The Knowledge Disclosure of Patents and Its Signaling Consequences*

Yoon-Suk Baik

Korea Advanced Institute of Science and Technology
Graduate School of Management
207-43 Chongryangri-2Dong Dongdaemoon-Gu
Seoul, 130-722, Korea
Phone: +82-2-958-3545
Email: ysbaik@kgsm.kaist.ac.kr

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Abstract

This study investigates the disclosure of enabling knowledge of patents. In the patent literature, there are two views of patent that treat the patent disclosure decision differently. The "strategic power" view of patent proposes that firms maximize the disclosure of patent knowledge since corporate patenting is for strategic purposes to enhance their power for negotiation or technology preemption, the power benefits which dominate the disclosure costs. In contrast, the "signaling" view posits that patents are signals to correct asymmetric information in the intellectual property markets, and hence, the knowledge disclosure of patents will increase with the signaling benefits countervailed by the disclosure costs. Based upon U.S. corporate patent data, we test the two recent views of patent. The data show that firm size is positively related to the information disclosure of patents. This appears to support for the strategic power view. We also find that the number of industry competitors is negatively associated with the patent disclosure, evidencing the signaling view that predicts a significant role of the disclosure costs for the patenting decision. Finally, more rather than less technology interdependence of patented technologies is positively related to the patent disclosure. This also supports for the signaling view that predicts considerable signaling benefits of patents by informing other firms of true innovation value if patented technologies are interdependent with other technologies. Overall we find that both the signaling and the strategic power view help understand firms' patenting decision of how to disclose enabling knowledge of patents.

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The Knowledge Disclosure of Patents and Its Signaling Consequences

Patenting decision is an integral part of a firm's managing its intellectual properties for competitive advantages in the markets. Prior studies have assumed a firm's patenting decision as a discrete choice: whether to patent an innovation or not. Following a recent "signaling" view of patent (Anton and Yao, 2003; 2004), however, this study views patenting as a decision of how much innovative knowledge for a firm's innovation should be disclosed in public for protection. We then investigate what determines the disclosure of enabling knowledge of an intellectual property.

Patent is a legal protection of an innovation in exchange of the revelation of the innovative idea. Many studies (e.g., Levin, et al., 1987; Cohen, et al., 1999), however, find that patent is one of the least reliable mechanisms that firms can choose for protecting their innovations, due mainly to its imperfect protection from imitations. Despite such imitation costs of patenting innovations, firms recently continue to increase patenting their innovations (Kortum and Lerner, 1998). While some studies (e.g., Kortum and Lerner, 1998) attribute the patent puzzle to strengthened legal system after early 1980s, others (e.g., Cohen, et al., 1999; Hall and Ziedonis, 2001) argue that the recent upsurge of patents is derived from firms' strategic power purposes, such as bargaining chips in cross-licensing negotiations (e.g., in electronics and semiconductor industries) and preemption in technology competition (e.g., in chemical and drug industries). This "strategic power" view of patent predicts that patenting and its patent disclosure will increase for maximizing strategic power against competitors.

In addition to the legal and strategic benefits, patent can be beneficial from its signaling effects. This "signaling" view of patent (Anton and Yao, 2003; 2004) suggests that the nature of patenting decision is how much enabling knowledge of a patented innovation to be disclosed. In this regard, an important incentive to disclose additional piece of innovative knowledge depends upon how much market participants (e.g., suppliers, customers, or competitors) can conjecture the true value of a patented innovation. The disclosure of enabling knowledge, however, still bears on costs from others' imitation. In this sense, a firm's optimal patenting decision should strike a balance between the signaling benefits and the imitation costs. This signaling approach predicts that patent disclosure will increase only if signaling benefits dominate the imitation costs.

We consider three conditions that signaling benefits are presumably contingent upon: firm complementary assets at the firm level, industry competition at the industry level, and technological interdependence at the technology level. The signaling view anticipates that patent disclosure will vary with the above three conditions because of changes in net signaling benefits, whereas the strategic power view expects that patent disclosure will increase regardless of changes of three conditions. Based upon U.S. corporate patent data from 1989 through 1999, we test the two recent views of patent.

The data show that firm size that approximates firm complementary assets is unrelated to the number of patent claims, which is used to measure the degree of information disclosure in patent. This appears to support for the strategic power view positing that firms attempt to disclose more patent information regardless of their size. In terms of industry characteristics, the number of industry competitors is negatively associated with the number of patent claims. This evidences the imitation costs incurred by patent, in support of the signaling view. Finally, more interdependent technologies (used in the computer and electronics sector) than less interdependent technologies (used in the chemical and drug sectors) is positively related to patent claims. This also supports for the signaling view that predicts more signaling benefits of patent from informing suppliers and partners of true innovation value if technologies are interdependent with each other. We overall find that both the signaling and the strategic power view of patent help understand firms' patenting decision over how much to disclose enabling knowledge.

This study is the first empirical consideration on the signaling view of patent. Traditional view of patent regards patenting decision a part of the choice of an optimal mechanism among various appropriability mechanisms. The signaling view endogenously explains this traditional view on the basis of information asymmetry in the market for new ideas. This allows us to understand patent as a part of managing intellectual properties based upon the market mechanism. This study also highlights the complementary relationship of the signaling view with the strategic power view of patent.

The rest of this study is organized as follows. The next section discusses the patent literature and background theory of patent. Hypothesis development follows in the next section. We then explain the data and empirical methods in the following section. The final section draws conclusions.

Literature Review and Theoretical Background

The patent literature has traditionally considered patent an alternative mechanism to appropriate economic returns from innovations. This traditional view of patent as an appropriability mechanism, in effect, is clear in the so-called “Yale” study by Levin, et al. (1987). According to their survey with a large number of research and development (R&D) managers of U.S. manufacturing companies, patent is the least reliable among other mechanisms to protect firms’ innovations, such as secrecy, lead time, and complementary assets, to protect firms’ innovations. This traditional view suggests that a firm’s managing intellectual properties is then a choice of an optimal mechanism (or a mix of different mechanisms) out of many alternative appropriability mechanisms, to maximize economic returns from its intellectual property. Hence, it is expected that firms’ dependency on patent to secure their returns from innovations will be constrained.

Contrary to the expectation of the traditional view, the number of U.S. patent applications has dramatically increased since 1985. Korum and Lerner (1998) report the unprecedented upsurge in patenting in the most U.S industries after the mid 1980s, earmarked by over 120 thousand patent applications in 1995 alone contrasted with a range between 40 and 80 thousand per year until the mid 1980s. In a patent study focusing on the semiconductor industry, Hall and Ziedonis (2001) also find a rapid growth of patent applications in that industry since early 1980s. The Yale study by Levin, et al. (1987) and subsequently the “Carnegie Mellon” study by Cohen, et al. (2000) consistently find that R&D managers of semiconductor companies view patents are among the least effective mechanisms for appropriating returns to R&D investments. Given this, it is surprising to see an aggressive patenting in such an industry.

Why then do firms patent so aggressive, if patents are least effective to profit from innovations? A recent “strategic power” view of patent proposes that firms strategically engage in patenting to achieve power against competing companies. Cohen, et al. (2000) in their "Carnegie Mellon" study provide that many companies are interested in using patents as bargaining chips for cross-licensing negotiation, particularly in industries where firms do not have proprietary control over all the essential complementary components, such as the semiconductor or the electronics industries. Other companies can also aggressively patent their innovations, to prevent competing firms from attempting to patent a related innovation. Cohen, et al (2000) find that this kind of strategic patenting for preempting technological domains frequently happens in such industries as the chemical or the drug industries. Hall and Zeidonis (2001) also suggest that patenting behavior of semiconductor firms in recent years focuses on dealing with other firms with crucial component technologies on more favorable terms.

A significant contribution of this strategic power view to the patent literature is that, in addition to legal rights (although imperfect), the source of benefits from patents expands into strategic purposes: more bargaining power in negotiating access to others' technologies, or locking rivals out of certain technology domains. The view anticipates that firms then will be more aggressive patenting their innovations. A concern related to this strategic power view, however, is that this patent view levels the downside of patenting, the expected costs from imitation or invention around. Although the strategic power view explains the recent rapid growth of U.S. patent applications by introducing new patent benefits, a skewed approach to patents by focusing on the benefit side is less informative to understand firms' patenting decision.

Along this spirit, the "signaling" view of patent is helpful integrating the traditional view and the strategic power view of patent into a rigorous theoretic framework. Anton and Yao (2003, 2004) propose that since patent, given its imperfect protection, can reduce the information asymmetry in the market for new ideas by disclosing enabling knowledge of innovations, patents can play a signaling role for revealing the true values of innovations. According to them, a firm's patenting decision is how much enabling knowledge should be disclosed in patenting an innovation, rather than whether patent is more effective than other appropriability mechanisms to profit from an innovation.

In addition to legal rights and strategic power, this signaling view also suggests another source of patent benefits: signaling benefits. As industry experts and other studies (e.g., Hall and Ziedonis, 2001) point out, certain firms with certain technologies need to draw more attention from complementary asset suppliers, or financial investors, or partners for strategic alliances. To this end, such firms should send relevant others a strong signal that conveys a sufficient amount of information to inform them of the true value of their innovations. The way that those firms can do so in patenting their innovations is to disclose more enabling knowledge relevant with innovations. If a firm discloses additional piece of enabling knowledge in a patent, the firm exposes itself to higher risks of imitations by others, incurring significant costs. Due to this kind of commitments of information disclosure, the firm can convey to suppliers or partners a clearer message about the true value of its innovation. This leads to signaling benefits. In this regard, the signaling view can suggest that more expected signaling benefits underlie the recent upsurge of U.S. patent applications, although the expected imitation costs incurred by disclosing more knowledge confines the scope of patent disclosure.

The strength of the signaling view in the literature is to articulate firms' patenting decision in a more rigorous way by introducing information asymmetry of the intellectual property markets into the patent literature. Instead of examining exogenous appropriability conditions to evaluate various appropriability mechanisms including patents, we can endogenously consider how firms manage their intellectual property by determining the scope of innovative knowledge disclosure. The knowledge disclosure of patent, in effect, determines a mechanism to secure profits from an innovation. The signaling view also includes the expected costs of patent that the strategic power view relatively ignores, while it provides another source of patent benefits from its signaling role in the intellectual property markets.

Hypothesis Development

The recent two views of patent described above predict firms' patenting decision differently. The signaling view of patent anticipates that the degree to which a firm discloses enabling knowledge of patent will vary with the firm's conditions for signaling benefits that countervail the imitation costs. In contrast, the strategic power view expects that, regardless of its condition, a firm will disclose patent knowledge as much as possible, for garnering bargaining power against cross-licensing partners or preempting competing firms from certain technology domains.

To test these two patent views, we consider three conditions that play a significant role for signaling effects. First, firm size is likely to influence the condition for the signaling benefits of the firm's patenting. Teece (1986) argues that a firm's complementary assets related to manufacturing, marketing, and other services can be a significant appropriability mechanism, through which the firm protect returns from its innovations. If a firm is large with extensive complementary assets, the firm has little incentive to send strong patent signals to complementary goods suppliers or partners for strategic alliance, because the firm is relatively self-contained for implementing and commercializing its innovation. Conversely, a small firm with limited complementary assets has more incentive to convey strong patent signals to suppliers or alliance partners. Such patent signals are to induce more investment and cooperation from others to implement and commercialize its innovation. This suggests that small firms are more likely to disclose enabling knowledge of patent than large firms.

Related to firm size, the strategic power view however takes a different stance. Due to the strategic purpose to gain more bargaining power against cross-licensing partners or blocking competitors from certain technology domains, firms are likely to increase the scope of their patent by disclosing patent information extensively. Regardless firm size, firms with innovations should attempt to increase the scope of patents to maximize the power benefits from large patents. If the strategic power view prevails, firm size will not be significantly associated with the variance of patent knowledge disclosure. Since the prediction of the strategic power view is the alternative hypothesis of the signaling view, we test the following hypothesis:

Hypothesis 1: The knowledge disclosure of patent will be more in small firms' innovations than in large firms' innovations.

Industry competition is another condition for signaling effects of patents. From the traditional patent view to the recent signaling view, the costs from imitation or invent around by competing firms are primary concerns related to patenting firms' innovations.

As an appropriability mechanism, patent is the least effective among others, because of its vulnerability to imitation that increases with industry competition (Levin, et al., 1987). The signaling view also considers industry competition to promote imitation in the technology competition. As the industry competition increases, then the signaling benefits from patent disclosure will decrease, because of the increased probability of imitations from others. This will lead to less knowledge disclosure of patent in face of high industry competition.

The strategic power view suggests that power-related benefits from patents will dominate costs incurred by patent disclosure. Since the benefits of bargaining power against cross-licensing counterparts and technological preemption will dominate expected imitation costs that will increase with industry competition. Hence, regardless of the level of industry competition, firms are likely to disclose enabling knowledge of patent as much as possible. The strategic power view then predicts an insignificant association between the patent disclosure and the level of industry competition. This is the alternative prediction to that of the signaling view. Again, we test the following hypothesis predicted by the signaling view as the null hypothesis.

Hypothesis 2: The knowledge disclosure of patent will be more in less competitive industries than in more competitive industries.

At the technology level of patent, we consider technological interdependence as the final condition for the signaling benefits of patent. Cohen, et al. (2000) explain that certain technologies lead to innovations relatively independent of other complementary new technologies (so-called “discrete” technologies), while other technologies need to be supported by many other related new technologies (so-called “complex” technologies). The first technology set is mainly comprised of technologies related to chemical products and drugs, while the second technology set is of technologies associated with computers and electronics.

Teece (2000) suggests that this attribute of technology interdependence is critical to examine firm innovations. The technology distinction between discrete and complex technologies differentiates the firms’ behavior of managing intellectual properties by inducing different interactions among competing firms. If firms' innovations are based upon discrete technologies, other firms' innovations are likely to be substitutes. This will lead the relationship among competing firms to be more competitive in gaining more own technological territories. In case complex technologies derive firms' innovations, however, other firms' innovations are likely to be complementary with each other. The interactions among other firms will be highly cooperative with exchanging each other's technologies to implement and commercialize technological innovations.

Given the different patterns of the firm interactions, the attribute of technological interdependence becomes another significant condition for the signaling effects. By definition, if the discrete technologies underlie patented firm innovations, the firms are less likely to require other technologies to implement and commercialize the patented technologies than do the complex technologies. Firms with discrete new technologies do not need to send stronger signals to draw attention from other firms than firms with complex new technologies. Conversely, since complex technologies need more complementary technologies for commercializing innovations, firms with complex new technologies are likely to attempt to convey strong signals to other firms for high cooperation from those firms. This implies that the signaling benefits from patenting discrete technologies will be less than patenting complex technologies. Hence, firms' patenting decision over the disclosure of patent knowledge will exhibit stronger signaling benefits if the patented technologies belong to the complex technology set than to the discrete technology set.

The strategic power view, however, postulates that the attribute of technology interdependence rarely matters in determining the disclosure of patent knowledge. As Cohen, et al. (2000) argue, patenting discrete (less interdependent) technologies allows firms to deter competing firms to explore new technologies within certain technology domains by preempting the relevant technology domains. In addition, firms' patenting complex (more interdependent) technologies provide more bargaining power in negotiating cross-licensing with other firms owing patented complementary technologies (Hall and Zeidonis, 2001). Thus, regardless the technology attribute of interdependence, the patent disclosure will increase to maximize the bargaining power against cross-licensing partners or the preemption of certain technological domains. This leads to the alternative hypothesis to the one derived from the signaling view. We test the following hypothesis predicted by the signaling view.

Hypothesis 3: The knowledge disclosure of patent will be more if patented technologies are highly technology interdependent (or complex technologies) than less technology interdependent (or discrete technologies).

Methods

Data

We test above three hypotheses in the context of U.S. patents granted to public U.S. companies listed in the Standard & Poor's COMPUSTAT database in 1989. Although the patent database is publicly available in the electronic database of U.S. Patent and Trademark Office (USPTO), we use the patent database built by Hall, et al. (2001). The strength of this database is that the names of patent granted companies are coherently cleaned for the extensive firm-level analysis, in addition to the built-in measures of patent citations received by following patents, which approximate the quality of patented innovations.

Sample firms are drawn from companies listed in COMPUSTAT in 1989. The focus on the year of 1989 allows us to observe the patent citations received by the future patents for a relatively long period. Since sample firms are listed in COMPUSTAT, their accounting information and firm characteristics are available from the database. There are 4,906 firms identified with their COMPUSTAT identifier (CUSIP) in the database. Among them, 617 firms are included in the sample for the empirical analysis. The attrition of the sample firms is mainly due to no patent records in the patent database, or data unavailability in the COMPUSTAT database.

Variables

Dependent variable. To measure the disclosure of enabling knowledge of patent, we use the count of patent claims as the dependent variable. Patent claims provide the definition of what the patent protects. They are the substance of a patent. Lerner (1994) and Sakakibara and Branstetter (2001) consider patent claims a measure of patent scope. By this nature of patent claims, the disclosure of patent knowledge is presumably embedded in patent claims. If the patent claims increase, patenting firms increase the disclosure of their patent knowledge to gain more exclusive patent rights (Merges and Nelson, 1994).

Independent variables. To test three hypotheses above, we consider three independent variables that measure firm complementary assets, industry condition for imitation costs, and technology interdependence. These three variables, in effect, are important conditions for signaling benefits of patents at the firm, the industry, and the technology level. First, to measure complementary assets of patenting firms, we use firm size, approximated by the accounting value of plant, property, and equipment (PPE). This information is available from COMPUSTAT.

Since Teece's study (1986) on the association between appropriability of firm innovations and its complementary assets (for manufacturing, marketing, and service), many studies have attempted to test the impact of complementary assets on the protection of innovations. Since the extensiveness of complementary assets is highly related to firm size, we focus on firm size measured by PPE (Hall and Ziedonis, 2001). In the empirical analysis, we take a natural logarithm of PPE (Ln (PPE)). We use total asset values as well, although the results are not sensitive to the two measures. From the signaling view (as predicted in H1), the count of patent claims measuring the disclosure of patent information will decrease with firm size, if the signaling benefits of patent are a critical determinant of the patent disclosure decision. If the strategic power purposes are dominant, however, there will be an insignificant association between the patent claims and firm size.

The second independent variable is the count of competing firms in the same industry. This variable is to measure the industry competition that is positively correlated with the threat of imitation. In case industry competition is high, patenting firm innovations is highly exposed to costs incurred by imitation. Industry competition can be measured in many different ways. This study focuses on the number of rivals, because this measure can capture the industry environment of how many independent firms seeking for innovations in an industry. For the normalizing purpose, we take a natural logarithm of the count of competing firms within an industry. The industry in this study is defined as the four-digit SIC. From Hypothesis 2 predicted by the signaling view, it is expected that the count of patent claims decreases with the count of competing firms in an industry. If this hypothesis is rejected, the strategic power view will be supported.

Technology interdependence is our final independent variable. This variable is to measure how much a patented new technology needs other relevant technologies for a final product or production processes. Teece (2000: 14) notes that out of many ways to classify the different technological natures, technology interdependence is an important dimension. While a set of technologies yields value without major modifications of the system in which the technology might be embedded, the other set of technologies requires modification to other technological sub-systems, so that such technologies are highly interdependent with other technologies. This technology characteristic is frequently measured by the distinction between "discrete" and "complex" technologies (Cohen, et al., 2000; Leven, et al., 1987; Merges and Nelson, 1990; Kusonoki, et al., 1998). The main distinction between the two sets of technologies is whether a new product or process is comprised of numerous patentable elements or relatively few. Underlying technologies for new chemicals or drugs are relatively independent of other complementary technologies. In contrast, computer and electronics products are comprised of a large number of patentable technologies, so that related technologies are highly interdependent with each other for a new product or process.

For the empirical analysis, we use the technological categorizations by Hall, et al. (2001). As described in Appendix 1 of their study, they categorize patented technologies largely six groups: Chemical (group 1), Computers & Communications (group 2), Drugs & Medical (group 3), Electrical & Electronic (group 4), Mechanical (group 5), and Others (group 6). Given this categorization, we designate two groups (Computers & Communications (group 2) and Electrical & Electronic (group 4)) into "complex" technologies. The other four groups are assigned to "discrete" technologies. Although this type of technology grouping is exposed to oversimplification concern, we can economically gain a measure of technology interdependence related to an extensive patent database. In effect, Cohen, et al. (2000) consider a similar indication variable to capture the same technology characteristic, on the basis of patent granted firms' industry standard codes. Since they run survey with R&D managers of large number of U.S. manufacturing firms, such categorizations based upon industry classification codes appear natural. In contrast, this study uses an extensive corporate patent database, and hence, we believe the technology categorizations developed by Hall, et al. (2001) are more relevant. As hypothesized in Hypothesis 3 from the signaling view of patent, we expect that "complex" technology patents show more claims than "discrete" technology patents. If this is negated, the strategic power view expecting no significant relationship between the patent disclosure and technology interdependence is believed to be evidenced.

Control variables. *R&D expenditure*: Firms' R&D activity as a major input factor of patent can affect the level of the knowledge disclosure of patent. More R&D activity is likely to increase the generation of innovations. This can increase the patenting costs due to multiple innovations to be patented. To reduce such administrative costs incurred by many separate patent filings, firms with high R&D activity are likely to increase the count of patent claims by integrating many innovations into one patent. In terms of the likelihood of patent grant, more claims that describe innovations in various ways can increase the probability of patent grant (Sakakibara and Branstetter, 2001). Since high R&D firms are likely to generate more patentable innovations, such firms are less concerned about the likelihood of patent grant. This leads the negative relationship between the count of patent claims and the level of firm R&D activity. Without a specific prediction related to firm R&D expenditure, we include the natural logarithm of firm R&D expenditure to control the effect of patent input factors on the patent disclosure decision.

Technology quality: We also consider the technology quality of each patented innovation as a technology-level control variable. If patented technologies are of high technological quality, the upper bounds of patent claims of such new technologies will be larger than otherwise patented technologies. Since this technological constraint affects the patent claims, we control for this possibility by including the quality of patented technologies. To measure the technology quality, we use the count of the citations received by recent patents (so called forward citations) (Trajtenberg, 1990). To normalize this count variable, we take a natural logarithm of the count of forward citations.

Technology domains: In the technology-group level, we also control for the potential effect on the patent disclosure. Since certain technological domains impose high or low upper bound of patent claims, the dependent variable also varies with technical constraints due to the idiosyncrasy of technological domains. Using the six technology groups categorized by Hall, et al. (2001), we use five dummy variables against the base group (group 6: Others).

Time: Since the data is stacked as a longitudinal data base, we control for the time effect on the patent claims. Hall, et al. (2001) reported that the count of patent claims has increased continuously over time in all of technological domains. Kortum and Lerner (1998) and Hall and Ziedonis (2001) regard the strengthened legal system to protect patent right one of the most significant drivers in this upward time trend. By grant year dummy variables, we assume away the year-related variation of the patent claims.

Empirical Method

For empirical analysis, we use negative binomial regressions, because our dependent variable is a non-negative count variable. The most common estimation method for a count variable can be Poisson regression approach. Poisson regression analysis, however, assume that a dependent variable follows Poisson distribution whose variance is equal to its mean. Our data appear to violate this mean-variance-equality assumption in most cases.[1] Accordingly, we decide to use negative binomial regression analysis whose special case is Poisson regression analysis. Our empirical models then are based on that the expected number of patent claims made by a firm i for patent j at time t ($E[P_{jit}]$) is an exponential function of the firm's signaling conditions and other control variables at time t (X_{it}):

$$E[P_{jit}|X_{it}] = \exp(X_{it}*b + U_{it}) \quad (1)$$

[1] We undertake overdispersion tests recommended by Cameron & Trivedi (1990) and Greene (1993) that exhibit significant overdispersion problems to use Poisson regression analysis in almost all models we consider. We do not report the results, but for each of negative binomial regressions, we test the significance of overdispersion parameter, alpha, reported as log (alpha). If log (alpha) significantly approaches to negative infinity (or overdispersion parameter of alpha is significantly close to zero), the model can be estimated by Poisson regression because of little overdispersion concerns (STATA, 2001).

where $\exp(U_{it})$ follows the gamma (1/a, 1/a) distribution.

Since patent-granted firms repeatedly appear in the patent database, the error term will not perfectly fit for the white noise assumption of log-transformed regressions. To correct this concern, we consider a fixed effect model. For the fixed-effects negative binomial model, we condition the joint probability of the counts of patent claims for each patent-granted firm on the sum of the counts for the firm (i.e., S_i):

$$S_i=\Sigma^{ni}_{t=1}\Sigma^{ji}_{j=1} P_{jit} \qquad (2)$$

where ni: firm i's last observation year (or time) and ji: firm i's last patent observation given time) (Hausman, et al., 1984). Then, the final regression model can be described as follows:

$$E[P_{jit}|X_{it}, S_i] = \exp (S_i + X_{it}*b + U_{it}) \qquad (3)$$

Although this conditional fixed effects negative binomial regression model is applicable given our count dependent variable and panel data structure, we also consider other models, such as fixed effect log-linear regression model (e.g., Sakakibara and Branstetter, 2001) and fixed effect Poisson regression model (e.g., Hall and Ziedonis, 2001). The empirical results turn out to be not sensitive to estimation methods.

Empirical Results

Table 1 reports the sample characteristics. The sample consists of 63,103 patents granted to 617 firms listed in the COMPUSTAT database in 1989. The study period of patent grant years expands from 1989 to 1998. The average patent claims are 16.1. Given the average patent claims of overall U.S. patents in 1974 and 1996 are 9.3 and 14.7, respectively (Hall, et al., 2001), the sample mean claims are slightly large. Since we focus on the sample of patents granted to firms and the study period through 1998 reflects an upward trend of the average count of patent claims (depicted in Hall, et al. (2001: Figure 18)), the sample average of patent claims looks higher than the average claims of overall U.S. patents.

Sample firms whose patents are granted between 1989 and 1998 look relatively homogenous. The average of natural logarithm of plant, property, and equipments is 8.4 while its standard deviation is 2.2. Since its standard deviation is far less than its average, sample firms' size (or complementary assets) is relatively centered on the average firm size. Sample firms' R&D expenditure exhibits a similar characteristic of relative homogeneity among sample firms. It also explains that logarithm transformations of firm characteristics appear to be appropriate.

[Insert Table 1 about here]

Table 2 reports the empirical results of conditional fixed effect negative binomial regression analysis. The first column is the base model to test three hypotheses developed above independently and jointly. The coefficient estimate of firm R&D expenditure (measured by Ln (R&D)) is -0.01, statistically significant at the 0.1 percent level. Firms with high R&D activity appear to be more likely to decrease the count of patent claims than firms with low R&D activity. This result is different from the find of Sakakibara and Branstetter (2001) in which the R&D expenditure of Japanese firms is insignificantly associated with a logarithm of patent claims. We find the different impact of R&D expenditure on patent claims between U.S. and Japanese firms.

In terms of patent quality, the coefficient estimate of forward citation of a patent (0.07) is strongly positively related to the count of patent claims at the 0.1 percent significance level. It is found that patents cited by more late patents are likely to increase patent claims. At the technology domain level, technology group 1 (Chemical) and 2 (Computers & Communications) exhibit statistically significantly more patent claims than technology group 6 (Others). Both coefficient estimates are 0.05 and significant at the 0.1 percent level. All of year dummy variables show significantly positive against the base year of 1989. As the magnitudes of the coefficient estimates of year dummy variables increase over time, the upward slope of time trend of patent claims is verified.

Testing Hypothesis 1 (H1): Model 2 in the table reports the test results of the size effect on the patent disclosure (H1). The coefficient estimate of firm size measured by Ln (PPE), 0.07 is statistically significant at the 0.1 percent level. Firm size is found to be positively significantly related to the count of patent claims. That is, firms with more extensive physical assets are more likely to disclose more knowledge of patent than firms with less extensive physical assets. The data do not support for H1 of the negative relationship between firm size and the disclosure of patent. The signaling view of patent anticipates that since small size firms are more likely to require cooperation with other related firms to commercialize their patented innovations, small firms have more incentive to send strong signals (i.e., extensive disclosure of patent) to the market for new ideas than large firms. Our empirical analysis rejects the prediction by the signaling view.

This result is, in effect, similar to the finding by Hall and Ziedonis (2001). They find that firms with more physical assets exhibit a high patenting propensity. Their explanation is that since firms' physical assets can incur significant holdup costs, firms with extensive physical assets are likely to accelerate "patent racing."[2] According to the strategic power view, the association between firm size and patent disclosure should be insignificant in this study. The empirical result, however, suggest that firms' physical assets may not be neutral to strategic power. Rather, due to potential holdup costs from physical assets, large size firms may have to disclose more patent knowledge than small firms. That is, large firms must need more bargaining power than small firms, to compensate for the potential holdup costs incurred by possessing physical assets.

Testing Hypothesis 2 (H2): The result of H2 is reported in Model 2. The coefficient estimate of industry competition measured by the count of competing firms in an industry (-0.04 with p-value of less than 0.001) is significantly negatively associated with the count of patent claims. This evidences H2 proposed by the signaling view. From the signaling view of patent, more industry competition implies more expected imitation costs of patent disclosure. This leads to less signaling benefits from big patents with extensive disclosure of patent knowledge. The data appear to support this prediction. In contrast, the result does not support the strategic power view, which anticipates no significant relationship between patent disclosure and industry competition.

[2] According to Hall and Ziedonis (2001: 109), Polaroid-Kodak case is a prominent example of holdup costs. When Polaroid filed patent infringement suit against Kodak, Kodak's large plants and manufacturing equipments that use a technology in question of patent infringement had experienced temporary shutdown. This incurred significant holdup cost that Kodak had to pay more than royalties from the beginning.

Testing Hypothesis 3 (H3): In model 3, the test result of H3 is exhibited. We find the relationship between "discrete" technology dummy variable and the count of patent claims is significant at the five percent level by one-tail test. As expected in H3, the signaling benefits from patent disclosure are larger in patenting "discrete" technologies than "complex" technologies. As the signaling view of patent predicts, the technology interdependence appears to be positively associated with the disclosure of patent knowledge. At the same time, the data do not support for the strategic power view of patent, in which no significant relationship is expected between the disclosure of patent and technology interdependence.

Model 4 shows the results of testing three hypotheses jointly. The coefficient estimates of firm size, industry competition, and technology interdependence from joint hypothesis test are similar to those from independent tests. The coefficient of "discrete" technology dummy variable rather becomes more statistically significant (at the one percent level by two-tail test). For robustness check, we also consider log-linear regression and Poisson regression, resulting in very similar results that are available upon request. It appears that the empirical results are robust.

[Insert Table 2 about here]

Concluding Remarks

This study investigated the disclosure of enabling knowledge of patent. Drawing from the patent literature, we consider two recent views of patent that predict firms' patent disclosure behavior differently. The strategic power view of patent posits that firms' decision on how much to disclose enabling knowledge of patent is to garner power for cross-licensing negotiation or preempting technology competition. In contrast, signaling view of patent argues that firms' patent disclosure is a function of signaling benefits from the knowledge disclosure of patent (signals) net costs incurred by publicizing enabling knowledge under the risks of imitation from competitors. The signaling view is different from the strategic power view largely in two ways. First, firms benefits from patenting new innovations, and hence, disclosing enabling knowledge of patent, because of, rather than gaining strategic power, reducing information asymmetry in the intellectual property markets. Second, the disclosure of patent knowledge is always vulnerable to potential imitation costs, which the strategic power view relatively ignores due to the dominance of power benefits from patenting innovations.

To test these two patent views, we examined three conditions that affect the signaling patent benefits: firm size, industry competition, and technology interdependence. The strategic power view is independent of such conditions in that it predicts firms' maximum disclosure of patent knowledge for maximizing their strategic power against other firms. In contrast, the signaling view expects the variations of patent disclosure among firms with the changes of the three conditions, since the three conditions influence the signaling benefits and disclosure costs related to patenting innovations.

Using a large size of U.S. corporate patent data from 1989 to 1998, we find that firms with large physical assets tend to disclose more enabling knowledge of patent than firms with small physical assets. This finding does not support for the signaling view that predicts the opposite. It appears, however, that the result is related to the strategic power view and potential holdup costs from firms' physical assets (Hall and Ziedonis, 2001). If firms with extensive physical assets are litigated due to patent infringement, litigations can temporarily or permanently destroy the economic value of physical assets. The injunction issued by patent litigation enforces to stop the use of physical assets if the patented technologies in question are key technologies in use of the physical assets. The data also suggest that firms competing with small rather than large number of rivals are likely to disclose more patent knowledge. This finding supports for the signaling view that highlights the potential imitation costs incurred by patent disclosure. Finally, we find that firms patenting "complex" technologies show a propensity to disclose more patent knowledge than firms patenting "discrete" technologies. This also evidences the signaling view that predicts more signaling benefits in patenting "complex" technologies by reducing information asymmetry in the intellectual property markets. Overall, this study shows that firms' patent disclosure is derived from the signaling patent benefits, disclosure costs, and strategic power.

Although this is the first empirical study on the signaling role of patents in the intellectual property markets, we need more study on the strategic power view of patent. Since the strategic power view is to explain the recent upsurge of patenting activities in the U.S. during the 1990s, its focus is on the power benefits accrued from patenting innovations. Its face value from the power garnered from patents is assumed to dominate any costs incurred by costs. As we discussed the potential holdup costs of physical assets and strategic power purpose of patent, future study should explore what conditions influence the strategic power incentives of firms' patent disclosure in contrast with the signaling incentives.

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Table 1
Descriptive Statistics and Correlations [a]

	Average	S.D.	Min.	Max.	1	2	3	4	5	6	7
1. Number of patent claims	16.05	11.93	1	212	1						
2. Firm size: Ln (ppe)	8.42	2.24	-9.21	11.68	-0.08	1					
3. # of industry competitors	1.85	1.05	0	3.58	0.05	-0.53	1				
4. Technology interdependence: Discrete technology (=1)	0.42	0.49	0	1	-0.03	-0.20	0.07	1			
5. Ln (R&D expenditure)	6.05	2.10	-3.44	9.09	-0.07	0.92	-0.49	-0.32	1		
6. Ln (# of forward citations)	1.34	1.01	0	5.53	0.08	-0.02	0.03	-0.13	0.02	1	
7. Grant year: 1989-1998	1994	2.34	1989	1998	0.09	0.03	-0.02	-0.17	0.10	-0.37	1

[a] The sample size of patents is 63,107.

Table 2
Results of Conditional Fixed Effects Negative Binomial Regression Analysis [a]

Dependent variable: # of patent claims	Base model	Model 1 (H1)	Model 2 (H2)	Model 3 (H3)	Model 4 (H1, 2, & 3)
Firm size: Ln(ppe)		0.07*** (0.01)			0.06*** (0.01)
Industry competition: # of industry competitors			-0.04*** (0.01)		-0.03*** (0.01)
Technology interdependence: Discrete technology (=1)[b]				-0.01* (0.01)	-0.02** (0.01)
Ln (R&D expenditure)	-0.01*** (0.00)	-0.08*** (0.01)	-0.02*** (0.00)	-0.01*** (0.00)	-0.08*** (0.01)
Ln (# of forward citations)	0.07*** (0.00)	0.07*** (0.00)	0.07*** (0.00)	0.07*** (0.000)	0.07*** (0.00)
Technology: category 1 (=1) v. 6 (=0)	0.05*** (0.01)	0.05*** (0.01)	0.05*** (0.01)		
Technology: category 2 (=1)	0.05*** (0.01)	0.06*** (0.01)	0.05*** (0.01)		
Technology: category 3 (=1)	-0.00 (0.02)	0.01 (0.02)	0.00 (0.02)		
Technology: category 4 (=1)	0.02 (0.01)	0.03* (0.01)	0.02+ (0.01)		
Technology: category 5 (=1)	0.01 (0.01)	0.01 (0.01)	0.01 (0.01)		
Patent grant year: Year 1990 (=1) v. 1989 (=0)	0.04*** (0.01)	0.04*** (0.01)	0.04*** (0.01)	0.04*** (0.01)	0.04*** (0.01)
Year 1991 (=1)	0.05*** (0.01)	0.05*** (0.01)	0.05*** (0.01)	0.05*** (0.01)	0.05*** (0.01)
Year 1992 (=1)	0.06*** (0.01)	0.05*** (0.01)	0.05*** (0.01)	0.06*** (0.01)	0.05*** (0.01)
Year 1993 (=1)	0.09*** (0.01)	0.08*** (0.01)	0.08*** (0.01)	0.09*** (0.01)	0.08*** (0.01)
Year 1994 (=1)	0.12*** (0.01)	0.11*** (0.01)	0.11*** (0.01)	0.12*** (0.01)	0.11*** (0.01)
Year 1995 (=1)	0.15*** (0.01)	0.15*** (0.01)	0.14*** (0.01)	0.15*** (0.01)	0.15*** (0.01)
Year 1996 (=1)	0.24*** (0.01)	0.23*** (0.01)	0.24*** (0.01)	0.24*** (0.01)	0.23*** (0.01)
Year 1997 (=1)	0.22*** (0.02)	0.22*** (0.02)	0.22*** (0.02)	0.23*** (0.02)	0.22*** (0.02)
Year 1998 (=1)	-0.08 (0.28)	-0.06 (0.28)	-0.08 (0.28)	-0.08 (0.28)	-0.07 (0.28)
Constant	0.93*** (0.02)	0.75*** (0.03)	1.06*** (0.03)	0.95*** (0.02)	0.89*** (0.04)
Log likelihood	-223846.73	-223783.22	-223829.1	-223872.07	-223800.33
N= # of patents (n: firms)	63107 (617)	63107 (617)	63107 (617)	63107 (617)	63098 (616)

[a] Standard errors are in parenthesis.
[b] For the hypothesized technology interdependence variable measured by the discrete technology dummy, one-tailed test is used.
* p <.05; ** p < .01; *** p < .001