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The influence of patent protection on firm innovation investment in manufacturing industries

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Abstract

Countries enact various mechanisms, such as patent protection, to encourage, protect, and reward firm innovation. The degree to which these mechanisms afford firms protection over their intellectual property influences the innovation strategy that firms pursue and innovation investments they make. To date, empirical evidence on the relationship between patent protections and firm innovation is lacking, despite the relationship being the subject of intense theoretical and policy debate. To further consider the influences on firm innovation, we test the influence of a country's patent rights and changes in them on firm-level investment in innovation. Data for 706 firms competing in ten manufacturing industries across 29 countries were gathered and analyzed. Even after controlling for various firm, industry, and national factors, there is a strong positive influence of patent rights and changes in patent rights on a firm's propensity to invest in innovation. In addition, we consider the sensitivity of this result to alternative measures of patent and other intellectual property protection. We also find that the influence of patent rights on firm-level innovation varies across industries for example, the impact appears greatest in the scientific instruments and industrial chemicals industries.

Keywords: Patent protection; Firm innovation investment; Industry dynamism; Munificence; Concentration

1. Introduction

How do countries go about encouraging and supporting innovation? With the increase of globalization, this is becoming a critical question asked by many policymakers as they attempt to

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enact laws and establish mechanisms that spur and protect investments in innovation. Countries can protect innovation through mechanisms such as patent and other intellectual property rights (i.e., copyrights, trademarks, and trade secrecy). Heated debate – both normative and positive – exists as to whether a strengthening of patent rights is appropriate for stimulating innovation. On the one hand, stronger protection enhances a firm's ability to appropriate the rewards to its innovation; on the other hand, it reduces the access to and/or raises the cost of technological inputs to other firms. Technological change is driven by both innovative and imitative activities. Thus, the presence of both stated and enforced protections shifts resources between these activities. How this influences the innovation process is of crucial interest to policymakers whose objective is to stimulate technological progress. However, the academic debate surrounding this issue has been primarily theoretical and speculative.

Limited previous empirical studies have largely depended on aggregate-level data. In this paper, we utilize a unique dataset of global firms in ten manufacturing industries. It is at this disaggregated level that we examine the influence of national policy on patent protection. We hypothesize that a country's patent rights and changes in patent rights positively influence firm innovation investment. Independent confirmation of the importance of patent rights on firm innovation is obtained from alternative measures of patent protection. In our data, we do not find evidence of endogeneity (or reverse causation) where firm innovation determines national patent protections. It is plausible for endogeneity to exist at the national level, but not at the firm level. We do, however, find that the positive, and statistically significant, effect of patent rights on firm-level innovation is influenced by the industry in which firms operate. We also find, as with previous research, that patent rights are particularly important for industries (such as scientific instruments and industrial chemicals) where technological reproduction and distribution is fairly easy. Industries characterized by high fixed costs, long lead times, and other natural barriers (such as Food and Household Appliances) are less dependent upon patents.

The paper is organized as follows: We first discuss recent trends in national patent protection. We then review the literature and discuss the empirical framework (providing a management-theoretic perspective). This is followed by a discussion of the data, method, and empirical results (including the results of sensitivity tests). In the last section, we summarize the findings, discuss limitations with the study, and suggest extensions for research.

1.1. Trends in Patent Protection and Laws

The global economy has become an aggregate of interdependent national economies and is therefore becoming increasingly complex. Chaos Theory predicts that the beating of a butterfly's wing in the Amazon can influence weather patterns in Siberia (Gleick, 1987), and this theory can also be applied to the economic world. The health or sickness of one economy can easily and quickly ripple through to its neighbors and across the world. The financial crises in Russia, Brazil, and Asia in the late 1990s were not confined within a single country or even region; their effects were geographically widespread and long lasting. Accordingly, a country's economic and legal environment can influence not only domestic, but also international activity.

Global economic interdependence is becoming increasingly apparent with subsequent rounds of the General Agreement on Tariffs and Trade (GATT), the actions of the World Trade Organization (WTO), and the rise of region trade agreements, such as the EU, NAFTA, ASEAN, and MERCOSUR. While these organizations attempt to harmonize and liberalize international trade rules and flows, they also highlight key differences that continue to exist between countries for issues such as patent and other intellectual property rights and the protection of innovation.

Understanding the patent and intellectual property regime is important for governments and businesses, both domestic and foreign. In addition, the changes that are occurring in patent rights can strengthen or weaken existing protections, send signals regarding government policies towards innovation, and also affect other dimensions. For example, Oxley (1999) found that intellectual property rights influences the structure of inter-firm alliances. Smith (2001) found that patent rights affect the structure of exporting and technology transfer (i.e. sales and licensing of U.S. affiliates).

1.2. Measures of patent protection

While issues surrounding patent rights have been researched for decades, the operationalization of patent rights has traditionally been difficult. Many studies have looked at national patent systems, yet only a limited number have attempted to gauge the strength of the country's system. For example, Ferrantino (1993) and Bosworth (1980) use dummy variables to capture whether certain patent-law characteristics exist, but do not provide a composite index. Rapp and Rozek (1990) aggregate their data, but still rely on dummy variables. Mogee (1989) focuses on the strength of laws for a single industry. Mansfield (1994) uses surveys to determine the perception of the strength of patent rights, but covers 16 countries. In addition, many of these approaches represent only one time period, and their index values are becoming dated.

While these works have provided valuable insights, a number of shortcomings need to be addressed. First, an index that takes on continuous values (rather than discrete) is in a better position to discriminate across different countries (or capture more variation). Secondly, the index needs to be longitudinal and current, and be available for a much broader set of countries (including newly emerging economies). The availability of broad panel data should better suit the needs of researchers as well as practitioners. To better accomplish this, we draw upon the index of patent rights, originally developed by Ginarte and Park (1997) and recently updated in Park and Wagh (2002). This index now includes data for 121 countries for the 40-year period from 1960 to 2000 and rates the strength of national patent laws, based on five categories of patent protections: (1) extent of coverage, (2) membership in international patent agreements, (3) provisions for loss of protection, (4) enforcement mechanisms, and (5) duration of protection. The measurement of each category is scored from 0 to 1 for each country at each point in time. The unweighted sum of the five measures constitutes the overall value of the index, with a score ranging from 0 to 5 awarded to each country. Higher index scores indicate stronger levels of protection.

1.3. The influence of patent protections on innovation debate

Innovation is an important driver of both firm success and national economic growth (Porter, 1990). Even with the obvious necessity for innovation, not all firms pursue aggressive innovation strategies. This is partially because external factors influence firm strategy and outcomes (Porter, 1990, 1980). The national environment not only plays an important role in framing the pressures on firms to innovate, but also on the reward structures for those benefiting from innovation-based investments. The structure of and changes in a country's innovation support system can have far-reaching implications on domestic activities and international relations (Mowery, 1998). For example, the degree to which innovations are protected by legal and other mechanisms affects how firms profit from innovation (Teece, 1986). The more likely a firm can appropriate the benefits from its investments, the more likely it will innovate.

Currently, however, a key issue of debate is the relative importance of patent protection as a means of appropriation. Inventors have means other than patent protection to appropriate the rewards from their innovation (such as lead time, reputation, sales and service effort, moving quickly down the learning curve, and trade secrecy). The conventional wisdom is that firms demand patent protection in order to safeguard their intangible assets, which are easy to copy and distribute at minimal marginal cost. Without such protection, other producers could copy the innovation without incurring any of the 'sunk' development costs. Infringement and imitation work to dissipate the gains to firms and thereby reduce (ex ante) their incentives to innovate.

Recent studies have challenged whether patent protection is necessary to stimulate investment in innovation. The Levin et al. (1987) study of U.S. firms finds that firms do not, in general, regard patent protection as very important to protecting their competitive advantage (compared to the alternative means for appropriating the rewards to their innovations). The question then is, if a patent is not important as an instrument for appropriating the returns to innovation, why do firms patent (and patent a lot)? Cohen et al. (2000) respond by pointing out that firms have various reasons to patent — as a means to block rivals from patenting related inventions, as strategic bargaining chips (in cross-licensing agreements), or as a means to measure internal performance (of the firms' scientists and engineers). Thus, the various "other" factors may be what primarily determines (or motivates) patenting, rather than just the protection of their R&D investment returns. Yet the study's results do indicate that both the importance of patent protection, and the purpose for which it is sought, vary by industry or sector, depending on whether the alternative means of appropriation are feasible.

These and other issues are being played out across the globe as firms grapple with how different countries handle intellectual property rights and infringement. Policymakers are also addressing issues concerning how to establish an appropriate intellectual property rights regime, one that best stimulates technological innovation and diffusion in their respective economies. Proponents of international patent reform argue that patent rights help stimulate domestic innovation and attract foreign technology, while opponents largely argue that *imitation* is an important means of technological catch-up, and that stronger patent rights deter learning and thereby innovation (see Commission on Intellectual Property Rights Report, 2002).

Moreover, recent theoretical work has challenged the reward-incentive paradigm underlying the effect of patent protection on innovation. For example, Takalo and Kannianen (2000) argue that a strengthening of patent rights can delay the introduction of a new technology to the market because it raises the incentive for the innovator to wait. Bessen and Maskin (2000) claim that in an environment of sequential and complementary innovation, patent rights held by different parties can block each other and deter innovation. The conclusions of theoretical models on either side of the debate are dependent on various specifications and assumptions, particularly about the sensitivity of R&D to patent protection. Ultimately, however, the issue of the influence of patent rights on innovation must be resolved at the empirical level.

1.4. Hypotheses development

The general proposition we test is whether firms in countries that have strong and strengthening patent rights have a higher propensity to innovate. We measure this propensity using a firm's R&D to sales ratio. Before turning to the empirical data and analysis, we first discuss some management-theoretic aspects of innovation, and how patent rights enter into play.

1.5. Patent rights' influence on firm innovation

1.5.1. Level of patent rights

Although the importance of patent rights to innovation is the subject of debate in the economics literature (see Mazzoleni and Nelson, 1998), management theory also addresses this subject. According to the resource-based view (RBV), firms attempt to create sustainable competitive advantages by effectively utilizing their resources and capabilities (Peteraf, 1993; Wernerfelt, 1984). Although imitation may be seen as the highest form of flattery to some, for businesses it erodes competitive position and profitability. Firm innovations that create resources and capabilities exhibiting certain characteristics are more likely to produce sustainable competitive advantages (Barney, 1991). Innovations that are difficult to imitate or substitute, as well as those that are rare and/or valuable can be better leveraged for long-term benefits.

Since the reaction to commercial success is for competitors to either copy or negate a firm's advantage, innovating firms must be assured of certain protections for their investments. Countries should establish mechanisms to enhance protection for innovation. Otherwise, there is little incentive to innovate. Since innovation is a key driver of economic growth (Rapp and Rozek, 1990), it benefits both innovating firms and the countries in which they operate. Effective protections allow innovating firms that produce novel and industrially applicable inventions the ability to better meet the characteristics for creating a sustainable competitive advantage. If patents are successfully administered and enforced, firms should be able to fend off imitation and maintain the value and rarity of their innovations. If the protection is weak, any potential advantage will be negated by others and quickly lost. This means that protection must go beyond laws. As laid out above, other country factors, such as enforcement, duration of protection, coverage, and membership in patent treaties indicate the degree of real protection a firm receives.

Interestingly, firm innovation does not always result in a patent. Technical knowledge that comes about as a result of innovation may not be patentable or the firm may not wish to seek a patent (Silverman, 1999). Even in these cases, national systems that protect innovation are important because the environment is supportive of innovation and its outcomes. Based on this discussion, patent protection is expected to influence firm innovative behavior. Countries with strong patent regimes have established control mechanisms that allow firms to more fully exploit their innovation investments. With such protection, firms are encouraged and rewarded for innovation. For example, a country's patent protection influences a firm's decision and timing to collaborate on innovation-based projects (Katila and Mang, 2003). Countries that offer limited patent protection essentially discourage firm-level innovation, since such innovation could be easily appropriated by others with little or no recourse. Using aggregate cross-country data, Varsakelis (2001) and Kanwar and Evenson (2003) have found that patent rights are positively related to national levels of R&D investment. Because individual firms are the primary source of innovation, it would be useful to focus on firms as the unit of analysis. Thus,

Hypothesis 1. There is a positive relationship between the level of a country's patent rights and a firm's propensity to invest in innovation (as measured by its R&D Intensity).

1.5.2. Change in patent rights

Changes in a country's legal system and patent regime can create increased incentives for innovators. For example, Kortum and Lerner (2000) find that policy changes resulting in increased venture capital investments lead to higher patenting rates. Hall and Zeidonis (2001) state that the U.S.'s strengthening of patent rights in the 1980s led semiconductor firms to increase R&D spending in order to create broad ‘patent portfolios.’ They also argue that such changes influenced investments of capital intensive firms, but also enabled industry entry by specialized design firms. While the level of a country’s patent rights is expected to influence innovation, changes in the level of patent rights are also proposed to influence innovation. Whereas the absolute level of patent rights indicates the current protection afforded innovating firms, changes in patent rights over time serve two purposes regarding firm-innovation investments. First, an increase in patent rights effectively strengthens the protection for innovation in a given country. Second, changes in patent rights send signals to firms concerning the direction that governments are moving with regards to innovation protections.

A review of the index of patent rights in Ginarte and Park (1997) data highlights the second point. From 1990 to 1995, Ghana reduced its patent rights. A decline of nearly 30% moved Ghana from having patent rights in the top third to the bottom fifth of the represented countries. This occurred during a period where the average country’s patent rights improved more than 10%. This change would be expected to have a materially negative impact on firm innovation in Ghana. In contrast, Singapore, a country that became a key player in Asian and global markets during the 1990s, strengthened its patent rights by over 50% over the same period to position itself near the top 10% of all countries. As Singapore strives to encourage investment and trade, it has had to improve its patent-rights position to encourage domestic-innovation investment and establish greater international legitimacy. Fortunately, Ghana’s patent rights improved significantly in 2000, with a rise of nearly 50% over the 1995 level and Singapore continued its patent rights improvement through 2000. A final example is Angola. While still being in the bottom 10% of all countries in 2000, Angola improved its patent rights from non-existent prior to 1995 to 1.65 in 1995 and 1.80 in 2000. This is a substantial advance and could signal further improvements and steadily encourage innovation investment on behalf of both domestic and foreign firms. The importance of these improvements is highlighted by Mowery and Oxley (1995), who demonstrate that countries that have strengthened their national innovation systems benefited the most from inward technology transfer.

The RBV supports the proposition that firms in countries that are strengthening their patent rights are more likely to escalate their innovative behaviors. For example, expectations are that a firm’s reluctance to invest in innovation will decrease as the government gradually creates more effective limitations on competition or allows for some degree of monopolistic control to innovators (Peteraf, 1993). Since anything bought cannot be the source of long-lived advantage (Dierickx and Cool, 1989), countries must steadily improve the mechanisms that both protect and encourage innovation. From this discussion, we would expect that firms would be more innovative in countries that upgrade their patent rights. An increase in a country’s patent rights should lead to increased innovation investment at the firm level. Countries that degrade their patent rights should see a decrease in firm innovation investment. Therefore,

Hypothesis 2. There is a positive relationship between an increase in the level of a country’s patent rights and a firm’s propensity to invest in innovation.

1.6. Method

1.6.1. Sources of data

Data for this study were drawn from Datastream/Worldscope. This database provides international data on a diverse selection of companies in terms of size, industry, country, etc. It also provides national-level data acquired from the IMF, worldwide government sources, and other providers of national and macroeconomic data. Approximately 14,500 companies in 47 countries are represented in this database. Additional national context data is drawn from the *World Development Indicators*

(World Bank, 1997), *The World Factbook* (CIA, 1997), and the *World Reference Atlas* (Dorling Kindersley, 1996). Firm, industry, and country data were selected and calculated for 1995.

1.7. Sample

Data for firms competing in ten manufacturing industries were collected. These industries were selected based on their broad global coverage and the fact that they represented different competitive environments. Following Ghoshal and Nohria (1993) classification, we selected industries that have been identified as global, multinational, or transnational. Manufacturing industries were selected because they have the imperative to continually invest in innovation and have greater consistency in reporting procedures for innovation investment over other industrial categories, such as services or non-profit.

Once the industries were identified, firm financial data were collected. The *Datastream/Worldscope* database uses an industry classification scheme based on the Standard Industrial Classification (SIC) codes used in the U.S. Based on the four-digit SIC code and selecting on the study's key variables, data for 706 firms in 29 countries were retained, after excluding extreme outliers and firms with missing data. The final sample included a wide variety of firms based in both industrialized and developing/recently industrialized countries, as well as representing the different economic and geographic regions around the world. See Table 1 for the distribution of companies by respective industry and country.

1.8. Measures

All firm, industry, and country variables are continuous measures and were gathered and calculated as described below. *Firm Innovation Investment* taps into the innovation investment and propensity of a firm. Firm innovation investment, or R&D Intensity, is the primary measure of firm innovation and is used extensively as a proxy for innovation (Allred and Swan, 2004, Baysinger and Hoskisson, 1989; Hambrick and MacMillan, 1985; Hitt et al., 1997; Hoskisson and Hitt, 1988; Kotabe et al., 2002). Firm innovation investment (R&D Intensity) is calculated by dividing R&D expenditures by sales (Hoskisson et al., 1993). The higher the innovation investment of a firm, the greater its strategic focus is on innovation, since that firm has chosen to invest larger percentages of revenue toward innovation activities. Firm innovation investment has been found to be positively related to other important measures of innovation output, such as new product introductions (Hitt et al., 1996) and patents (Hitt et al., 1991), which is of particular interest and relevance to this study. While concerns regarding the location of innovation activity in a multinational corporation can be raised, Dunning (1977) has found that a high percentage of a multinational firm's R&D activities are undertaken in its home market, supporting the use of this measure in this study. Table 1 also shows the mean R&D Intensity by industry and country. According to this measure, the semiconductor industry has the highest propensity to invest in innovation, followed by the scientific instruments industry. The food and beverage industries have the lowest propensity to invest. By country, firms in Norway and the U.S. have the highest propensity to invest in innovation. In most of the industrialized countries, the mean R&D Intensity tends to exceed 2%.

1.9. Patent Rights

Our measure of Patent Rights was taken from Ginarte and Park (1997) for each of the 29 countries for which firm data were available in 1995. *Patent Rights Change* was calculated as the 5-year change in patent rights from 1990 to 1995 for each country.

Table 1
Sample data breakdown (706 firms)

	No. of firms	Mean R&D Intensity %
Industry		
Beverage	29	0.77
Construction machinery	43	1.89
Electrical components	96	4.35
Food	97	0.78
Household appliances	17	1.26
Industrial chemicals	86	2.34
Nonferrous metals	43	1.23
Rubber	24	1.69
Scientific instruments	214	6.10
Semiconductors	57	10.09
Country		
Australia	12	2.22
Belgium	1	0.52
Brazil	1	1.66
Canada	12	5.45
Chile	3	0.13
Denmark	6	4.57
Finland	9	3.50
France	13	4.88
Germany	16	5.14
Greece	3	0.43
Hong Kong	3	1.43
India	37	0.33
Indonesia	1	0.09
Ireland	5	0.45
Italy	5	3.34
Japan	142	2.04
Korea Rep. (South)	29	0.86
Malaysia	6	0.36
Netherlands	9	4.71
New Zealand	2	1.06
Norway	5	10.63
Pakistan	2	0.37
Singapore	1	0.03
South Africa	6	2.77
Sweden	7	4.09
Switzerland	11	3.80
Turkey	4	0.32
United Kingdom	79	2.30
United States	276	6.42

1.10. Control variables

Three sets of control variables were included in the analysis to capture influences on firm innovation at the firm, industry, and country levels. *Firm Size* (*Industry Adjusted*) is controlled for, since the size of the firm is found to be important in studies that involve innovation (Hitt et al., 1996; Tyler and Steensma, 1998; Kotabe and Swan, 1995). By controlling for size, potential economies or diseconomies of scale are also accounted for (Hitt et al., 1997). This measure is calculated by taking the individual firm's sales and dividing it by the industry average, resulting in a variable that measures the firm's relative size within industry. Country-level control variables were included to account for the effects of national size and development on firm innovation. The natural log of *National Gross Domestic Product (GDP)* was used to measure the absolute size of the national economy. *Per Capita GDP* was used, following the economic growth literature, to proxy for the level of a country's economic development (Jones, 2002).

At the industry level, the measures of munificence, dynamism, and concentration (Dess and Beard, 1984) capture the key elements that comprise industry structure (Snell, 1992). These measures were calculated following the method employed by Keats and Hitt (1988) and are discussed below. For this study, the industry is considered to comprise all firms across the world competing in a given industrial class. The measures for each of the ten industries were calculated using all available data from the extended Datastream/Worldscope database across 47 countries. *Munificence*, the measure of the abundance of resources in the industry environment, was calculated by first regressing the natural logarithm of sales against time. This determined the average industry growth for the 5-year period from 1991 to 1995. The munificence for each industry was calculated by taking the antilogarithm of the regression slope (Keats and Hitt, 1988). *Dynamism,* the measure of volatility or instability in the industry environment, was calculated taking the antilogarithm of the standard error from each of the above regressions. This measure assesses the degree of volatility in the industry's sales (Keats and Hitt, 1988). *Concentration,* the measure of heterogeneity or concentration of resources in the industry environment (Boyd, 1990; Aldrich, 1979), is measured by creating a concentration ratio following the Herfindahl–Hirschman index of industry complexity (Herfindahl, 1950; Hirschman, 1945). Acar and Sankaran (1999) note the increasing managerial attention that this measure is gaining in light of the consolidations that are occurring in many industries. The concentration index of the top twenty firms in each of the industries was used for this study. See Table 2 for descriptive statistics and correlations among the study variables.

2. Results and discussion

This study proposes that a country's patent rights and changes in patent rights are positively related to firm innovation. While the influence of the direct effects is central to this study, the inclusion of the control variables not only strengthens the overall results, but provides interesting insights. The control model was first run to capture the influence of firm, industry, and country effects on firm innovation investment. The R^2 for the control model is 0.202 ($p<0.001$). In the control model *Firm Size* is negative and significant ($p<0.001$). This means that the larger the firm, the lower the level of innovation investment. In other words, larger firms spend a smaller percentage of total sales on innovation activities and smaller firms are more innovative. While smaller firms tend to invest more heavily in innovation in an attempt to gain a competitive advantage and market presence, larger firms must use their resources to build their brand, distribution network, and manufacturing facilities. This finding is consistent with other recent research (Hitt et al., 1996; Kotabe and Swan, 1995).

All three industry effects are significant in the control model. Industry *Munificence* and *Dynamism* are both positive ($p<0.001$ and $p<0.01$ respectively), industry *Concentration* is negative ($p<0.01$). This indicates that the abundance of resources in an industry seems to encourage innovation. A dynamic industry environment also leads to greater innovation. This

Table 2
Correlations and descriptive statistics

Variable	Mean	Std Dev	1	2	3	4	5	6	7	8	9	10
(1) Firm innovation investment	3.956	4.387	1.000									
(2) Patent rights	4.093	0.851	0.418***	1.000								
(3) Change in patent rights	0.221	0.229	0.263***	0.372***	1.000							
(4) Firm sales-industry adjusted	0.936	0.121	−0.129***	0.226***	0.052	1.000						
(5) National GDP-Logged	28.416	1.409	0.303***	0.682***	−0.093*	0.130***	1.000					
(6) Per capita GDP	25,595	10,997	0.129***	0.501***	−0.176***	0.290***	0.599***	1.000				
(7) Industry munificence	1.099	0.074	0.330***	0.201***	0.073	−0.017	0.212***	0.124***	1.000			
(8) Industry dynamism	1.015	0.006	0.272***	0.101**	0.040	−0.022	0.117**	0.017	0.698***	1.000		
(9) Industry concentration	0.050	0.035	0.066	−0.082*	−0.024	−0.031	0.046	−0.052	0.365***	0.467***	1.000	
(10) Patent protection (Rapp–Rozek) [a]	4.364	1.053	0.364***	0.809***	0.136***	0.236***	0.500***	0.470***	0.142***	0.061	−0.124***	1.000
(10) Global comp. rating of IPR [b]	7.988	1.612	0.402***	0.826***	0.250***	0.211***	0.595***	0.563***	0.160***	0.068	−0.088*	0.937***

$n=706$, *** $p<0.001$, ** $p<0.01$, * $p<0.05$.

[a] $n=703$, The Rapp-Rozek Index does not include data for Hong Kong, resulting in three less firms for analysis.

[b] $n=704$, The Global Competitive Rating does not include data for Pakistan, resulting for two less firm for analysis.

may be explained by the fact that when industries are characterized by uncertainty and volatility, firms are investing more heavily in product innovation in an attempt to set industry standards and create new technologies (Anderson and Tushman, 1990). As an industry stabilizes, investments may shift to concentrate more on manufacturing efficiencies or marketing until new technologies emerge that displace the current standard (Kotabe, 1992a,b). Incremental product improvements that require less innovation investment, rather than radical changes, characterize the industry until the next significant technological breakthrough is achieved (Wade, 1996). The more concentrated an industry is, the less innovative firms are. This would support the contention that as an industry becomes more concentrated, fewer and larger firms emerge. In this case, these firms may exhibit more monopolistic behavior and be less innovative. Additionally, in the control model, *National GDP* is significant ($p<0.01$) and positive. The country's *Per Capita GDP*, while negative, is not significant. For this model, the size of the economy has a strong positive influence on firm innovation. Since larger economies have superior customer and resource bases to draw from there is a greater imperative on behalf of domestic firms to innovate.

The R^2 for the direct effects only model is 0.188 and highly significant ($p<0.001$). Both direct effect variables' coefficients are positive and significant ($p<0.001$). While this result is encouraging, the hypotheses cannot be supported until the control variables are included in the analysis. The full model that includes all control variables and direct effects has an R^2 of 0.300. The above relationships that are found in the control model continue to hold, with the exception of industry *Concentration* and *National GDP,* which become non-significant in the full model. These findings provide strong support for Hypothesis 1 and Hypothesis 2.[2] In other words, even after controlling for firm size, industry structure, and other national factors, a country's patent rights and changes in patent rights are positively related to domestic firm innovation investment. When considering the different national-level variables, it is interesting to note that in the full model only the two patent rights variables remain significant. After controlling for the various factors, the influence of the country's size and development are not found to be factors predicting firm innovation investment, while the country's patent rights and changes in patent rights are still highly influential. See Table 3 for the regression summary for the various models. After entering all control variables first, the inclusion of *Patent Rights* and *Patent Rights Change* improves the R^2 of the full model by 0.098, a nearly 50% improvement in explained variance.

Another issue to address is that of reverse causality and endogeneity. That is, does a strengthening of patent protections affect innovative activity, or does innovation activity influence a country's patent regime? For example, countries in which limited innovative R&D occurs, or where the local economy thrives on imitation, policymakers may have little vested interest in protecting patent rights and in investing resources in the judicial and administrative system. Countries with greater innovative activity have at least something of value to protect. It is quite possible for R&D to both influence and be influenced by patent policy. For example, Ginarte and Park (1997) found that national levels of R&D activity, measured as a percentage of GDP, influence a country's level of patent protection. While aggregate level R&D activity may influence a country's patent protections, it is difficult to see, with the exception of rare cases, how individual firm R&D investments have major national policy ramifications. Instead, the opposite

[2] To address potential concerns regarding outlier or national effects in the sample, we reran the regression model excluding India (a country with strong representation in the sample and a Patent Rights score near the bottom of the range) and again excluding the U.S. (the country with the highest representation in the sample and a Patent Rights score at the top of the scale). In both cases, the results were similar to that for the full sample, indicating that there is not an "India" or "U.S." effect and that the data at the extremes of the sample do not have an unduly strong influence on the results.

Table 3
Regression analysis

Variables	Firm innovation investment		
	Control model	Direct effects model	Full model
Constant	−131.033***	−4.418***	−109.089**
Firm size (industry adjusted)	−5.550***		−7.010***
National GDP-logged	0.889***		0.277
Per capita GDP	−0.00001		−0.00001
Munificence	12.666***		9.868***
Dynamism	100.369**		92.622*
Concentration	−11.602*		−4.160
Patent rights		1.917***	1.697***
Change in patent rights		2.398***	2.202**
Patent rights squared			
R^2	0.202	0.188	0.300
Change in R^2 from control model			0.098
Adjusted R^2	0.195	0.186	0.292
F	29.474***	81.556***	37.363***

$n=706$, ***$p<0.001$, **$p<0.01$, *$p<0.05$.

relationship would be expected, where national patent protections ultimately affect the R&D activity and investments of domestic firms. In order to test for possible reverse causality and endogeneity, we ran two-stage least square regression models (Greene, 2003).[3]

First, when assessing reverse causality, we used *Concentration* as an instrumental variable for *Firm Innovation Investment* ($r=0.101$, $p<0.01$, and uncorrelated with *Patent Rights* and *Patent Rights Change*). The results indicated that reverse causality was not present when regressing either *Patent Rights* or *Patent Rights Change* (as independent variables) on *Firm Innovation Investment* (as the dependent variable). Second, when investigating the threat of endogeneity, we used the country's *Population* as the respective instrument. *Population* was significantly correlated with *Patent Rights* or *Patent Rights Change* ($r=-0.342$, $p<0.001$ and $r=-0.076$, $p<0.05$, respectively), but uncorrelated with *Firm Innovation Investment*. The results indicated that endogeneity was not present. These results are also intuitive. To the extent that policymakers respond (endogenously) to R&D, they are likely to base policy decisions on total firm (or national) R&D as a whole, not to that of any specific firm, which is the unit of analysis in this study.

2.1. Sensitivity analyses

In this section, we examine the sensitivity of the results to (i) alternative measures of patent protection and (ii) industry composition. While we have found that patent rights explain firm innovation investment, the question may be raised as to how it compares to other measures of property rights. The alternative measures of patent strength we consider for further analysis are the Rapp and Rozek (1990) index and the index of intellectual property protection of the Global Competitiveness Report. The Rapp and Rozek index is multinational and based on a 1984

[3] See Kennedy (1996) for further details on the two-stage least square methodology.

evaluation of conformity with the U.S. Chamber of Commerce guidelines on patent rights.[4] Thus their index does not incorporate reforms in patent laws around the world since the late 1980s. The Rapp and Rozek index also does not incorporate enforcement mechanisms (such as burden of proof reversals). Moreover, because the index is discrete (i.e. taking on values 1, 2, 3, 4, or 5) there is very little variation among particular groups of countries. For example, both Denmark and France score 5. Thus a regression involving a sample of only European or industrialized countries would detect little or no significant effects of patent rights.

The second measure is that of the Global Competitiveness Report (henceforth GCR) from the World Economic Forum (2000), which is based on a survey of managers' perceptions of the strength of intellectual property protection. A concern with this index is that it is subjective and difficult to quantify since there is no information on how managers scale their responses (for example, how does one manager's rating of 8/10 compare to another's rating of 4/10 on the same issue? Does the first manager really perceive a regime that is twice as strong as that observed by the latter, or is his or her perception truly insignificant?) Nonetheless, the GCR aggregates across manager responses to derive a value for each country's intellectual property regime. The second concern is that the GCR index over-aggregates intellectual property rights (IPRs) because IPRs are multi-dimensional. There are different kinds of IPRs: copyrights, trademarks, patents, trade secrets, geographical indications, protection for industrial designs, and protection for semiconductor layout designs. In light of this, it is difficult to generate one number for all of these different kinds of IPRs. Some countries have weak patent regimes but strong copyright regimes, and so forth. Finally, another limitation with the GCR index, as with the Rapp and Rozek index, is that data are only available for a snapshot year (i.e. cross-sectional variation only, not longitudinal).

Yet, as a test of the impact of patents and other intellectual property rights on innovation, these alternative measures are instructive. As the results in Table 4 show, these measures of patent rights (as seen from different angles or perspectives) provide additional support and insight for our earlier results—namely that patent rights positively and statistically significantly explain firm innovation investment. The first three columns show the regression results of entering both the Patent Rights Index and the Rapp and Rozek index jointly, while columns 4–6 show those of entering both our index and the GCR index. The last column (7) shows the results of including all three indexes. Except for the latter regression, we also examine split samples — i.e. dividing the sample between developed vs. developing countries, where the demarcation level of per capita income is $10,000 U.S.

For the full sample (1), both the Patent Rights Index and Rapp and Rozek are statistically significant ($p<0.001$ and $p<0.01$ respectively). This remains so for the developed country sub-sample (2) — that is, for countries whose GDP per capita exceeded $10,000 U.S. However, for the developing country sample (3), while the Rapp and Rozek index does not have much variability and is not significant, the Patent Rights Index remains significant ($p<0.05$). Note that the sample size for firms in developing countries is small due to fact that general representation of firms globally is typically based in developed countries. For the next full sample (4), both the Patent Rights Index and GCR are also positively and statistically significant ($p<0.001$). One way

[4] In their 1990 article, Rapp and Rozek present data for 87 countries. Critical omissions, as noted by Oxley (1999), include countries such as Japan, Switzerland, U.K., and South Korea. Due to the nature of international business activities and research, an adequate patent protection index would require that all critical industrialized and emerging economies be covered. Interestingly, the authors did gather data on 97 countries, including the countries mentioned above, although these data were not presented in their article. Countries are ranked on a scale and assigned a score based on their patent systems as of 1984: 0= No patent protection laws, 1= Inadequate protection laws, no law prohibiting piracy, 2= Seriously flawed laws, 3= Flaws in law, some enforcement laws, 4= Generally good laws, and 5= Protection and enforcement laws fully consistent with minimum standards proposed by the U.S. Chamber of Commerce (1987).

Table 4
Sensitivity analysis I: alternative measures of patent protection

Variables	Firm innovation investment						
	(1) Full sample	(2) Subsample per capita GDP >$10,000 US	(3) Subsample per capita GDP <$10,000 US	(4) Full sample	(5) Subsample per capita GDP >$10,000 US	(6) Subsample per capita GDP <$10,000 US	(7) Full sample
Constant	−100.361**	−90.906*	123.946***	−101.657***	−96.694**	143.504	−103.011**
Firm size (industry adjusted)	−7.582***	−6.850***	−6.139*	−7.352***	−6.698***	−6.161*	−7.097***
National GDP-logged	0.150	−0.463*	0.953^{++}	0.118	−0.360*	0.857	0.053
Per capita GDP	−0.00004*	−0.00004*	−0.00006	−0.00005**	0.00001	−0.00007	−0.00006**
Munificence	10.461***	11.212***	−29.488***	10.362***	11.035***	−32.646	10.423***
Dynamism	86.197*	80.515*	−113.105	87.205*	85.081*	−127.135	89.451*
Concentration	−2.607	−3.950	−2.757	−3.067	−4.828	−2.835	−3.987
Patent rights index	1.559***	2.864***	1.317*	1.187***	2.462***	1.627^{++}	1.324***
Patent protection (Rapp–Rozek)	0.641**	1.630***	0.314				−0.721^{+}
Global competitiveness report rating				0.731***	1.006***	0.133	1.152***
R^2	0.300	0.298	0.224	0.312	0.301	0.214	0.314
Adjusted R^2	0.292	0.289	0.110	0.304	0.292	0.094	0.305
F	37.109***	33.457***	1.953^{+}	39.382***	34.158***	1.774^{+}	35.185***
n	703	640	63	704	643	61	701

***$p<0.001$, **$p<0.01$, *$p<0.05$, $^{+}p<0.10$, $^{++}p<0.15$.
The Rapp–Rozek index and Global competitiveness report rating do not provide data for Hong Kong and Pakistan respectively, resulting in fewer firms for analysis.

of interpreting this result is that while the Patent Rights Index indicates the importance of laws on innovation, the GCR indicates the importance of managerial perception (and actual experience). Again, the joint significance holds for the developed country sub-sample (5), at $p<0.001$. Among developing countries (6), the GCR index has limited variation (i.e. all managers report of complaints about the IPR systems in developing countries) and shows up as statistically insignificant. The Patent Rights Index remains significant at the $p<0.15$ level. While this is clearly not a conventional level of significance, the results show the importance of having "variability" in the measures of patent rights. Though most developing countries do have weak systems, the Patent Rights Index picks up some nuances or slight differences among them. Whereas Ginarte and Park (1997) did not find a relationship between aggregate national-level R&D activity and patent protections for developing countries, we find that patent protection in such countries does influence individual firm-level innovation investment. Lastly, when all indices are entered jointly (7), the Rapp and Rozek index drops in statistical significance and produces a *negative* coefficient, while both the Patent Rights Index and GCR remain significant ($p<0.001$). From these results, we can see that even though we controlled for managerial experience, the Patent Rights Index remains highly significant.

Finally, we consider and find that the influence of patent rights on firm innovation investment actually varies by industry. Table 5 reports the results of estimating the model separately for each of the ten industries. Note here that we drop the original industry control variables, such as

Table 5
Sensitivity analysis II: industry comparison

Variables	Firm innovation investment				
	Beverages	Construction machinery	Electrical components	Food	Household appliances
Constant	−0.013	−11.080	−7.243	2.376	−2.916
Firm size (industry adjusted)	−2.797	0.025	−3.883	0.825	2.546*
National GDP-logged	0.077	0.440	0.303	−0.119	0.033
Per capita GDP	0.00006*	0.0000004	−0.00004	0.00003**	0.000001
Patent rights	−0.143	−0.074	1.723	0.060	0.252
Change in patent rights	3.676*	2.336*	1.636	0.009	−0.6330
R^2	0.390	0.198	0.161	0.172	0.797
Adjusted R^2	0.257	0.089	0.115	0.127	0.705
F	2.942*	1.823	3.463**	3.783**	8.638***
n	29	43	96	97	17
Variables	Industrial chemicals	Nonferrous metals	Rubber	Scientific instruments	Semiconductors
Constant	8.577	2.819	−5.690	14.752$^+$	−35.130
Firm size (industry adjusted)	3.079	−0.499	6.728*	−3.692	−11.650$^+$
National GDP-logged	−0.455$^+$	−0.101	−0.012	−0.489	1.362
Per capita GDP	0.00003	0.0000423$^+$	0.00003	−0.00004	−0.00004
Patent rights	0.765*	0.214	0.253	2.008*	3.073
Change in patent rights	−0.412	−0.165	−1.422	3.905*	10.6890*
R^2	0.317	0.197	0.494	0.163	0.414
Adjusted R^2	0.274	0.089	0.354	0.143	0.356
F	7.409***	1.818	3.518*	8.081***	7.197***
n	86	43	24	214	57

***$p<0.001$, **$p<0.01$, *$p<0.05$, $^+p<0.10$.

munificence, since these remain fixed per industry. Individually, we find that the level of patent rights significantly explains firm innovation investment in the industrial chemicals industry and the scientific instruments industry, where plausibly innovations are fairly easy to imitate, and thus the benefits of investments harder to retain. The change in patent rights significantly explains firm innovation investment in the Beverages, Construction Machinery, Scientific Instruments, and Semiconductors industries ($p<0.05$). Note, though, that when we disaggregate the sample by industry, a number of industries have fewer observations, such as the household appliance, rubber, food, construction machinery, and nonferrous metals sectors and that this could influence the individual industry results.

This confirms previous research (see Cohen et al., 2000; Levin et al., 1987; Mansfield, 1994) which finds that the influence of patent protection varies – and should vary – by industry, since firms in certain industries are better able to appropriate the returns from their investment using means other than patent protection. These studies find that industries such as chemicals and instruments are particularly dependent on patent protection. It is important that our results are consistent with these findings. It corroborates, indirectly at least, that the Patent Rights Index picks up features of patent regimes that firm innovation in the patent-sensitive industries responds to. The results from this study and stream of research have important implications for policy; namely, that a one-size-fits-all patent policy is not likely to be appropriate for all industries.

3. Conclusions, limitations, and future research

3.1. Conclusions

The primary contribution of this paper is an empirical test of the influence of patent rights and changes in patent rights on firm innovation investment. This study shows that, even after controlling for firm, industry, and other national factors there is a very strong positive relationship between the level of a country's patent rights and changes in patent rights on firm innovation investment. This finding is especially important for managers who are considering expanding into new international markets. Countries with strong and strengthening patent rights encourage innovation through providing effective incentives and protections. However, the impact of patent rights on innovation varies by industry. Innovation in chemicals and instruments-based industries responds positively to patent rights, while those in other industries (such as food and household appliances) may not be as strongly influenced.

The scale of this study also adds to its contribution. Data for over 700 firms competing in ten industries across 29 countries are used. Since the nature of the Patent Rights Index data allows for a much broader range of countries to be considered in research and the generalizability of the results is improved, studies such as this one further add to our understanding of the influences on firm innovation. It also captures a broader range of firms and countries to better deal with the increasing complexity of the global economy.

3.2. Limitations and future research

While we have attempted to address potential difficulties with the design and scope of this study, there are limitations that remain, some of which offer opportunities for future research. First, broad international firm-level data is generally available for only publicly-traded companies. While these companies typically represent most of the major firms in a given country or industry, private or national companies are not well represented in the database. This concern is common for most research using archival databases, even for research involving only U.S. companies. As such, the findings in this study may not be applicable to all types of firms. Future research could replicate this study in those contexts.

Second, and also related to the restricted nature of international data gathering and representation, data for firms in the sample do not reflect activities across different business units and countries. There is a great need for improved data collection in the future that allows researchers to disaggregate the multinational corporation into its business units across countries to better understand the influence of national-level factors on its behavior and outcomes.

Third, the data in the study are only drawn from manufacturing-oriented industries. While these industries rely heavily on innovation investments to build competitiveness, the findings from this study may not be generalizable to other types of industries, such as services or non-profit. Although only manufacturing industries were used for this study, the selected industries cross many different industry competitive environments and matched those identified by Ghoshal and Nohria (1993).

Finally, the company-level data is more heavily represented in certain countries and industries. This is a result of the nature of the industries and data availability. Some industries are larger or more concentrated than others. In addition, countries such as the U.S. or Japan have a greater representation of companies across almost every industry than smaller and less developed countries. The sampling procedure selected and retained every company in a given industry that had adequate data. Accordingly, the distribution of sampled companies across industry and country should be representative of the international economy. While some industries and countries are not as highly represented as others, their inclusion allows for greater variation in the data to test the hypotheses and generalize the results.

Further extensions of this line of research could explore the influence of patent rights on other key areas of IB research involving innovation and new product development. For example, while we have considered the influence of patent rights and changes in them on innovation investment, future research could extend the model to look at actual firm innovative outputs, such as actual patent grants, and firm performance implications. In addition, the effect that changes in patent rights have on changes in firm innovative behavior should also be addressed.

This study offers only an initial test of the influence of patent rights on firm innovation. Future research can consider the effect of country patent rights and changes in patent rights on other issues involving firm innovation and other firm strategic behaviors, such as technology sourcing (Kotabe, 1992a,b; Murray et al., 1995) interfirm knowledge transfer (Madhok and Tallman, 1998; Mowery et al., 1996, 1998; Mowery, 1998), and international cooperative venture formation (Buckley and Casson, 1996; Tallman and Shenkar, 1994). In addition, future research should also go beyond firm strategic issues and evaluate the influence that patent rights have on firm performance and outcomes.

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