.236	0.118	0.042	0.808
rdemp	638	360.198	1526.873	1	32130	454	478.791	1794.662	4	32130	393	540.842	1921.431	5	32130
div	638	0.357	0.298	0	0.877	454	0.411	0.293	0	0.877	393	0.431	0.289	0	0.877
grsales01_9	638	0.267	0.970	−0.754	16.125	454	0.222	0.680	−0.627	6.287	393	0.226	0.702	−0.618	6.287
age	638	61.950	20.209	4	131	454	63.656	20.255	4	131	393	65.242	20.001	9	131
ind.dummys	638	106 industries				454	90 industries				393	83 industries			

Appendix Table A2-2

Variable	sample1									
	pat	jishar	emp90	tfa90/emp90	license	pcm90	rdemp	div	grsales01_90	age
pat	1									
jishar	−0.12	1								
emp90	0.579	−0.185	1							
tfa90/emp90	−0.007	0.024	0.144	1						
license	0.120	−0.272	0.232	0.043	1					
pcm90	−0.012	0.005	−0.037	0.087	0.019	1				
rdemp	0.558	−0.095	0.647	−0.010	0.092	0.034	1			
div	0.164	−0.219	0.266	0.111	0.201	−0.042	0.138	1		
grsales01_90	−0.015	0.018	−0.052	0.045	−0.009	0.145	0.020	−0.006	1	
age	0.058	−0.066	0.101	0.005	0.132	−0.043	0.050	0.163	−0.231	1

Variable	sample2											
	pat	jishar	emp90	tfa90/emp90	success	aveyear	license	pcm90	rdemp	div	grsales01_90	age
pat	1											
jishar	−0.113	1										
emp90	0.573	−0.154	1									
tfa90/emp90	−0.010	−0.056	0.263	1								
success	−0.064	0.024	−0.061	0.007	1							
aveyear	0.078	−0.137	0.105	0.011	−0.147	1						
license	0.101	−0.173	0.198	0.110	0.017	0.092	1					
pcm90	−0.006	0.005	−0.025	0.113	0.167	0.101	0.043	1				
rdemp	0.552	−0.072	0.642	−0.015	−0.087	0.118	0.060	0.049	1			
div	0.161	−0.142	0.247	0.185	−0.130	0.070	0.121	−0.031	0.121	1		
grsales01_90	−0.011	−0.049	−0.053	0.029	−0.014	0.005	0.035	0.167	0.031	−0.032	1	
age	0.054	−0.018	0.082	−0.003	0.059	0.057	0.101	−0.005	0.041	0.163	−0.183	1

Variable	sample3												
	pat	jishar	emp90	tfa90/emp90	success	citation	aveyear	license	pcm90	rdemp	div	grsales01_90	age
pat	1												
jishar	−0.117	1											
emp90	0.575	−0.158	1										
tfa90/emp90	−0.013	−0.037	0.261	1									
success	−0.070	−0.001	−0.055	0.035	1								
citation	0.023	0.142	−0.006	−0.103	−0.013	1							
aveyear	0.072	−0.126	0.089	0.015	−0.101	−0.044	1						
license	0.102	−0.184	0.194	0.114	−0.019	0.007	0.085	1					
pcm90	−0.014	0.007	−0.036	0.088	0.170	−0.050	0.094	0.034	1				
rdemp	0.549	−0.072	0.643	−0.018	−0.091	0.035	0.110	0.055	0.045	1			
div	0.161	−0.152	0.236	0.156	−0.090	−0.053	0.053	0.132	−0.079	0.115	1		
grsales01_90	−0.012	−0.039	−0.058	0.024	0.049	0.007	0.004	0.036	0.170	0.031	−0.049	1	
age	0.044	−0.024	0.065	0.004	0.078	−0.094	0.050	0.088	0.028	0.027	0.169	−0.165	1