Responses of Incumbents to Patent Enforcement: An Examination of the Korean Case

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Does stronger patent enforcement stimulate innovation activities? After the 1994 Korean patent reform, a substantial increase in the number of patent applications in the electronics and related equipment industries has been observed. This paper investigates how stronger patent enforcement affected the activities of firm innovation and whether the observed upsurge of patenting propensity is attributable to the increase in innovation activities. The regression results show that incumbents with large fixed capital strategically responded to patent enforcement by substantially increasing patent applications, but not research and development intensity. The results were consistent with the *strategic response hypothesis* and suggested that the 1994 Korean patent enforcement did not stimulate the innovation activities of firms.

Keywords: Patent reform, Innovation, Strategic response

JEL Classification: L5, L6, O3

I. Introduction

The effectiveness of strong intellectual property rights as an innovation incentive mechanism has been a controversial issue among economists and policy makers. People favoring strong patent protection argue that

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it provides stable economic opportunities to appropriate innovation results and offers strong incentive for inventors to stimulate innovation activities. However, skeptics argue that the effectiveness of strong patent protection is different across industries, and depends on the characteristics of the technological field. For instance, Cohen *et al.* (2000) argue that the appropriations of firms in “discrete product industries,” such as the pharmaceutical or chemical industry, rely heavily on legal protection, whereas firms in “complex product industries,” such as the electronics and machine industries, are more likely to protect their innovations through “secrecy” or “technological lead-time.” The rapid pace of technological development is also likely to decrease the marginal contribution of legal protection.

The controversy is still ongoing in theoretical and empirical literature. Some comparative country studies document the positive effect of a stronger patent system on economic growth (Gould and Gruben 1996; Kanwar and Evenson 2003; Dincer 2007), whereas other studies based on firm-level micro analysis find no positive effect of stronger patent on the innovation activity of firms (Jaffe 2000; Hall and Ziedonis 2001; Sakakibara and Branstetter 2001).

In this study, we examine whether stronger patent enforcement through the Korean patent reform in 1994 stimulates the innovation activities of the private sector. In 1994, the Korean government expanded the duration of patent right from 15 to 20 years, and reinforced inventor rights corresponding to the protection level outlined by the Trade Related Intellectual Property Rights Agreement (TRIPs). Therefore, the 1994 patent reform effectively raised Korean intellectual property rights to the level of advanced countries and offered a natural experiment to assess the economic effect of stronger patent reform on innovation.

This analysis focuses on the *electronics and related equipment industry* because this industry exhibited a significant increase in patent applications immediately following the 1994 patent reform, whereas other industries, such as the chemical or pharmaceutical industries, did not. Such phenomenon is somewhat paradoxical as the electronics and related equipment industry have substantially complex, rapidly progressive, and cumulative technological characteristics. According to Cohen *et al.* (2000), firms in “complex product industries” are generally expected to be less reliant on legal protection and to show modest response to the patent reform. We investigate this disjuncture between theoretical prediction and reality, and attempt to understand the motivations behind the observed patent increase. Thus, the objective of this study is twofold. We first examine whether stronger patent regulation stimulates the innovation activity of firms, and then, we identify the strategic behavior of incumbents that is attributable to the 1994 patent reform.

One of our key empirical findings is that the response of large firms is quite different from the responses of small to medium-sized companies. After the patent reform, large incumbents with high fixed costs significantly increased the number of patent applications without increasing R&D spending, whereas small to medium-sized firms showed no significant changes, either in the number of patent applications or in R&D spending. The result implies consistency with the "strategic response hypothesis," which states that firms with high fixed costs tend to increase patent applications under a stronger patent regime to avoid nuisance patent litigations or patent "hold-up" problems. The empirical results, thus, suggest that the 1994 Korean patent reform did not stimulate the innovation activities of the private sector, but caused a strategic response among large firms to fence the market against potential entrants.

The remainder of the paper is organized as follows: Section II briefly reviews related theoretical and empirical literature, and describes the 1994 Korean patent reform. Section III discusses the data and sample used for estimation, and delineates the econometric model. Section IV presents the regression results, and section V concludes this study.

II. Patent Reform and Innovation Activity of Korean Firms

A. Literature Review

Theoretical literature on patent and innovation activity has formally proved the relationship between patent scope and optimal innovation effort, and that government policy makers and public interest groups have advocated strong patent protection. However, contrary to this common perception, recent empirical studies offer mixed results regarding the effect of patent enforcement on innovation activities. Kanwar and Evenson (2003) utilize cross-country panel R&D investment data from 1981 to 1995 and argue that more stringent protection of intellectual property right provides a significant incentive with inventors to spur innovation. Stronger intellectual property right increases R&D expenditure not only in developed countries but also in developing countries. Yueh (2009) explores whether the reform of patent laws in China has resulted in innovation by using 29 regional data sets from 1991 to 2003. Despite criticism on imperfect legal enforcement, the reform of the patent law system has produced a stock of patents that has grown rapidly alongside economic growth. Nevertheless, the imperfect IPR system of China generates innovation as the country develops and hinges on the key factor of researchers.

However, some studies focusing on the relatively short-term and microeconomic effects of stronger patent reform found no significant empirical evidence of spurred innovation activities. Kortum and Lerner (1999) investigate the cause of an unprecedented surge of US patenting in the 1990s. Using both international and domestic data on patent application and awards, they found that the upsurge of patenting is attributable to an increase in US innovation spurred by changes in the management of research rather than institutional changes.

Sakakibara and Branstetter (2001) examine the effect of an expansion of patent scope in 1988 on firm innovation activities by using data obtained from 307 Japanese firms, and argue that the marginal effect of stronger patent is quite modest. They found no empirical evidence that the Japanese patent reform has spurred either R&D spending or innovation output in the private sector.

Meanwhile, Cohen *et al.* (2000) show that the importance of patent protection and the degree of patent dependency are quite different among industries, and are based on the approach of each industry to protect against the appropriation of innovation. According to the Carnegie-Mellon Survey, firms perceive secrecy, technological lead-time, and patent rights as important mechanisms for appropriating the economic benefit of innovation, but patent is the least important instrument among them.[1] They show that patent is overall the least important tool for protecting firm innovation outputs, and no industry indicates patent to be the most effective instrument.

Studies on firm behavior using industrial data from the US also found no empirical evidence to support the idea that strengthened patent rights spurred innovation in the private sector. Using US R&D data, Jaffe (2000) finds that expanded patent rights did not induce more innovative activities in firms. Jaffe (2000) argues that R&D investment in the US had increased before the patent enforcement, and that expanded patent rights did not contribute to innovation.

[1] Secrecy was the dominant mechanism in the chemical and semiconductor industries, whereas the communications equipment, computer, steel, car, and truck industries indicated "lead-time" as the key mechanism. The electrical equipment sector showed low scores overall, which suggested that the appropriability of innovation in that sector was low.

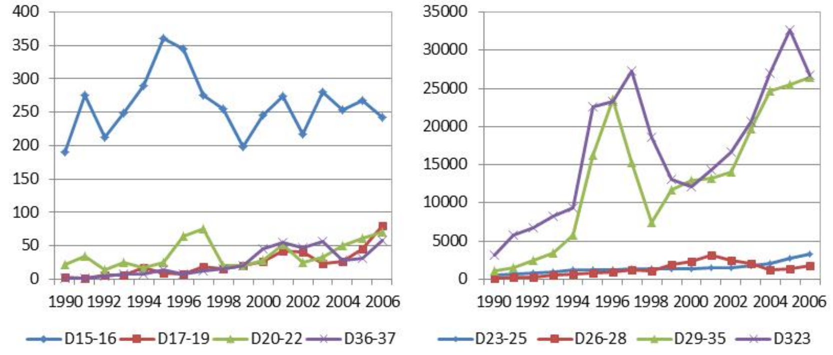
Hall and Ziedonis (2001) investigate the US semiconductor industry by using data from 1979 to 1995, and find that strengthened patent rights are effective only for R&D-intensive small firms, but not for large conglomerates. They further argue that expanded patent rights caused a rapid increase in patent applications in the 1980s without associated increases in R&D expenditures.

Mowery and Sampat (2001) provide little evidence of the effect of institutional change on innovation activity. Using data on three leading universities (University of California, Stanford University, and Columbia University), they argue that the Bayh-Dole Act was only one of several important factors behind the rise of university patenting and licensing activity. Bayh-Dole appears to have little effect on the content of academic research at the universities, which revealed similarities in their patent and licensing portfolios 10 years after the passage of the Bayh-Dole Act.

Notably, empirical results differ across cases and econometric settings. Several studies use patent application data as a proxy variable for innovation activity. The basic assumption is that as R&D activity increases, the number of patent applications increases proportionately. However, this assumption does not work when firms apply for patent based on strategic concerns rather than as an outcome of innovation. In fact, we observe significant discordance between R&D expenditure and patenting propensity after the 1994 Korean patent reform, which is discussed in more detail in the following section.

B. 1994 Patent Reform and Response of Incumbents

Economic literature on patent reform generally assumes that broader patent scope or extended patent length induces more R&D efforts, and the positive relationship between patent scope and optimal R&D effort is widely accepted by many economists and policy makers. The Korean government joined the agreement on TRIPs and expanded a corresponding patent scope in December 1993. The most noteworthy change from the reform is the expansion of patent duration from 15 to 20 years from the date of patent application filing. Through the 11^{th} amendment (1994 reform), patent protection level is extended to products and processes in all fields of technology, which include the patentability of material produced by nuclear transformation. The 11^{th} amendment also effectively reinforces inventor rights corresponding to the level of TRIPs. Through the reform, the patent rights of Korea have reached the level of developed countries.

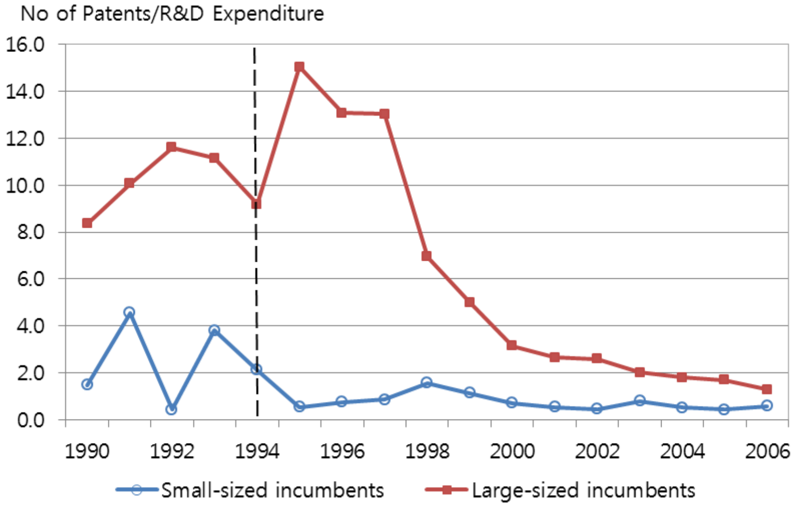


Note: D15-D16: food products, beverages and tobacco; D17-D19: textiles, textile products, leather and footwear; D20-D22: wood, pulp, paper, paper products, printing and publishing; D23-D25: chemical, rubber, plastics, and fuel products; D26-D28: other non-metallic mineral, basic metals, and fabricated metal products; D29-D35: machinery and equipment and transport equipment except D323; D323: electronics and related equipment industry; D36-D37: manufacturing n.e.c. and recycling.
Source: Korean Intellectual Property Office (2007).

FIGURE 1
NUMBER OF PATENT APPLICATIONS IN KOREAN MANUFACTURING (1990-2006)

Following the patent reform, the number of patent applications increased significantly, especially in the electronics and related equipment industry. Figure 1 presents data from patent applications for Korean manufacturing industries from 1990 to 2006. The number of patent applications in the electronics and related equipment industry (D323) increased in 1995, just after the patent reform, and continued to exhibit a sharp rise until 1997.[2] A similar pattern is observed in the "machinery and equipment and transport equipment" industries (D29-35, except D323), but no similar response happened in other sectors, which suggested that the 1994 patent reform may have contributed to a pro-patent shift in the Korean manufacturing industry, particularly in the electronics and machinery related industry. However, the phenomenon observed is quite inconsistent with previous studies and predictions. As noted above, the electronics and machinery equipment industries are

[2] However, the number of patent applications substantially decreased from 1998 to 2001, when Korea experienced financial crisis.



Note: R&D Expenditure = million US Dollars at 2000 constant value.
Source: Korean Intellectual Property Office (2007).

FIGURE 2
R&D INTENSITY BY FIRM SIZE IN D323

characterized by "complex product technology," and are expected to be the least responsive to patent enforcement.

The responses of incumbents vary across firm size. Figure 2 presents the trend of patenting propensity to R&D expenditure of large and small to medium-sized firms. Large firms exhibit a sharp increase in patent propensity following the 1994 patent reform, whereas small to medium firms show little or no significant changes in patenting propensity. This upsurge in the patenting propensity of large firms is due to the disparity of R&D expenditure and the number of patent applications. Large incumbents show significant increase in the number of patent applications right after the reform, but there is no substantial change in associated R&D expenditures. For small to medium-sized firms, we did not observe any significant changes either in the number of patent applications or in R&D spending after the patent reform. This finding suggests that the upsurge of patent applications in large firms can be attributable to the patent reform, but the innovation activity measured by R&D intensity may not be appreciably affected by the patent reform.

The data presented in Figure 2 highlight two important issues. First, the innovation activity of industry, which is measurable by R&D expenditure or intensity, seems to have been unaffected by the 1994 patent reform. Second, the comparative volume of patent applications reveals different behaviors between large and small firms, which suggest that dominant incumbent firms strategically respond to stronger patent reform by aggressively applying for patents to avoid possible nuisance litigations or patent "hold-up" problems. We present more accurate econometric models to examine whether the observed feature is consistent with statistical analysis controlling for other factors.

III. Econometric Model: Patent Production Function

The main objective of this study is to explore whether the Korean patent reform of 1994 stimulated innovation efforts in the private sector, and if it did not, to investigate the main motivation underlying the significant increase in the patent applications of incumbents in the electronics and related equipment industry (D323). The tendency to patent is measured by the number of patent applications, while the innovation activity of individual firms is measured by real R&D expenditures and R&D expenditures per worker. The trends of R&D intensity in Figure 2 demonstrate that firm size could be an important factor for firm patenting behavior. Thus, we split the data and run separate regressions across firm size, large versus small to medium-sized firms.

For the econometric model, we employ a patent production function introduced by Pakes and Griliches (1980), and adopt a negative binomial regression model to explore incumbent response to patent reform. The negative binomial regression model is a Poisson model because the number of patents is count-variable. However, the assumption on equality of the conditional mean and variance in the Poisson regression model is typically taken to be the major shortcoming. Alternatives have been suggested, and the most common is the negative binomial model, which arises from a natural formulation of cross-sectional heterogeneity. The negative binomial regression model is an extension of the Poisson regression model that allows the variance of the process to be different from the mean. Thus, the model introduces an unobserved individual heterogeneity or over-dispersion into the Poisson model.

For the over-dispersion fixed effect models, let y_{it} be the count for the t^{th} observation for firm i. We began with the model $y_{it} \mid \gamma_{it} \sim$ Poisson (γ_{it}), where $\gamma_{it} \mid \delta_i \sim$ gamma (λ_{it}, $1/\delta_i$) with $\lambda_{it}=\exp(X_{it}\beta+\varepsilon_{it})$, and δ_i was the dispersion parameter. This yields the model:

$$\Pr(Y_{it} = y_{it} \mid X_{it}, \delta_i) = \frac{\Gamma(\lambda_{it} + y_{it})}{\Gamma(\lambda_{it})\Gamma(y_{it} + 1)} \left(\frac{\delta_i}{1+\delta_i}\right)^{\lambda_{it}} \left(\frac{1}{1+\delta_i}\right)^{y_{it}}$$

When considering only within-group effects, this specification yields a negative binomial model for firm i with dispersion (variance divided by mean) equal to $(1+\delta_i)$.

We estimate a series of "patent production functions" under various specifications that measure whether a change in firm-level patenting behavior took place during the period associated with stronger patent reform. To estimate the patent production function, R&D expenditures or R&D expenditures per worker are first considered as a main determinant of patent production. Previous studies (Lerner 1995; Lanjouw and Lerner 1996; Hall and Ziedonis 2001) argue for economies of scale in generating patents because of the fixed cost of maintaining a legal department that handles intellectual property rights and related work. Thus, we incorporate firm size, which is measured by the number of workers, into the regression equation to test for scale effect in firm patenting behavior.

Hall and Ziedonis (2001) argue that firms with large sunk costs in complex manufacturing facilities are vulnerable to "hold-up" in the new US patent regime, and appear to have larger incentives to expand their patent portfolios. These firms have to safeguard against the threat of costly litigation, and to negotiate access to external technologies on more favorable terms. This hypothesis is called the strategic response hypothesis. Under this hypothesis, the firm with larger sunk costs is expected to respond strategically, and to patent more aggressively when patent enforcement becomes stronger. Thus, we include the capital intensity variable (lnCapint) of firms in the regression equation to test whether the strategic response hypothesis is consistent with the case of the Korean electronics industry under the stronger patent regime.

The dummy variable, Post-1994, is also introduced to isolate the effect of the institutional change of patent reform. The value of this variable is 0 if the year is 1994 or before, and 1 if after 1994.

IV. Data Sources and Empirical Results

A. Descriptive Summary

Following Hausman, Hall, and Griliches (1984), we adopt a negative binomial regression model for the electronics and related equipment industry in Korea during the sample period of 1990 to 2006. We analyze how R&D investment and patenting behavior were changed corresponding to the patent reform. Two different sources of data are combined based on company name and industry code. Data on the number of patent applications by individual firms were obtained from the Korean Intellectual Property Office, while R&D expenditures, sales, number of workers, and tangible fixed assets were retrieved from the Korea Investors Service-Financial Analysis System (KIS-FAS).

We focus on the electronics and related equipment industry, which is characterized by rapidly changing and cumulative technologies. By focusing on a specific industry, we expect that we will be able to control industrial heterogeneity and to identify more accurately the characteristics associated with the R&D activities of individual firms. This study uses unbalanced firm-level panel data obtained from 35 individual firms in the electronics and related equipment industry, and employs only the firms established before 1994 to investigate the responses of incumbents to the 1994 patent reform. We also limit our sample to firms with at least two-year occurrences in patent applications during the sample period. R&D expenditures were deflated by the producer price index to convert them to 2000 constant values.[3]

Table 1 presents the summary statistics for the sample used in the regression. The maximum number of patent applications by a single firm is 17,832 by Samsung Electronics in 2005. This firm also achieved the maximum observed value of real R&D spending and the maximum number of employees in the sample in 2006, which were 16.3 billion US dollars and 85,813 workers, respectively.

Comparisons of the mean and median in Table 1 exhibit severely skewed sample distributions for each variable. The mean of each variable was generally larger than the median, which suggests that large firms generally dominate innovation activities. The mean value of patent applications for each year is up to 545.2, but the median firm usually has zero

[3] R&D expenditure is classified as R&D asset and cost in the KIS-FAS database. We define R&D expenditure as the sum of those two classifications.

TABLE 1

SUMMARY STATISTICS DURING 1990-2006 (obs. = 529)

Variable	Mean	Median	Std. Dev.	Min	Max
Patent application[1]	545.2	0.0	2,208.2	0	17,832.0
R&D spending (2000 constant million US$)[2]	180.9	1.4	1,207.6	.004	16,318.3
R&D spending per worker (2000 constant thousand US$)	20.3	6.1	51.7	.013	879.1
Number of workers	3,512.4	221.0	10,933.4	1	85,813.0
Tangible fixed asset per worker (2000 constant thousand US$)	85.0	45.2	110.4	.599	982.2

Notes: 1) The number of patent application of 75 percentile in the sample is 4.
2) Purchasing power parity used here is 753.2 Korean Won per US dollar of 2000.

patent applications per year. The average value of R&D expenditure is 180.9 million US dollars, whereas the median firm spends no more than 1.4 million US dollars. R&D intensity (measured by R&D spending per worker), firm size (measured by number of workers), and capital intensity (measured by tangible fixed assets per worker) exhibit asymmetry across firm size as well. The standard deviation is larger than the mean value of each variable. The features of the data suggest that the over-dispersion of variance is substantial, and that the negative binomial model fit better than the simple Poisson regression model.

B. Empirical Results

The response of incumbents to patent reform is measured based on the number of patent applications. Table 2 presents the estimation results based on a negative binomial fixed effect model under various specifications.[4] The fixed effects for each firm with a constant term are not reported for simplicity.

We first estimated the effect of R&D expenditure on patent application,

[4] For the robustness of empirical results, we also estimated the regression models by using the negative binomial random effect model. The empirical results were almost the same as the results of the fixed effect model. The results are available from the authors upon request.

TABLE 2
EMPIRICAL RESULTS OF PATENTING PROPENSITY
DEPENDENT VARIABLE = NUMBER OF PATENT APPLICATIONS

Variable	(1)	(2)	(3)	(4)	(5)	(6)
LnRndr (Log R&D)	.374 *** (.027)					
LnRndrwk (Log R&D per worker)		.224 *** (.023)	.217 *** (.052)	.199 *** (.054)	.184 *** (.054)	.184 *** (.054)
LnCapint (Log P&E per worker)			.180 ** (.081)	.140 * (.085)	.154 * (.082)	.154 * (.083)
LnSize (Log workers)			.440 *** (.046)	.468 *** (.049)	.402 *** (.061)	.402 *** (.061)
Post-1994 (Dummy for post-1994)				.296 # (.191)	.340 * (.179)	.339 * (.181)
Dummy for Samsung-LG					.696 * (.366)	.697 * (.366)
Dummy for 1998						.006 (.194)
Log-likelihood	-1034.5	-1090.0	-1027.2	-1026.0	-1024.2	-1024.2
Wald chi-squared	188.4	44.58	228.3	232.0	266.4	266.4
No of obs.	529	529	529	529	529	529
No of firms	35	35	35	35	35	35

Note: ***, **, * and # indicates 1%, 5%, 10%, and 15% significance level, respectively. The figures in parentheses are standard errors.

which indicates the estimated elasticity of patent applications with respect to R&D spending. The estimated coefficient is .374, which is somewhat lower than the estimates for the US. Hall, Griliches, and Hausman (1986) obtained an R&D elasticity of .52 for a sample of 642 firms. Hausman, Hall, and Griliches (1984) obtained an elasticity of .75 by using the negative binomial regression model for 128 large manufacturing firms, which represented the entire manufacturing sector of the 1970s.[5] Hall and Ziedonis (2001) obtained an R&D elasticity of .989 for a sample of 95

[5] The elasticity of patent applications with respect to R&D spending for the large-firm sample was .329, with standard error of .043 by using the same variable in column (1).

US semiconductor firms from 1979 to 1995. The estimated patent propensity with respect to R&D spending in developing countries, such as Korea, is lower than developed countries. The difference in R&D elasticity between developing and developed countries may reflect the "catching up" nature of the industry in developing countries, particularly limitations in research related to equipment and workers.

In columns (2) to (6), R&D intensity, which is measured by R&D expenditure per worker (LnRndrwk) instead of R&D expenditure, is included in the regression models as an indicator of innovation activity or an input to produce patent applications. According to empirical results, the innovation activity shows a statistically significant and positive effect on patent applications. The estimated coefficients of R&D intensity were stable and ranged from .184 to .224 at 1% significance level.

Regression results also show that capital intensity (defined by plant and equipment (P&E) fixed asset per worker) significantly influences the propensity to patent application. The estimated coefficient in columns (5) and (6) is .154, which is statistically significant at 10% level. This value implies that, other things being equal, the firm with higher capital intensity is more likely to patent for their inventive output. The regression result is consistent with Hall and Ziedonis (2001). Further, this finding suggests that capital-intensive firms in Korea are also concerned about the patent "hold-up" problem, which could be caused by the nuisance patent litigation of potential competitors, and are more likely to invest aggressively in patent applications.

Of note are regression results for the effects of firm size and a dummy variable for dominant firms. The estimates of firm size and the dummy variable for Samsung and LG are statistically significant at the 1% and 10% levels, respectively, and the coefficients are larger than those of any other variables. These results indicate that Samsung and LG tended to file patent applications more often than any other firm, and even after controlling the Samsung and LG effects, a statistically significant scale effect on patenting behavior existed. According to Hall and Ziedonis (2000), large firms obtain the benefit of economies of scale in patenting because of the large fixed cost of initiating and maintaining legal procedures.

Finally, the coefficient of the post-1994 dummy variable showed statistical significance at the 10% level. This result implied that, on average, the firms increased the number of patent applications after the 1994 patent reform, and that aggressive patent portfolio races occurred among incumbents after the patent reform in 1994 even after controlling for

TABLE 3
EMPIRICAL RESULTS OF PATENTING PROPENSITY BY FIRM SIZE

Variable	Small-size incumbents		Large-size incumbents	
	(1)	(2)	(3)	(4)
LnRndrwk	.404 ***	.395 ***	.160 **	.125 *
	(.088)	(.092)	(.075)	(.068)
LnCapint	.094	.091	.193 *	.125
	(.126)	(.126)	(.115)	(.115)
LnSize	.737 ***	.736 ***	.572 ***	.643 ***
	(.194)	(.194)	(.094)	(.098)
Post-1994		.164		.445 **
		(.463)		(.219)
Log-likelihood	-363.9	-363.8	-629.7	-627.6
Wald chi-squared	61.9	61.18	98.9	99.8
No of obs.	382	382	132	132
No of firms	30	30	10	10

Note: 1) ***, **, and * indicate 1%, 5%, and 10% significance level, respectively. The figures in parentheses are standard errors.
2) The dummy variables for year-1998 and Samsung-LG were dropped from the regression equation since those variables were not statistically significant.

other variables, such as R&D intensity, capital intensity, and firm size.

However, the effect of patent reform is asymmetric such that large firms were the only firms responding to the reform. We divided the sample into two groups, large versus small to medium-sized firms. Table 3 presents the regression results of these two groups. The overall results in Table 3 are consistent with the results in Table 2. R&D intensity and firm size effect are statistically significant in both groups, and the estimated coefficients of firm size in both groups are larger than R&D intensity. However, the 1994 patent reform is only effective for large incumbents. The estimated coefficient of the post-1994 dummy variable for large incumbents is 0.445 and statistically significant at the 5% level, whereas the dummy variable for small to medium-sized firms does not show any statistical significance. This result indicated that the stronger patent enforcement of 1994 is effective only for large firms, but not for small to medium-sized firms.

However, to interpret the effect of the patent reform, we have to keep in mind that the Korean economy experienced serious economic downturn

TABLE 4
PATENTING PROPENSITY BY FOUR-YEAR INTERVALS

Variable	Period I: 1990–1993 Before reform	Period II: 1994–1997 Short-term after reform	Period III: 1998–2001 Medium-term after reform	Period IV: 2002–2006 Long-term after reform
LnRndrwk	.515 ***	.015	.619 ***	.248 **
	(.155)	(.088)	(.219)	(.106)
LnCapint	.585	.966 ***	.101	-.127
	(.409)	(.288)	(.267)	(.178)
LnSize	.422	.473 ***	.122	.699 ***
	(.256)	(.132)	(.151)	(.103)
Log-likelihood	-100.4	-152.7	-185.3	-282.8
Wald chi^2	45.2	31.5	19.6	66.7
No of obs.	40	75	96	157
No of firms	10	19	24	32

Note: ***, **, and * indicate 1%, 5%, and 10% significance level, respectively. The figures in parentheses are standard errors.

(the so-called financial crisis) that resulted in substantial changes in industrial structures and firm governance during 1998 to 2001. During this period, the shares of the foreign ownership of Korean firms dramatically increased, and many scholastic papers argued that the innovation behavior of Korean firms was qualitatively changed (Chang and Shin 2002). To incorporate the possible change of firm innovation behavior attributable to the "financial crisis," we separated the sample period into four 4-year periods, and ran separate regressions. With this analysis, we expected that we could show how firm behavior changed after the patent reform as well as the main motivation in the upsurge of patent applications.

Table 4 presents the regression results with separate periods. The first period, 1990-1993, reflects the patenting behavior of firms before the patent reform. We may call this period the "weaker patent regime." The second period, 1994-1997, indicates patenting behavior during the pro-patent regime, which reflects short-term response to the pro-patent regime. The third period, 1998-2001, as mentioned above, represents the period of the Korean financial crisis, which might have a substantial economic impact on firm behavior. We observed a substantial decrease in patent application filing during this period, and we identified which variable is the most significant factor to explain firm patenting behavior.

Finally, the 2002-2006 period indicates the period after the financial crisis. The last period in this paper indicate the relatively long-term effect of the patent reform in 1994 on patenting.[6]

The regression results in Table 4 demonstrate significant changes in the patent application behavior of incumbents. From 1994 to 1997 (period II), which is the period right after the patent reform, patent propensity is substantially increased, but the effect of R&D intensity (LnRndrwk) on patenting disappeared, although this effect is statistically significant during the first period (before the patent reform). The capital intensity and size of firms demonstrate significant effect on patent application, but this effect is not significant during the first period. The estimated coefficient of capital intensity soared to 0.966 from 0.585, and showed statistical significance at 1% level. During the second period, firm size (Lnsize) also exhibits a statistically significant and positive effect on patent applications. These results are consistent with the strategic response hypothesis of Hall and Ziedonis (2001) in which capital-intensive firms with large scale are more likely to increase patent applications under a stronger patent enforcement regime.

However, the strategic response of large incumbents was observed only in the second period (1994-1997), which implied a short-term response to stronger patent enforcement in our model. During the third and fourth periods, the estimated coefficient of capital intensity lost its statistical significance, whereas R&D intensity regained its significance. The estimation results provided indirect evidence that firm behavior in patenting changed during and after the financial crisis as the capital intensity variable, which represents firm strategic responses lost its statistical significance even though it exhibited a significant correlation with patenting propensity during the second period. Whether the switch of patenting motivation is the result of either the financial crisis or the long-term effect of stronger patent reform being unclear, the patent reform initiated a strategic response of large incumbents during the short term at least.

In summary, regression results show that the 1994 Korean patent

[6] The strategic response disappeared in periods III and IV, and the importance of R&D intensity and economies of scale increases in period IV. Korean firms changed their economic behavior after the economic crisis, but the reasons are multifaceted. Some argue that the substantial increase of foreign direct investment was one of the most important factors, whereas others insist that structural change in industrial distribution was one of the most important factors. The examination of the reason is beyond our study. Thus, we defer analysis as a future research topic.

reform affected the patent propensity of firms (Table 2). However, the effect was limited to large incumbents and only in the short term (Tables 3 and 4).[7] These results supported the spirit of the strategic response hypothesis such that patent propensity was not associated with increased R&D intensity at least for the short term after the patent reform in 1994. Firm size was also an important factor in explaining the patenting propensity of firms, and suggested that economies of scale in applying for patents are important factors in explaining the increased number of patent applications in small and large incumbents (Table 3).

V. Conclusion

This paper examined the response of incumbents to the 1994 Korean patent reform in the electronics and related equipment industry. The main question of the study focused on whether stronger patent enforcement effectively induced more innovation activities of incumbents. We explored the causes of the significant upsurge in the number of patent applications immediately following the 1994 patent reform in Korea.

The 1994 patent reform in Korea did not stimulate the innovation activity of private sectors, but was accompanied with a strategic response of large incumbents by aggressively filing patent applications without increasing R&D intensity. R&D intensity was an important factor for firm patenting behavior during the first period (before the patent reform), but it lost its statistical significance during the second period (after the patent reform, 1994-1997), which represented the short-term response of firms to stronger patent reform. Capital intensity, which was introduced to test the strategic response hypothesis, showed statistically significant and positive correlation with the number of patent applications only during the second period. This finding implied that, all other things being equal,

[7] We also ran regressions that separated the sample with firm size and each period. The regression results were consistent with Table 4. For large incumbents, strategic behaviors attributable to the 1994 patent reform were observable only in period II (1994-1997) as capital intensity variable is statistically significant at the 1% level only in period II. However, for small firms, capital intensity related to patent applications showed no statistical significance during any sample period, which implied that the 1994 Korean patent reform influenced the patent propensity of firms, but the effect was limited to large incumbents and only during short term. These results are consistent with the spirit of the strategic response hypothesis. However, the sample size of each regression analysis seemed too small to warrant the credibility of statistical analysis. We present the regression results in Appendix.

the firm with large fixed capital asset was more likely to patent under a stronger patent regime. However, for small incumbents, we found no statistically significant results during the sample period. Large firms with large fixed costs responded to stronger patent enforcement in accordance with the strategic response hypothesis.

Empirical results also suggested the importance of firm size in patenting propensity. After the economic crisis (the third period), the magnitude of the estimated coefficient of firm size increased and showed statistical significance for both large and small incumbents, which implied that economies of scale are increasingly important factors in explaining patenting propensity.

The R&D intensity of large incumbents was not significantly correlated with patenting propensity during the second period, but it appeared to have a significant correlation with patent propensity during the third and fourth periods (1998-2001 and 2002-2006). By contrast, capital intensity was statistically significant only during the second period, 1994-1997, but not in the third and fourth period, which suggested that the strategic motive of large incumbents in patenting was sustained only for a short time, and that the motivation for patenting behavior has changed over time. R&D intensity rather than "strategic motive" became a more important factor to determine patenting behavior during and after the financial crisis. The change could be the result of substantial changes in firm structure and foreign ownership during the financial crisis or to the long-term effect of stronger patent enforcement. Even though the regression results confirmed that large incumbents with high fixed costs strategically responded to stronger patent enforcement in the short term, we need further investigation to understand whether the observed increase in R&D intensity comes from the long-term response to stronger patent enforcement.

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APPENDIX

TABLE A1

RESULTS BY FIRM SIZE AND FOUR-YEAR INTERVALS

Variable	Period I: 1990–1993 Before reform	Period II: 1994–1997 Short-term after reform	Period III: 1998–2001 Medium-term after reform	Period IV: 2002–2006 Long-term after reform
		Small-size firm		
LnRndrwk	.722	.509 *	.757 ***	.120
	(.997)	(.283)	(.315)	(.197)
LnCapint	.400	-.201	.471	-.085
	(3.684)	(.718)	(.334)	(.227)
LnSize	6.047	.579	.315	1.505 ***
	(4.481)	(.516)	(.498)	(.434)
Log-likelihood	-7.3	-32.0	-63.7	-130.0
Wald chi^2	2.1	3.9	10.8	13.1
(p-value)	(.543)	(.275)	(.013)	(.004)
No of obs.	12	47	72	117
No of firms	3	12	18	25
		Large-size firm		
LnRndrwk	.611 ***	-.069	.695 **	.251 *
	(.174)	(.075)	(.353)	(.141)
LnCapint	.456	1.122 ***	-1.272 **	-.294
	(.428)	(.282)	(.502)	(.300)
LnSize	.062	.124	.886 **	.982 ***
	(.386)	(.308)	(.392)	(.192)
Log-likelihood	-90.7	-116.2	-112.7	-136.0
Wald chi^2	43.8	16.4	13.1	55.0
(p-value)	(.000)	(.001)	(.004)	(.000)
No of obs.	28	28	23	36
No of firms	7	7	6	8

Note: ***, **, and * indicate 1%, 5%, and 10% significance level, respectively. The figures in parentheses are standard errors.

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