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Abstract

This paper provides an empirical analysis of the effects of patent protection on innovative activity. It provides evidence from both an output perspective of innovation (namely patent applications) and an input perspective (namely research and development).

In order to implement the empirical analyses, the paper updates an index of patent rights to year 2000 and provides an index of enforcement effectiveness (in practice). Using both firm-level and national level panel data, the paper finds that the relationship between patent protection and innovation typically is U-shaped (or inverse U-shaped), holding other factors constant. The idea is that patent protection can both stimulate as well as deter innovation, depending on circumstances. For poorer economies dependent on imitative and adaptive research, patent protection tends to raise the cost of innovation and thereby reduce the rate of innovation. For richer economies, where patent strength is already fairly high, a further strengthening of patent rights may enhance market power to the extent that incentives to introduce new technologies are reduced. For other situations, stronger patent regimes can encourage domestic innovation and attract foreign innovation.

Key Words: Patent Rights, Firm Research and Development, and National Patenting

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1. Introduction and Motivation

Innovation is an important driver of both firm success and national economic growth (Porter, 1990). 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 engaging in innovation activities. The structure of 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.

The environment for innovation has changed recently due to global intellectual property reforms, which have accelerated during the past decade. A major development has been the formation of the *World Trade Organization (WTO)* in 1995. The WTO is founded on three key treaties, one of which is the *Trade-Related Intellectual Property Rights Agreement (TRIPS)*. Member nations accept all three treaties as a package. The TRIPS agreement involves far reaching reforms in various aspects of intellectual property rights, enforcement, and dispute resolution. Furthermore, through ongoing WTO meetings, such as at the *Doha Round*, member nations have expressed a renewed commitment to raise global intellectual property standards.

Heated debate exists, however, as to whether a strengthening of intellectual property rights (particularly patent rights) is appropriate for stimulating innovation. On the one hand, stronger protection enhances a firm's ability to appropriate the benefits of innovation; on the other hand, stronger protection tends to raise the cost of new technological inputs, and hence increase the cost of innovation. Moreover, technological change is driven by both innovative and imitative (learning) activities. Changes in the level of protection tend to shift resources between these activities. How this influences innovation is of crucial interest to policymakers and to businesses. However, the academic and policy debate surrounding these issues have been largely theoretical or speculative. This paper seeks to contribute empirical evidence on the relationship between patent rights and innovation from a broad international perspective.

In this manuscript, we present an updated index of patent rights for 121 countries and an index of enforcement effectiveness. Using national level data on patenting and firm-level data on research and development, we provide an empirical test of the influence of patent rights on innovation behavior. We view the analysis of patenting and R&D as complementary. Patents provide a picture of the output side of innovation, while R&D shows the input side. We also analyze the implications of patent reform for both developed and less developed economies.

The paper is organized as follows: in the next section, we provide a literature review, focusing on the theoretical relationship between patent rights and innovation. In section 3, we discuss our methods for quantifying the strength of patent regimes and discuss some trends in patent rights. In section 4, we discuss the empirical methodology and data, and in section 5 we present the empirical results. In the concluding section, we summarize the findings and discuss extensions for further research.

2. Literature Review & Theoretical Propositions

Theoretically, the effects of patent protection on innovation appear ambiguous, judging by the academic literature. Different models lead to different conclusions about the positive and normative impact of strengthened patent rights.

On the one hand, the standard textbook argument is twofold (see Maskus 2000). First, stronger patent rights enhance the ability of innovators to appropriate the returns to their innovations and thereby earn larger returns from innovative activity. Secondly, improved legal certainty helps to reduce contracting and monitoring costs and thereby encourage firms to undertake R&D investments, introduce technologies to the market, and possibly license to third parties (and thereby encourage technological diffusion).

On the other hand, stronger patent rights may negatively affect innovation for at least two reasons. First, the increased market power of patent holders may retard their innovative efforts. They may have less incentive to seek additional profits when faced with less competition (see Arrow (1962)). They may, as a result, be slower in replacing technologies with superior ones. For example, Takalo and Kanniainen (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. Secondly, the innovation efforts of other firms are affected. Stronger patents increase the technological space around which substitute technologies may infringe on existing property rights. This increases the cost of research and innovation to other firms or rivals. Either they will have to develop technologies that are sufficiently different (incurring greater resources to invent sufficiently away from existing patented inventions) or pay licensing (or cross licensing) fees to utilize the technologies owned by others. To the extent that innovation is a cumulative process, stronger patents may better enable a firm to enforce its right against subsequent inventors, but stronger patents may put that firm at risk of infringing upon previous inventors' rights (see Gallini (2002)).

The patent system may also inhibit innovation by creating patent blocking or "hold-up" problems. This may occur when the rights holder impedes the innovation of others by preventing the application of particular technologies. These hold-up problems are highlighted in recent studies (see, for example, Shapiro (2001) and Jaffe and Lerner (2004)). These studies describe the adverse effects of patent thickets (overlapping rights and costs of cross licensing negotiations). By seeking injunctive relief, patent holders may potentially hold up the research of other firms. Hall and Ziedonis (2001) provide some of the context behind patent thickets. They find that firms in the semiconductor industry are patenting strategically in order to use patents as bargaining chips in cross-licensing negotiations or in infringement suits (or countersuits). The nature of the semiconductor is such that many innovations consist not of entire products per se but of technological components. Thus with multiple patent holders owning different "pieces" of technological products, greater prospects for blocking – and infringement – suits may arise. Bessen and Maskin (2000) claim that in an environment of sequential and complementary innovation, such as in the software industry, patent rights held by different parties can block each other and deter innovation.

The theoretical literature is also sharply divided over the impact on developing nations. On the one hand, stronger patent protection is seen as conducive to economic development, in fostering domestic innovation and attracting foreign technologies (see Sherwood (1997)). On the other hand, concerns exist that stronger patent rights will reduce the ability of developing countries to imitate foreign technologies. Imitation is an important means for technological catch-up (see Tabatchnaia and Eby Konan (1997) and van Elkan (1996)) so that stronger patent rights may potentially deter learning and thereby innovation (see Glass (2004)).

As the Commission on Intellectual Property Rights (2002) points out in its report (p. 22), weak (rather than strong) intellectual property rights were the norm during the formative periods of national economic development. Consider, for example, Korea, Taiwan, Japan, Brazil, Mexico, and the United States during the 19th century. In the early stages of industrialization, the theory is that countries need to be able to freely imitate foreign technologies. Developing economies tend generally to have limited capacity for innovation, so that imitation is the means by which widespread technology diffusion may occur. Moreover, for emerging innovators, they learn and innovate by inventing around and adapting existing goods to local needs.[1]

Thus the theoretical effects of patent protection are complex. It may not be the case that one or more of the hypotheses above dominates, but that they all have some validity and operate in some fashion or other. The empirical analyses in this paper will show that to be the case.

There have also been mixed empirical evidence on the impacts of patent strength on innovation. Mansfield (1986), for example, examines a sample of 100 U.S. manufacturing firms to assess whether inventions would have been developed or commercialized in the absence of patent protection. Patent protection was judged to be essential for 30% or more of inventions in the chemicals and pharmaceutical industries, 10-20% in petroleum, machinery, and fabricated metals, and relatively unimportant for inventions in the office equipment, electrical equipment, motor vehicles, textiles, and rubber industries. Thus the importance of patent rights varies by industry.[2] In a more recent study, Sakakibara and Branstetter (2001), using patent citation data, find that patent reforms in Japan in 1988 (in particular the shift from a single claim system to a multiple claim system) did not have any appreciable impact on firm innovation. In contrast, Korenko (1999) finds that, for the Italian pharmaceutical industry, a strengthening of local patent rights helped expand domestic R&D and market share (vis-à-vis foreign competitors).

1 Evenson and Westphal (1997) discuss technological strategies in developing nations.

2 Levin et al. (1987) also finds that the importance of patent protection varies by industry. This study especially highlights that patent protection is but one of several means by which firms can appropriate the returns to their innovation (e.g. other means include trade secrecy, reputation, lead time, and so forth).

These are just a select sample of varying evidence on the effects of patent rights on innovation. The previous empirical studies we have mentioned each focused on a particular country. In this paper, our aim is to exploit a panel data of several countries (including developing and least developed countries) and examine whether international differences in innovation can be accounted for by differences in patent systems.[3]

3. Measuring Patent Rights and Enforcement

In this section, we describe two extensions to the index of patent rights of Ginarte and Park (1997). First, we present an updating of the latter to 1995 and 2000. Secondly, for a subset of countries, we derive a measure of enforcement effectiveness of patent rights (for 1990-2000). In what follows, we will first provide a brief review of previous quantitative measures of patent rights, then discuss the construction of our indexes and the role played by the WTO/TRIPS agreement, and lastly discuss some key trends in patent protection (including a discussion of the sources of changes in world patent strength).

A. Previous Measures of Patent Rights

In previous work, researchers tended to look at a few features of national patent systems. Bosworth (1980) used dummy variables to indicate whether certain patent law features exist (for example, duration, novelty, compulsory licensing). Ferrantino (1993) used dummy variables to indicate whether a country was a member of an international patent treaty. Rapp and Rozek

[3] An international study on the effects of intellectual property reforms is also in Branstetter, Fisman, and Foley (2002). The focus there is on the extent to which intellectual property rights affect international technology transfer

(1990) considered further features of patent systems, but did not incorporate enforcement mechanisms. A disadvantage with these previous measures, for purposes of our research, is that they are based on a snapshot of one year. For example, the Rapp and Rozek (1990) index is based on patent regimes in 1984 and the Bosworth (1980) measure on regimes in 1978. For our study, we need measures over time as well as more recent information.

Another approach to measuring patent strength is by surveying expert opinion and experience. Mansfield (1994) and Sherwood (1997), for example, have carried out in-depth surveys in various nations, especially developing countries. The survey approach has the advantage of being better able to capture enforcement of laws in practice than approaches which examine laws on the books. Unfortunately, but understandably, these studies provide ratings for a few countries and a single time period, due to the time-consuming process of gathering information in such in-depth surveys. The World Economic Forum's *Global Competitiveness Report (GCR)* does have ratings for several more countries, but again these ratings are based on surveys of company managers taken in one period. A couple of other disadvantages with the GCR survey is that the interviewees were asked to rate the overall intellectual property regime of countries (and not just the patent system). This poses a problem since the different instruments of intellectual property function in different ways and have different social and regulatory purposes. Secondly, issues arise about the comparability of different interviewees' responses 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 8/10 on the same issue?

(via licensing deals). Again, the evidence is mixed. Stronger intellectual property rights are found to stimulate U.S. foreign licensing to affiliated parties, but not to unaffiliated (arms-length) parties.

Thus, for our study, we utilize a broader cross-section of countries and longitudinal data. In addition, we complement our index of patent rights with reports of enforcement experiences (for which we derive a separate categorical index).

B. Construction of the Patent Rights Index

In Ginarte and Park (1997), the patent rights index was initially created for 110 countries in 5-year increments from 1960 – 1990. This index has been updated through 2000 and covers an additional 11 countries (such as China and the formerly socialist European nations).[4]

The index of patent rights ranges from zero (weakest) to five (strongest). The value of the index is obtained by aggregating the following five components: extent of coverage, membership in international treaties, loss of rights (or abstention therefrom), enforcement provisions, and duration of protection. Each of these components is scored out of 1 (reflecting the fraction of legal features that are available). Thus the overall value of the patent rights index is the sum of the component scores.[5] Higher index scores indicate stronger levels of protection. See Table 1 for a summary of index scores by country (grouped by level of development) and selected years. The grouping of nations by developed, developing, and least developed nations is

[4] The source of information is the English translations of national patent laws. See Baxter, J., Sinnott, John, Sinnott, Jessica, and Cotreau, William (eds.), *World Patent Law and Practice*, serial publication, 1968 – present.

[5] The implicit assumption here is that each component is weighed equally. We experimented with different weighting schemes and found that in general the overall rankings of countries are insensitive to the choice of weights. One weighting scheme was obtained through "principal components analysis" which seeks the weighted averages of the components which yield the highest variance. Another approach was to specify ad-hoc weights (such as 40% to one component, and 15% to the other four). Using the Spearman rank correlation and Pearson Method of Moment tests, we found the rankings of variables to be statistically insignificantly different. An advantage of equal weighting is its transparency and simplicity. The actual weights to attach to the components are likely to vary among individual inventors and researchers.

based on United Nations classification.[6] The Appendix also provides a quick overview of the rating methodology. The individual components of the patent rights index are as follows:

Coverage. Patent laws are evaluated for the patentability of certain subject matter; namely, chemicals, food, microorganisms, pharmaceuticals, plant and animal varieties, surgical products, and utility models (e.g., new arrangements or forms introduced or obtained in known objects, such as tools). The score assigned to this component is the fraction of these seven items that the patent law allows to be specifically patentable or not specifically declared unpatentable.[7]

Membership in International Agreements. Many countries in the past have treated domestic and foreign firms differently in the patent granting and application processes (Kotabe, 1992). Countries that participate in international patent treaties indicate their willingness to provide national, nondiscriminatory treatment to foreigners. The three major agreements are: a) the Paris Convention of 1883 and subsequent revisions, b) the Patent Cooperation Treaty (PCT) of 1970, and c) the International Convention for the Protection of New Varieties of Plants (UPOV) of 1961. Participation in each of these agreements receives a score of 1/3, for a total of 1 if the country participates in all three.

Loss of Rights. Even if a patent is awarded, certain risks exist that the patent holders may later forfeit their patent rights. This category measures whether loss of rights will *not* occur due to: a) 'working' requirements, b) compulsory licensing, and c) revocation of patents. Each area is scored 1/3, for a total of 1 if none of the three occur. 'Working' requirements deal with the exploitation of innovations and whether the patent grantee may be required to either manufacture or import the patented good into the country. In many cases, the innovator may

[6] See the documentation in United Nations Conference on Trade and Development (UNCTAD) *Handbook of Statistics*, 2003. http://www.unctad.org/en/docs//tdstat28_enfr.pdf.

wish only for protection and exclusivity. The innovator may not choose, or have the means, to manufacture or import the product for all markets. Compulsory licensing requires patentees to share use and exploitation of the innovation with third parties. A concern stemming from this requirement is that it diminishes the benefits received by the innovator. If a country does not impose compulsory licensing within three or four years from the date of the patent grant or application, it receives credit for this area. Countries which do not revoke patent rights (due to non-working or other reasons) receive credit for this area.

Enforcement. Patent protection requires mechanisms for enforcement. Countries receive a score of 1/3 for providing each of the following: a) preliminary injunctions, b) contributory infringement pleadings, and c) burden-of-proof reversals. Preliminary injunctions require individuals to cease alleged infringements prior to the time that the case is heard. While firms involved in contributory infringement pleadings may not in themselves violate the patent, their actions may cause or result in an infringement by others. For a burden-of-proof reversal, the assumption is that the alleged infringer used the patented process and bears the burden to prove otherwise.

Duration of Protection. The duration of patent protection is critical for allowing innovators time to appropriate the benefits from their innovation investments. Either twenty years of protection from the date of patent application or 17 years from the date of patent grant is considered standard. A score ranging from 0 to 1 is awarded based on the percentage of the appropriate standard duration provided. For example, a country that allows 15 years of protection from the date of application date receives a score of 0.75 for this component (i.e. 75% of twenty years).

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[7] Other subject matter could have been included, such as machinery, but only those invention categories that

C. Construction of the Index of Enforcement Effectiveness

No formal studies have yet been conducted on how patent laws are actually enforced in practice. The closest available are reports filed with the *U.S. Trade Representative (USTR)* concerning intellectual property enforcement in various countries.[8] A major limitation is that the reports may largely represent the views of U.S. firms as to what constitutes effective and adequate enforcement. Another limitation is that some complainants may have ulterior motives for filing complaints; for example, to seek assistance in penetrating foreign markets because they are not able to compete against local firms on price, product quality, or other factor alone. On the other hand, much useful information is contained in these reports (and treated seriously by policymakers and business enterprises). Thus, notwithstanding these limitations, an index is developed to reflect the experience of patent rights enforcement as documented in these reports.

The index focuses on the execution of laws. Laws may be ineffectively implemented for two main reasons: i) because of a *lack of willingness* on the part of policy authorities to provide or enforce them (because the authorities, for whatever reason, do not agree with a strong intellectual property policy), or ii) because of a *lack of capacity* to enforce laws effectively. This may arise because of a lack of resources, training, and experience.

It should be stressed that violations of patent rights occur not only because of weak laws and enforcement, but also because imitators or infringers are very capable of copying. Therefore, in deciding the effectiveness of enforcement, it is important to adjust for the capacity of a nation's "imitative" sector to make copies. In nations where the capacity for imitation is

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yielded the greatest variation across countries were included.

[8] See USTR, *National Trade Estimate: Report on Foreign Trade Barriers*, Washington, D.C., serial publication, 1986 - present.

low, weak enforcement may not be an important factor to innovators. The weak capacity for imitation itself acts as a protection against imitation. On the other hand when a strong capacity for imitation exists, even if strong laws exist (on the books) and enforcement is strong (that is, the authorities are both willing and able to protect rights), there will always be some infringement. Thus the level of infringement activity is not in and of itself a good indicator of whether the laws are lax or ineffective. While lax laws and poor enforcement do contribute to patent infringement, there are other factors that drive infringement activity (including the capacity for imitation, such as the level of technology for copying, and quantity of innovations).

Thus, for purposes of this index (which is to try to measure the actual enforcement of patent laws), the focus will be on how the authorities carry out the laws in practice – not on the actual extent of infringement activity. This particular index looks first for whether enforcement mechanisms are available or adequate; secondly, whether laws are enforced; and thirdly, how effectively laws are enforced. For instance, if enforcement measures are not available or are inadequate, the enforcement of laws is not going to be effective. Thus, countries in this situation would score 0. Countries also score 0 if they have the enforcement mechanisms but are not enforcing the laws (as a policy choice or because certain other policy choices make enforcement ineffective, e.g. weak sentences). However, if countries are deemed to be enforcing the laws, but not effectively because of barriers to enforcement (e.g. resource constraints) or because of delays in the implementation of policy (that is, a law goes into effect six months or a year later), they would score ½. Essentially countries should score half if they are trying to enforce the laws (but are less successful because their capacity to enforce needs to be strengthened). For countries without enforcement problems, a score of 1 is given. Note that complaints about the lack of laws (other than enforcement provisions) are not counted in this index since the patent rights index already incorporates information about the absence of laws.

To summarize, the value of the enforcement effectiveness index ranges from zero (if enforcement measures are unavailable or inadequate) to half (if enforcement measures are available but not effectively carried out) to one (adequate). The Appendix also provides a quick overview of the scoring methodology for this index of enforcement effectiveness.

D. TRIPS Agreement

The updating of the patent rights index requires addressing the TRIPS agreement that went into effect in 1995. Any modifications to the index to incorporate new features would need to deal with keeping the index backward compatible to earlier years. One option is to introduce TRIPS as a fourth item in the membership component. But then the other key international treaties would get less weight than they did in prior years (affecting backward compatibility).

There are some reasons, however, to keep the index intact, despite TRIPS. First, whether being a signatory nation to TRIPS represents any effective change in regime is a moot issue given that several countries have received extensions to implement the agreement (even though they are officially members). Developing and least developed nations, for instance, have five and 11 year transition periods respectively.

Secondly the TRIPS agreement is far-reaching. It covers not only patent rights but also other forms of intellectual property rights, such as trademarks, copyrights, industrial designs, semiconductor layouts, and geographical indications. Thus the patent index cannot conceptually subsume the entire TRIPS agreement.

Thirdly, in the patent portion of the TRIPS agreement, there is quite an overlap between it and the patent rights index. For example, the agreement incorporates the enforcement mechanisms featured in the index as well as the coverage and duration components. The agreement also requires that one of the features of the membership component – the Paris Treaty – be part of the TRIPS agreement. That is, the agreement incorporates by reference the Paris Treaty. Thus in some respects there would be much 'double counting' if we tried to include the TRIPS agreement into the index.

Finally, and controversially, the TRIPS agreement may not wholly represent a strengthening of patent rights. Provisions exist which involve a weakening of rights. This should be expected because the TRIPS agreement involves a bargain between developed and less developed countries. The latter have adopted it in exchange for some concessions, such as trade concessions as well as direct intellectual property-related concessions. For example, Article 30 allows member states to provide "limited exceptions to the exclusive rights conferred by a patent, provided that such exceptions do not unreasonably conflict with a normal exploitation of a patent . . . , taking account of the legitimate interests of third parties."[9] Article 31 permits compulsory licensing and government use without permission from the rights holder, subject to the condition that the legitimate interests of the rights holder are protected. Compulsory licensing may be used if a third party could not obtain a license voluntarily from the rights holder on reasonable terms. The Doha declaration also permits countries to import cheaper generics (made under compulsory licensing) if local producers do not have the capacity to manufacture the good locally, such as essential medicines. Thus while these flexibilities offered by TRIPS may enhance poor countries' welfare, seen strictly from the viewpoint of patent strength, some of

[9] The full text of the agreement can be found at http://www.wto.org/english/docs_e/legal_e/legal_e.htm#TRIPs.

the provisions work to reduce patent rights. Thus the TRIPS agreement both "giveth and taketh away" some patent rights.

Nonetheless, rather than modify the patent rights index to incorporate certain provisions of TRIPS, the empirical section provides an analysis of the differences in innovation between TRIPS members and non-members, as a way to highlight the impact of the agreement.

E. Trends in Patent Rights

As shown in Table 1, patent rights have strengthened worldwide. The table shows the values of the index of patent rights (IPR) for 1960-90 (average), 1995, and 2000. It also indicates whether countries were members of the WTO in 1995, and thus signatories to the TRIPS agreement.

The bottom of Table 1 provides the mean patent strength for all countries. In 2000, the mean score is 3.07, which represents a 33% increase over the mean strength during the 1960-1990 period. The developed economies have stronger systems on average than the developing countries, and the latter have stronger systems than the least developed economies.[10] All of the developed nations were members of the WTO in 1995, while 73% of developing nations and 54% of least developed nations were members in that same year.

While the mean strength of patent rights has risen, the range between countries with high and low patent rights has increased somewhat over the 40 year period (judging by the standard deviation of the patent rights index). Across country groups, there is less variability in patent

[10] Some of the least developed nations – particularly those of Africa – have had strong patent systems due to their colonial ties to the U.K. and adoption of British patent laws. Often foreign patent applicants were allowed to simply register patents that they acquired elsewhere. Some doubt whether their systems were that strong. Due either to the weak imitative capacity and small innovation bases in these countries, there was not a lot of patenting activity, and therefore not a lot of litigation activity to test the laws (and determine whether or not laws could actually be enforced).

rights among developed nations than among developing nations, and less variability among developing nations than among least developed nations. Overall, the gap between countries with strong and weak patent rights has fallen somewhat since 1995 but is still wider than it was during the 1960-1990 period. Further narrowing should occur when, or if, the developing and least developed nations eventually implement their TRIPS obligations.

In table 2, we present the index of enforcement effectiveness for 1990 – 2000. The observations in the table have been sorted in descending order of the index value in year 2000. Thus, among the countries whose enforcement of patent rights has been rated high, Belgium and Hong Kong show strengthening over time. The other high enforcement countries have always rated high during this period. Among the medium enforcement countries, several have strengthened their actual enforcements of the law – in particular, the Latin American economies such as Argentina, Brazil, Chile, and Peru, and Asian economies such as China and Singapore. The low enforcement countries in 2000 have always rated low during the sample period.

In the bottom of table 2, the correlations between the patent rights index and the enforcement effectiveness index are shown for each year. The simple correlations are relatively high. They are 0.72 – 0.73 in the years 1990 and 2000. The correlation dips slightly in 1995 to 0.67. This is due to the fact that patent reforms took place in 1995 (for example, the TRIPS Agreement came into effect). Around that time, actual enforcement or implementation of the laws lagged changes in the "laws on the books."

We also examined the correlations between the enforcement effectiveness index and each of the components of the patent rights index, such as coverage, enforcement mechanisms, duration, etc. (not reported in the table), but we did not detect any one component to dominate. For example, enforcement in practice did not just correlate highly with enforcement mechanisms, but also with the other components. This is the case since actual enforcement depends on all the various aspects of patent laws and rights to be carried out or implemented, such as the statutory length of protection or permitted subject material that can be patented, and so forth.

Note that in the table we also indicate (with an asterisk) which countries are in the R&D sample that we later investigate empirically. Slightly more than half the sample countries are strong enforcement nations.

We next examine the sources of changes in the patent rights index. We address two issues: first, which of the components dominated the changes in the overall patent rights index? Secondly, are changes in any of the components precursors to changes in the overall patent regime? In other words, do changes in any component precede those of others?

Part A of table 3 focuses on the first issue. In the first column, we show the variance in the overall index of patent rights (IPR), and in the remaining columns, we show the covariances between IPR and the individual components of the index (naturally the last five columns must sum to the first). For all countries (pooled), it is the joining of international treaties that seem to drive most of the changes (or volatility) in the overall patent regime, followed closely by changes in enforcement mechanisms. Indeed, if we look at sub-periods, we see that the variance of IPR in the 1990s is contributed most by countries joining international patent treaties. Secondly, changes in duration also contribute to the variance in IPR as most countries have passed laws making the statutory duration 20 years from the date of patent application. Prior to the 1990s, the variance of IPR was less and driven mostly by enforcement changes.

When we look at the split samples, we see that among developed countries, the variance in IPR is lower, as most of these countries have strong patent regimes and have made relatively few changes in their systems (compared to the developing world). For instance, duration accounts for a small share of the volatility in IPR because most of these countries were providing long patents (namely 20 years from date of filing). The increases in the index were driven largely by membership in treaties.

In the developing and least developed countries, we observe that changes in the loss of rights provisions have accounted for most of the variance in IPR. This is due to the fact that these countries reduced the revoking of patents, the use of compulsory licensing, and the mandating of working requirements, which policy authorities in developing economies have tended to resort to in order to increase local access to first-world technologies. The coverage component also accounted for changes in developing world patent regimes, as developing nations introduced new areas of patentability, such as food and medicine (including pharmaceuticals).

In part B of table 3, we examine the second issue by applying Granger causality tests. These tests, strictly speaking, test less for causality than for temporal precedence (for example, testing whether a variable X precedes variable Y). Thus, let Z be the vector of the components:

$$Z = \begin{bmatrix} \text{COV} \\ \text{ENF} \\ \text{RIG} \\ \text{MEM} \\ \text{DUR} \end{bmatrix}$$

We then ran a VAR (vector autoregression) of Z on its lags:

$$Z = \mathbf{\Lambda_0} + \mathbf{\Lambda_0}\, Z_{-1} + \mathbf{\Lambda_2}\, Z_{-2} + \mathbf{e},$$

where $\mathbf{\Lambda_0}$ is a vector of constants, $\mathbf{\Lambda_1}$ and $\mathbf{\Lambda_2}$ matrices of coefficients, and $\mathbf{e}$ a vector of error terms. We generally found that third or more lags are statistically insignificant. In other words, we regress each component on its own first and second lags and on the first and second lags of the other four components.

So as not to clutter up Table 3B, we simply report on whether a particular lag of a particular component was statistically significant at conventional levels. Thus in the first section of table 3B, each row represents an equation. For example, the first row is the equation for coverage. We find that the first lag of coverage strongly determines coverage (but not the second lag). We also find that past enforcement (namely the first lag) and membership in treaties (second lag) are also significant in determining coverage. Since each lag is 5 years in length (since the index was created every five years), this suggests that coverage is influenced by policy events or legal shifts 5 to 10 years prior.

Overall, we find that each component depends on its own (first) lag. This reflects the gradual nature of legal changes. Secondly, changes in enforcement tend to precede (or Granger cause) all of the other components. This seems intuitive in that enforcement mechanisms are required before other patent laws and rights can be strengthened. Laws on the books have little force if weak enforcement mechanisms are in place. Secondly, changes in treaty membership also tend to precede changes in the components (except for the loss of rights). Becoming a member of an international treaty indicates that reforms in the member state are (or should be) forthcoming. Changes in past duration also tend to positively affect future changes in enforcement and membership in treaties. An increase in patent lifespan may signal an "ability" to make legal changes in the system (since a system is already in place to offer longer patents).

In some cases the second lag of enforcement can have a negative effect on the future components. This may be due to some adjustment process; that the process of IPR reform is gradual. Indeed, in cases where the second lag has a negative coefficient, it is less in absolute value than the coefficient of the first lag (which is always positive when statistically significant).

Finally, we repeated the Granger test for the VAR system involving the overall patent rights index and the index of enforcement effectiveness. In the second section of Table 3B, we again find that each variable depends on its own lag. However, IPR does not depend on lagged enforcement effectiveness, but rather enforcement effectiveness depends on lagged IPR. This suggests that changes in "laws on the books" precede effective enforcement, not the reverse. It is not the case (at least as far as the simple VAR analyses seem to show) that effective enforcement in practice occur before statutory changes can be made. Rather it appears that strong laws and rights are the prerequisite to actual, effective implementation.

4. Empirical Specification and Data

A. Empirical Specification

Defining and measuring innovation precisely is elusive. In this paper, we examine an output measure of innovation, namely patent applications, and an input measure such as research and development. It should be noted that patents do not represent the universe of inventions, since some are not patented (but are kept as trade secrets) for some strategic or other reason, or are not patentable, such as mathematical ideas (see also Silverman, 1999). Similarly R&D is one type of investment into developing innovations (others could include organizational effort). We therefore exploit two datasets (both of which are international in scope). The first looks at national patent applications (by domestic and foreign agents) and the second looks at firm level R&D expenditures. The estimating equations are, respectively:

$$(1)\ \ln\left(\frac{Patents}{GDP}\right)_{nt} = \alpha_0 + \alpha_1 \ln IPR_{nt} + \alpha_2 (\ln IPR_{nt})^2 + \alpha_3 \ln GDP_{nt} + \alpha_4 \ln Z_{nt} + 'Time\ Dummies' + \varepsilon_{nt}$$

$$(2)\ \ln\left(\frac{R\,\&\,D}{Sales}\right)_{int} = \beta_0 + \beta_1 \ln IPR_{nt} + \beta_2 (\ln IPR_{nt})^2 + \beta_3 \ln Firm\_Size_{int} + \beta_4 \ln GDP_{nt}$$
$$\beta_5 Enf\_Effect_{\mathrm{nt}} + \beta_6 \ln Z_{\mathrm{int}}\ 'Industry\ Dummies' + 'Time\ Dummies' + \varepsilon_{int}$$

where t = 1, . . . , T indexes time, n = 1, . . . , N countries, and i = 1, . . ., I firms. Patents denote the number of patent applications (by domestic or foreign agents), IPR *index of patent rights*, GDP real gross domestic product, Enf_Effect index of enforcement effectiveness, Z other control variables, and ε the error. Firm_Size is proxied by industry adjusted firm sales. Firm size is controlled for since it is generally found to be important in studies on innovation.[11] This measure is calculated by dividing the individual firm's sales by the industry average, resulting in a variable that measures the firm's relative size within its industry.[12] All variables except for the 'dummies' and enforcement effectiveness index (which is a categorical variable) are in natural logs, thus producing coefficient estimates that can be interpreted as elasticities.

A few comments about the specifications are in order. First, the dependent variables are each deflated by another variable. In the case of patents it is GDP, or a proxy for market size. This is to avoid statistical problems with non-stationary series. Patents in levels tend to exhibit a unit-root.[13] Hence we take ratios. We find that either dividing the numbers of patents by either GDP or size of the labor force give qualitatively similar results. Also, by dividing by GDP, we get a measure of the intensity of patenting relative to aggregate economic activity. Otherwise larger economies tend in general to have greater innovations and patent filings. The ratio of patenting to GDP therefore controls for country size. The results are not qualitatively different if

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[11] See, for example, Hitt et al. (1996) and Tyler and Steensma (1998).

[12] Firm sales vary considerably by industry in a way that raw sales may not be a comparable measure of firm size.

we use domestic patents in levels (without deflating by GDP or workers), but statistical problems would arise. For the input side of innovation, R&D intensity (in terms of sales) is used. Previous studies have also extensively used the ratio of R&D to sales as a proxy for innovation.[14]

Secondly the regression equations control for firm size and/or market size. The expected coefficients are a priori ambiguous, depending on whether there are scale effects at the national or firm level. The theoretical priors can go either way. A separate literature exists on the effects of firm size or market size, a full exploration of which would be beyond the scope of this paper.[15]

Thirdly, it is only in equation (2) that we employ the enforcement effectiveness index. Given the data available, this index was created only for a smaller sample of countries and only for the period 1990-2000. Hence this measure is only used in the R&D data set.

Fourthly, as to our main concern on the relationship between patent rights and innovation, we have introduced both the index of patent rights (IPR) and its square. This allows us to capture situations where the effects could be negative or positive depending on the existing level of patent rights. For instance if the coefficient on the squared term is negative (positive), we obtain a U-shaped (inverse U-shaped) relationship between patent rights and innovation, holding other variables constant. The critical point (i.e. maximum or minimum of the U-curve) for the patent equation (1) can be found from the necessary condition:

$$\frac{\partial \ln(\frac{Patents}{GDP})}{\partial \ln IPR} = \alpha_1 + 2\alpha_2 \ln IPR = 0 ,$$

[13] See Hall (2004).
[14] See, for example, Baysinger and Hoskisson (1989) and Kotabe et al. (2002).
[15] See, for example, Hitt, et. al. (1997) and Kotabe and Swan (1995).

such that IPR* = exp ($-\alpha_1/2\alpha_2$). The critical value of IPR for the R&D equation (2) can be found analogously.

A U-shaped (or inverse U-shaped) curve could accommodate the different theoretical predictions of patent rights on innovation. For instance, a U-shaped curve would indicate that a strengthening of patent rights is initially associated with a fall in the rate of innovation. This may be attributable to the fact that in low IPR countries, which depend on adaptive research and development, a stronger patent system restricts the ability of agents to imitate and acquire technological ability. For stronger patent regimes (namely those whose index levels exceed the critical value, IPR*), a tightening of patent rights is associated with a rise in the rate of innovation. For these regimes, the composition of the economy is likely to differ, reflecting a smaller share of imitators and larger share of innovators. Thus, on the whole, the appropriability effect of tighter IPRs may dominate.

Alternatively, an inverse-U shape curve would suggest that stronger IPRs stimulate the rate of innovation, but up to a point. When patent strength is very strong, the increased market power effect may become more influential (reducing the incentives of incumbents to innovate).

Finally, in estimating equations (1) and (2) we take into account unobserved nation and/or firm specific effects that may affect the consistency and unbiasedness of the coefficient estimates. The method of estimation that we adopt is *fixed effects*.[16]

B. Data Sources

Patent data by country are from the World Intellectual Property Office *Industrial Property Statistics* and *100 Years of Industrial Property Statistics 1883-1983*. Our sample covers 1965 – 2000 (every five years). Prior to 1965, not a large sample of countries was reported. GDP and other national country data (such as education, life expectancy, government spending, and interest rates) are from the World Bank's *World Development Indicators*.

Firm level data on research and development and sales are from *Datastream*.[17] This database provides international data on a diverse selection of companies. Firm level data from 35 countries were selected for 1990, 1995, and 2000. Moreover, the data represent firms competing in various manufacturing industries. The manufacturing industries were selected for their broad global coverage and for their greater consistency in the reporting of innovation investments compared to other industries, such as services or non-profit.

While concerns regarding the location of innovation activity in a multinational firm can be raised, Dunning (1977) 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 4 presents sample statistics for our dependent variables of interest. Part A focuses on the patent data, while part B focuses on the R&D measure. In part A, we present the mean number of domestic and foreign patents as well as the mean ratio of domestic and foreign patents to GDP. Since the latter are very small in magnitude, we scaled them so that we can examine patents per *billion* dollars of real GDP (in 1995 U.S. dollars). The GDP in the denominator refers to the host countries' gross domestic product. Each entry in table 4A represents the value for the average country in the respective group.

First, for all countries, there is a rising trend in both the number of patents filed by domestic and foreign agents alike. Moreover, the rate of patenting (in terms of GDP) has also

[16] We also tried random effects estimation, but as will be explained below, we found the explanatory variables to be correlated with the individual-specific random effect.
[17] Datastream is distributed by Thomson Financial (http://www.thomson.com/financial).

risen over time, and significantly so in the case of foreign patenting. The latter reflects the increased global technology diffusion of the 1990s.

Similar trends are visible when we split the sample between the developed and the less developed countries. However, there are a couple of noticeable differences. The developed world experienced a very significant increase in the rate of domestic innovation. However, very little change in the rate of innovation among developing and least developed economies has occurred. In the 1990s, the average country in the latter group produced 6.6 domestic patents per billion dollars of GDP, which is only slightly higher than the rate during 1960-1990.

Nonetheless the rate of foreign patenting is much higher in the developing world than in the developed world. The average developing and least developed economy received 11,037 foreign patents per billion dollars of GDP in the 1990s, while the average developed country received 1,074. Of course, in terms of volume, the developed world has received more foreign patents than the developing world has (145,341 versus 47,899). What accounts for the higher rate in the developing world can be attributable to two factors: first, the World Intellectual Property Office as well as other regional patent offices have made it easier to designate developing countries and least developed countries on a patent application.[18] Secondly, as businesses and firms have gone global, they have tended to set up branches in developing countries (where factors costs are relatively lower and market sizes growing). Thus, as firms have expanded into developing country markets, their demand for patents in those regions has increased as well. Thus, relative to their demand for patents in developed markets, the demand

[18] For example, the Patent Cooperation Treaty (PCT) provides for an international patent filing process. There are designation fees up to 11 countries. After that, the marginal cost of adding a country to the patent application is zero.

for patents in less developed markets has increased faster, which helps to account for the greater increase in the rate of foreign patenting observed in table 4A.

In table 4B, we report the mean ratio of R&D to sales from Datastream. The figures here are based on firm-level R&D investments. Here too the data suggest an increased rate of innovative activity (from the 'input' perspective). In 1990, for instance, firms' R&D on average equalled 4.33% of sales, and in 2000, it equalled 6.69% of sales.

The rate of R&D is, of course, much higher for firms in developed countries. However, the coefficient of variation of R&D to sales is higher in developing countries. Furthermore, the mean rate of R&D of firms in developing countries is 3.5 times higher in 2000 than it was in 1990. Thus, R&D activity among firms in developing countries has been experiencing greater growth, but quite a gap still exists between the R&D activities of developed and developing nation firms.

For the R&D sample, table 5 shows the distribution of observations by industry and country. There are 35 countries and 10 industries represented in the sample. Most of the data come from the U.S. (namely 43.4%), followed by Japan (21.6%), and the U.K. (8%). India accounts for 4.8% of the observations and Korea 3.9%. The remaining 30 countries each accounts for less than 2% of the observations. Most of the data represent the scientific instruments industry (namely 35.7%), and then the food and industrial chemicals industries.

5. Empirical Results

In this section, we first explain how the TRIPS agreement impacted on patenting. Next, we discuss the regression analysis of patents, and then the regression analysis of R&D.

A. TRIPS

Without having to formally incorporate TRIPS into the patent rights index, we can analyze the impact of the agreement on innovation by comparing the distribution of patenting activities between signatory states and non-signatory states.

The *distribution analysis* (known also as the *rank-sum test*) works as follows: Consider two samples of countries: those that joined the WTO and those that did not.[19] Recall that member states of the WTO must adopt the TRIPS agreement along with other trade liberalization agreements as a package. To the extent that membership in the WTO has an important impact on patenting activities, the distribution of patents (domestic or foreign) should differ between groups. Of course, the two samples could differ along other dimensions (such as culture, geography, or technological progress). However, the one certain dimension along which the countries differ is membership in the WTO. The test simply determines whether WTO members and non-members are distinguishable in some measure of economic activity. Any differences or absence of differences cannot be attributed wholly to a "WTO effect." The regression analyses later in this paper, of course, will allow for the controlling of other effects.

The outcome of the rank-sum test is a test-statistic value (i.e. p-value) that indicates how probable it is that the two distributions are *similar*.[20] Thus, if the p-value is relatively *high*, it is *doubtful* that the distributions are different. For example, if the p-value equals 70%, there is a 70% probability of *wrongly* concluding a difference in distribution. But if p = 5%, more confidence can be placed on concluding that membership in the WTO matters (as the chance of error is smaller).

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[19] Metaphorically, one group receives *treatment* while the other does not (or receives a *placebo*).

As mentioned above, this method does not control for a variety of factors (other than membership in the WTO). However, to control at least for the level of development, the test treats developing nations and least developed nations separately. That is, the sample of developing countries is put into two groups: those that joined the WTO in 1995 and those that did not. The same procedure is applied to the sample of least developed countries. The results are based on patenting activities in 1995 and 2000.

As Table 6 reports, the distribution of domestic patent applications in developing WTO nations is significantly differently from that in developing non-WTO nations. The probability of making the wrong call (that is, of concluding a difference when there really is not) is only 3.7%. The distribution of domestic patenting, however, is insignificantly different between WTO and non-WTO *least developed* countries. Thus, among least developed nations, innovative activity is no more intense in WTO countries than in non-member countries.

When we examine domestic patenting relative to GDP, the difference between WTO members and non-members is modest among developing nations, but insignificant again among least developed nations. (The difference is modest in the sense that the p-value of 9% falls short of the conventional significance level of 5%.) Thus adjusting for the relative size of the economy, developing nations that joined the WTO in 1995 enjoyed a modestly higher rate of innovation than those that did not (but the differences in innovation rates are not very highly significant, statistically speaking).

For foreign patents received, insignificant difference exists between members and non-members, in both developing and least developed regions. But when we examine the distribution

[20] See Mood et. al. (1974) for a background on the rank-sum tests.

of foreign patenting relative to GDP in developing nations, a moderate difference exists between members and non-members.

Thus the rank-sum tests suggest overall that it may be too soon to tell if the WTO/TRIPS has had, or is having, a strong effect on domestic innovation or on foreign technology diffusion. The member states experience at most a modest difference in domestic and foreign patenting relative to GDP, and that this applies only to developing nations – not to least developed nations. It is likely to take more than joining the WTO to alter the innovative capacities of the least developed nations. Moreover, WTO membership is multi-faceted, covering patents and other kinds of intellectual property rights and trade liberalization measures. Thus several other factors need to be controlled for. It would be interesting to test for a WTO/TRIPS effect after nations have had a chance to complete their transition periods.

B. Patents

Table 7 reports on the impact of patent rights on the rate of domestic (resident) patenting. In column 1, we see that the impact of patent rights is not monotonic (or not linear). There is a U-shaped effect. This indicates that at low levels of IPR, holding other factors constant, a strengthening of patent rights would lower (not raise) the rate of domestic patenting. Typically, less developed economies have weaker patent systems. Thus the result suggests that for them, strengthening patent rights would not stimulate innovation (in terms of the intensity of patenting). This supports some in the literature that have argued that a stronger patent system may inhibit innovation because it restricts or reduces the ability of agents to imitate and copy. However, according to our finding, this argument applies to situations or regions where patent rights are initially low.

As our finding also indicates, for patent systems that exceed a threshold level of strength, a strengthening of patent rights would increase the rate of innovation (holding other factors constant). Stronger patent rights would increase incentives to innovate by providing better protection against infringers and by augmenting the market for the property owner.

According to the estimates in column 1, the critical point is where the index of patent rights equals 2.63 (= exp(2.34/2(1.21))). In our sample, 51% of the observations are below this critical value of patent rights. They include Latin American economies such as Argentina and Uruguay, Asian economies such as Bangladesh, Nepal, Singapore, and Sri Lanka, African economies such as Ghana and Kenya, and European economies such as Greece and Portugal.

Also, the elasticity of patenting with respect to the patent rights index varies by level of the index (or by how strong the patent system is). The stronger the system is the greater the percentage change in patents to GDP per a 1% change in IPR (since α_2 in equation (1) is estimated to be positive). Thus patent reforms have bigger impacts on those economies that have stronger patent regimes to begin with.

Note also that market size (as given by the natural log of GDP) is positively associated with the rate of domestic patenting. The measured elasticity is 0.59%. Note that time dummies are included but their coefficient estimates are not reported to conserve space.

We should point out that we tried a random effects estimation but according to a *Hausman* test, the null hypothesis of no correlation between the individual effects and the regressors was rejected. The chi-square test statistic value was 30.4 which well exceeds the critical value (with ten degrees of freedom, taking into account the time effects as regressors)

Column 2 shows that the U-shaped impact of patent reform on innovation holds even after other national variables are controlled for. We introduced the following additional regressors (taken from the economic growth literature)[21]: (a) government size, as proxied by the ratio of government consumption to GDP (which could reflect the tax burden or the level of financial or resource crowding out); (b) human capital, as given by years of education (at the tertiary level since innovation activities tend to require higher education); (c) health capital, as given by life expectancy; and (d) average annual lending rate to reflect the time preference rate or discount rate, given that innovation is an intertemporal decision variable. We find that health capital has a modestly significant positive impact and the lending rate a modestly negative impact on the rate of innovation. Fiscal policy is found to have an insignificant effect on patenting. Education is also a weak influence. Perhaps the more appropriate measure of human capital, in the context of innovation, is the stock of scientists and engineers, who possess even more specialized training. However, data on this is not widely available (for our sample at least).

The next two columns show the results of splitting the sample between developed countries and developing and least developed countries. As with the aggregate sample, the developed country sample exhibits a U-shaped relationship between patent rights and domestic patenting, but the U-shape is modestly significant given that the coefficient on IPR is significant at the 10% level. Naturally the U-shape is weakened because the weak IPR countries are removed from the sample. Here the critical value of the patent rights index (at which there is a turning point) is 2.48, which is not too dissimilar from the overall sample. For the developed country sample, 12% of observations are under this critical value of the patent rights index.

In the developing and least developed country sample, patent rights have a statistically weak but negative influence on the rate of domestic patenting. Thus it is by pooling the two split-samples that we get an overall U-shaped relationship. The results thus show that the effects

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[21] See empirical studies summarized in Barro and Sala-i-Martin (2004).

of patent reform depend on the stage of development. Patent rights have a positive effect on domestic innovation after a certain level of development of the patent regime has been reached.

In table 8, we show the results of disaggregating the patent rights index by its underlying components. Like the overall index, we examine for any nonlinear effects (hence the presence of the quadratic terms). For the pooled sample, two components drive domestic patenting: coverage and abstention from loss of rights (through compulsory licensing, revocation, or working requirements). Coverage matters to patenting because an expansion in subject matter that is patentable attracts inventors to file more patents for their inventions. The abstention from loss of rights matters overall since it provides credibility that property rights are more secure. Note that both the coverage (COV) and protection against loss of rights (RIG) have statistically significant positive and increasing effects. Thus the U-shaped relationship that was found for the overall index is due not to U-shaped effects in each or in any of the components of the index but to offsetting effects from the components themselves. For instance, the other three components have weak or weakly negative effects on domestic patenting and hence would offset the effects of COV and RIG.

The next two columns focus on the split samples. For the developed economies, coverage and protection against loss of rights continue to be statistically important determinants of the rate of domestic patenting. But so is enforcement. For developed economies, the ability to enforce one's property rights is likely to be particularly important due to the presence of more sophisticated pirates in the developed world. Duration is modestly important to the rate of domestic patenting in the developed region (i.e. at the 10% level of significance).

For the developing and least developed economies, most of the patent rights components are statistically insignificant explanatory factors. Membership in international treaties has a negative influence on domestic patenting. Apparently, joining world treaties that define stronger standards has a disincentive and "imposing" effect on domestic patenting in the less developed region. The one component that is important to domestic patenting here is the protection against loss of rights. Though patent rights largely raise the cost of innovation in the developing world, innovators at least benefit from security against compulsory licensing or revocation of rights.

In table 9, we present the results on foreign (non-resident) patenting. These refer to patent applications by non-residents (aggregated across foreign source countries). The dependent variable is the natural log of the ratio of foreign patent applications to domestic GDP. Again, domestic GDP is used to measure the intensity of foreign patenting in the local economy. The first column shows that local patent strength is an important factor in attracting foreigners to file applications for their technology in the local economy. Thus stronger patents could potentially help facilitate technology transfers.

In the pooled sample, though, we do not find a U-shaped relationship between patent rights and the rate of foreign patenting (as can be seen from the statistically weak coefficient on IPR). In observing the split sample, we do find a U-shaped relation among developing and least developed economies. The critical level of IPR here is 1.46 (for which 10% of the developing and least developed country observations are below this value). Again, this shows that for weak IPR countries, raising patent strength may dissuade innovation, including by foreigners, since the cost of innovation is raised. Foreigners may have incentives other than patent rights to bring their technologies to relatively poor countries (for instance, to access cheaper inputs, like labor or raw materials).

Among developed economies, however, we find an *inverse* U-shaped relationship between domestic patent strength and the rate of foreign patenting. This suggests that after patent strength reaches a certain level, increases in patent rights (holding other factors constant) reduces the rate of foreign patenting. Among developed economies, patent strength is generally high. Thus even stronger patent rights may increase market power and reduce incentives among rights holders to upgrade or develop new technologies, giving them opportunities to extract more rents from existing technologies they own. According to the estimates the inverse-U curve reaches a peak at an IPR level of 3.40 (for which 43% of the developed country observations are above this value). Why there is an inverse-U for foreign patenting but not for domestic patenting may be explained by the fact that typically firms file first domestically (i.e. "priority filings") and subsequently file internationally. Thus international patent applications are a further source of income or rent to patent rights holders. International patent protection serves to enhance the market power of the rights holder and augment the ability of the rights holder to earn economic rent. In some cases, pure rent may be earned if a firm was successfully able to recoup the fixed costs of innovation from the domestic economy and/or in a few other foreign markets. In that case, getting a patent right in the nth country largely yields rent.

In the last two columns of Table 9, we show the results of splitting the sample. For the developed countries, the key component is duration. An explanation is that foreign patent applications tend to represent more valuable innovations. Domestic applications in contrast consist of more marginal patents. The reason is that foreign patenting is costly (e.g. agent fees, translation costs, renewal fees, and so forth) so that there is a selection bias. Inventors will only seek patent protection for those innovations whose value exceeds the cost of obtaining protection. Indeed, usually a smaller share of national patents is filed for protection internationally. Therefore, to the extent that foreign patent applications represent more valuable innovations, they are likely to have greater R&D resources invested in them. Hence it is likely that there are greater fixed costs to recoup. Thus longer-lived patents are in that case advantageous. They provide more opportunity for patent owners to recoup their costs. Thus the results seem to pick up that effect on foreign patenting behavior.

For patenting in developing and least developed regions, foreigners appear to be concerned about patent enforcement, membership in treaties, and duration (as shown in column 5).[22] Thus enforcement is more of an issue to foreign technology owners operating in the developing region. In developed economies, patent rights are already relatively strong.

C. R&D

Column 1 of Table 10 has the estimates of the basic specification. The dependent variable is the natural log of the ratio of R&D to firm sales. The counterpart of market size here is firm sales (adjusted for industry size) (in natural logs).[23] But we also control for overall market size given by the log of real GDP. Estimation is by fixed effects.[24] For this sample, the unit of analysis is the firm-country pair. Both time and industry dummies are included.[25]

Overall, we find a statistically significant positive effect of national patent rights on the intensity of firm level research and development. Moreover, the patent rights index is significant even after controlling for a variable that measures enforcement effectiveness in practice. The

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[22] Note that column 5 represents foreign patenting (by all source countries) in the less developed region. It does not represent foreign patenting by agents from the less developed countries only.

[23] Since some firms reported zero sales in certain periods, we lost observations (due to taking logs of zero). Hence tables 10 and 11 report that the number of observations is 2440 instead of 2451 as was reported in Table 5.

[24] Random effects were also tried but again we found correlations between the regressors and the individual effect.

[25] We also controlled for measures of industry munificence (i.e. resource abundance), dynamism (volatility of industry sales), and concentration (Herfindahl-type index for top 20 firms in an industry). However, these variables were statistically insignificant determinants once the industry dummies were controlled for.

latter itself is an important positive explanatory factor. Firm level R&D thus depends on both enforcement in practice as well as on strong laws and institutions. Unlike the patenting data, we find weak indication of a U-shaped (or inverse U-shaped) relationship between the index of patent rights and R&D intensity. As we show below, this is not the case if we split the sample between richer and poorer nations. As for the other variables, firm size exerts a statistically significant negative effect on R&D to sales. This indicates "diminishing returns" – that larger size does not in general lead to economies of scale in (or increasing returns to) R&D. National market size overall has an insignificant effect on R&D to sales.

In the split samples, we find (as shown in column 2) that R&D and IPR have a U-shaped relationship in the developed region. The critical value of IPR is 2.99. Thus, as before, this suggests that stronger patent rights inhibit research at low levels of patent rights by likely raising the cost of research and prohibiting the free use of existing innovations. At higher levels of patent rights, stronger patent rights encourage research by strengthening the ability to appropriate the returns to innovation and increasing legal certainty. In weaker patent systems, innovation sectors are less mature, have less experience with licensing and cross-licensing, and are less likely to be to handle the costs negotiating multiple licensing agreements. For this developed country sample, enforcement effectiveness continues to be an important determinant of the intensity of R&D. Firm size and GDP both have a negative influence on R&D to sales. GDP here may be picking up effects other than the benefits of a larger market or demand. It may reflect a supply expansion (increased output) which reduces national price levels (and profits), although a richer framework is needed to test this, which is beyond the scope of this paper.

For developing and least developed countries, neither the index of patent rights nor the index of enforcement effectiveness significantly determines R&D intensity. As the next table shows, the weak effect of IPR on developing country R&D is largely due to offsetting effects from the individual components of IPR.

Table 11 shows which components of IPR have been driving the intensity of firm level research and development. For the pooled sample (see column 1), coverage and enforcement are overall important determinants, as they were for patenting. Membership in treaties is also an important factor in so far as it helps signal which destinations are willing to provide internationally accepted standards of rights. The pooling of countries from different stages of development, however, blends the influences of these different components of patent rights.

Thus turning to the developed countries (column 2), we find that enforcement mechanisms, enforcement effectiveness, and abstention from loss of rights, are important determinants of R&D intensity. Membership in treaties is not very important for firms in developed regions because patent systems are relatively strong here, and most countries in this region are already members of the major international treaties. It is when one compares across regions that one finds a positive effect of treaties because a number of developing regions are not or were not members of those treaties.

Among developing and least developed countries (see column 3), the components of patent rights and enforcement effectiveness have negative effects on R&D intensity. Thus for firms in this region, the results seem to suggest that patent reform is not conducive to stimulating research and development. The developing economies that are in the sample tend to be the imitating nations (e.g. India, Brazil, Mexico, etc.). Note though that in this situation, GDP has a positive and significant influence on the intensity of R&D among firms in developing countries. Firm size has an insignificant influence on firm level R&D intensity in this region.

Thus while determinative conclusions can be drawn about the effects of patent rights on innovation, there are no uniform (one-size-fits-all) conclusions to be drawn. The effects (whether positive or negative) depend on what type of patent right (coverage, enforcement, etc.), on the measure of innovation (output or input), on the stage of development of the economy in which firms operate, and on whether the innovator is domestic or foreign. Patent reforms and academic research need to take into account the diversity of patent regimes and the surrounding environment.[26]

6. Conclusion

This paper has provided a quantitative analysis of the state of international patent rights and enforcement. Awareness of national patent regimes can inform managers regarding the protection that will be afforded their global investments. Secondly the paper has provided an empirical analysis of the relationship between patent rights and innovative activity.

First, we find that it is premature to tell whether the TRIPS agreement per se has a strong impact on patentable innovations. For developing countries that are signatories to the agreement, we find that they have a modestly higher rate of innovation than non-signatory developing countries. However, no appreciable difference could be found between least developed countries that are signatories and those that are not. This is partly due to the fact that least developed countries have a longer transition period for implementing the required reforms. It may also be

[26] As Murmann's (2003) study of the synthetic dye industry in Germany during the 19th century shows, the appropriateness of patent strength depends on the circumstances, including timing. The patent law of 1877 was successful because it "came after the industry had already developed strong firms and science was providing the tools to do systematic R&D on new dyes . . . . Had the German patent law arrived in 1858, it is doubtful that as many German firms would have developed into strong competitors. Fewer firms would have entered the industry, and inefficient firms would have been more likely to survive." (p. 33.)

due to the fact that innovation in the least developed region simply does not respond to mere legal changes, but requires other substantive infrastructural changes which may occur with a lag.

The regression analyses confirm that patent rights have varying effects on innovation, depending on the level of development of countries and on the specific type of patent reforms that are undertaken. In other words, we find that patent rights are capable of having both a significant positive and negative effect on innovation depending on circumstances. Our findings in general are that patent rights may adversely affect innovation in developing and least developed economies that are dependent on the ability to imitate external technologies. Patent rights are generally conducive to innovation in developed country markets. Stronger patent rights also help attract foreign technologies (i.e. attract foreign patent filings). However, there is some potential for excessively strong patents to slow the rate of foreign technology diffusion.

We also find that the impact of different components of patent rights on innovation varies by level of development. For instance, in developed countries, enforcement mechanisms and absence of loss of rights provisions (such as compulsory licensing) have a positive and significant effect on domestic rates of innovation. But in less developed economies, the domestic rate of innovation responds adversely to the joining of international treaties on patent rights. Foreign patenting in the less developed countries, however, does respond positively and significantly to the strength of local enforcement mechanisms and to whether the destination country is a member of international patent treaties. The duration of protection matters to foreign patenting in developed, developing, and least developed regions. Both enforcement mechanisms and enforcement effectiveness in practice are significantly positive determinants of the intensity of research and development by firms in developed countries; however, they are significantly negative determinants of R&D intensity by firms in developing countries. Thus some critical threshold level of development – of the economy and of its patent regime – seems to be required before a stronger patent system can stimulate innovative activity. Hence policy reforms will have to be sensitive to initial conditions.

There are several possible extensions to this study. First, it will be useful to distinguish the effects of patent protection by different industries and/or by different types of technology (for example, pharmaceuticals, chemicals, software, machinery, and so forth). Secondly, other types of intellectual property rights could be examined, such as copyright and trademark rights, or other policies that could affect innovation, such as public subsidies and tax policy (such as R&D tax credits). We could then compare the efficacy and efficiency of different policies on innovation. Thirdly, for firm level analysis, it would be useful to examine privately owned firms as well as firms in non-manufacturing sectors (such as services). Our sample consisted only of publicly-traded manufacturing companies. While our sample may represent most of the major firms in a given country, it is of interest to examine whether our findings are generalizable to other types of firms.

Appendix: Index Methodologies and Data Sources

A. Patent Rights Index

(1) Membership in International Treaties	Signatory	Not Signatory
-- Paris Convention and Revisions	1/3	0
-- Patent Cooperation Treaty	1/3	0
-- Protection of New Varieties (UPOV)	1/3	0
(2) Coverage	Available	Not Available
-- Patentability of pharmaceuticals	1/7	0
-- Patentability of chemicals	1/7	0
-- Patentability of food	1/7	0
-- Patentability of plant and animal varieties	1/7	0
-- Patentability of surgical products	1/7	0
-- Patentability of microorganisms	1/7	0
-- Patentability of utility models	1/7	0
(3) Restrictions on Patent Rights	Does Not Exist	Exists
-- "Working" Requirements	1/3	0
-- Compulsory Licensing	1/3	0
-- Revocation of Patents	1/3	0
(4) Enforcement	Available	Not Available
-- Preliminary Injunctions	1/3	0
-- Contributory Infringement	1/3	0
-- Burden-of-Proof Reversal	1/3	0
(5) Duration of Protection	Full	Partial
	1	$0 < f < 1$

-- where f is the duration of protection as a *fraction* of the full potential duration. Full duration is either 20 years from the date of application or 17 years from the date of grant (for grant-based patent systems).

B. Enforcement Effectiveness Index

This index is a qualitative measure of the effectiveness of IPR enforcement in practice. It is based on reports filed with the U.S. Trade Representative (USTR) which document the experience of patent rights enforcement across countries. The reports are available annually since 1986.

The reports describe complaints, if any, about enforcement procedures and/or about the failure of the proper authorities to carry out the laws on the books. The failure to enforce may be due to some inability on the part of the authorities to carry out those laws or due to a conscious policy choice. The absence of substantive laws (other than enforcement provisions) is already incorporated in the previous indexes, and thus complaints about the lack of substantive laws are not incorporated here. Thus, the index (and scoring system) is given by:

Enforcement Effectiveness =	0	if enforcement measures are not available or inadequate (e.g. weak deterrents);
	½	if enforcement measures are available but not effectively carried out (due to lag in policy implementation or resource barriers);
	1	otherwise.

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Table 1. Patent Rights Index Updated

A. Developed Nations:	Average 1960-1990	1995	2000	WTO Member in 1995
Australia	3.05	3.86	4.19	1
Austria	3.65	4.57	4.71	1
Belgium	3.50	3.90	4.04	1
Canada	2.76	3.57	3.91	1
Denmark	3.13	4.05	4.20	1
Finland	2.44	4.19	4.19	1
France	3.44	4.05	4.05	1
Germany	3.21	3.86	4.53	1
Greece	2.44	2.65	3.20	1
Iceland	2.12	2.45	2.71	1
Ireland	2.82	3.32	4.00	1
Italy	3.56	4.19	4.33	1
Japan	3.54	3.94	4.19	1
Korea	3.19	4.20	4.20	1
Luxemgb.	2.73	3.05	3.20	1
N. Zealand	3.19	3.86	4.00	1
Netherl.	3.72	4.38	4.38	1
Norway	2.97	3.90	3.91	1
Portugal	1.98	2.98	2.98	1
Spain	3.29	4.05	4.05	1
Sweden	3.06	4.24	4.38	1
Switzerl.	3.25	3.91	4.05	1
U.K.	3.22	3.57	4.20	1
U.S.A.	4.09	4.86	5.00	1
Mean	*3.10*	*3.82*	*4.03*	*1*
Std Dev.	*0.51*	*0.58*	*0.53*	*0*

B. Developing Nations	Average 1960-1990	1995	2000	WTO Mem. in 1995
Algeria	3.29	3.38	3.53	0
Argentina	2.17	3.19	3.34	1
Bolivia	2.02	2.31	2.42	1
Botswana	1.79	1.90	2.23	1
Brazil	1.71	3.05	3.05	1
Bulgaria	n/a	2.57	3.23	0
Cameroon	2.29	2.57	2.90	1
Chile	2.28	3.07	3.40	1
China	n/a	1.55	2.47	0
Colombia	1.56	2.57	3.24	1
Cost. Rica	1.83	1.80	2.41	1
Cyprus	2.14	2.24	3.24	1
Czech Rep	n/a	3.19	3.53	1
Dom. Rep.	2.37	2.41	3.21	1
Ecuador	1.69	2.71	3.72	0
Egypt	1.99	1.99	2.46	1
El Salv.	2.19	2.86	3.67	1
Fiji	2.01	2.01	2.68	0
Gabon	2.29	2.57	3.19	1
Ghana	2.56	2.07	3.05	1
Grenada	1.70	1.70	2.41	0
Guatemala	1.28	1.08	1.70	1
Guyana	1.42	1.42	1.89	1
H. Kong	2.22	2.57	2.90	1
Honduras	1.93	2.10	2.23	1
Hungary	n/a	3.37	3.71	1
India	1.64	1.51	2.17	1
Indonesia	0.33	1.24	2.27	1
Iran	2.38	2.38	2.52	0
Iraq	2.27	2.46	2.79	0
Israel	3.47	3.57	4.05	1
Ivory Cst.	2.44	2.52	2.85	1
Jamaica	2.89	2.86	3.52	1
Jordan	1.71	2.19	2.99	0
Kenya	2.46	2.90	3.05	1
Lithuania	n/a	2.90	3.04	0
Malaysia	2.48	2.85	3.07	1
Malta	1.80	1.89	2.36	1
Mauritius	2.70	2.89	3.36	1
Mexico	1.69	2.86	2.86	1
Morocco	2.38	2.38	2.71	1
Nicaragua	1.17	0.92	1.59	1
Nigeria	3.00	3.05	3.05	1
P.N.Guin.	0.00	0.00	0.00	0
Pakistan	1.99	1.99	1.99	1
Panama	2.41	3.52	3.86	0
Paraguay	1.80	2.80	2.80	1
Peru	1.14	2.71	2.71	1
Philipp.	2.58	2.67	2.67	1
Poland	n/a	2.90	3.23	1
Romania	n/a	2.71	2.71	1
Russia	n/a	3.04	3.52	0
S. Africa	3.41	3.57	4.05	1
Saudi Ar.	2.05	2.05	2.05	0
Singapore	2.46	3.90	4.05	1
Slovak Rep	n/a	3.19	3.53	1
Sri. Lanka	2.78	3.12	3.59	1
Swazil.	2.19	2.86	2.86	1
Syria	2.46	2.46	2.94	0
Thailand	1.65	2.24	2.24	1
Trin.& Tob.	3.01	3.35	4.00	1
Tunisia	1.90	1.90	2.23	1

Table 1 continued

B. Developing Nations	Average 1960-1990	1995	2000	WTO Mem. in 1995
Turkey	1.76	1.80	2.86	1
Ukraine	n/a	3.04	3.52	0
Uruguay	2.13	2.60	3.07	1
Venezuela	1.35	2.90	2.90	1
Vietnam	n/a	3.13	3.28	0
Zaire	2.71	2.86	2.86	0
Zimbabwe	2.60	2.90	3.58	1
Mean	*2.10*	*2.52*	*2.92*	*0.73*
Std. Dev.	*0.64*	*0.70*	*0.68*	*0.44*

C. Least Dev. Nations	Average 1960-1990	1995	2000	WTO Mem. in 1995
Angola	0.00	1.65	1.79	0
Banglad.	1.99	2.32	2.66	1
Benin	2.44	2.86	3.19	0
Burk. Faso	2.15	2.57	2.57	1
Burma	0.00	0.00	0.00	0
Burundi	2.67	2.86	3.19	1
Cent. Afr.	2.29	2.57	2.57	1
Chad	2.48	2.71	3.04	0
Congo	2.29	2.57	2.71	0
Ethiopia	0.00	0.00	1.00	0
Haiti	3.19	3.19	3.33	0
Liberia	2.19	2.86	2.86	0
Madagas.	1.58	2.27	2.94	1
Malawi	2.86	3.24	3.24	1
Mali	2.10	2.57	2.90	1
Mauritan.	2.24	2.57	2.90	1
Mozamb.	0.00	0.00	0.00	1
Nepal	2.52	2.52	3.19	0
Niger	2.15	2.57	2.90	0
Rwanda	2.62	2.86	3.00	0
S. Leone	2.52	2.52	3.00	1
Senegal	2.24	2.57	2.90	1
Somalia	1.80	1.80	2.28	0
Sudan	3.05	3.52	3.53	0
Tanzan.	2.79	2.90	2.90	1
Togo	2.14	2.57	2.90	1
Uganda	2.41	2.90	2.57	1
Zambia	3.52	3.52	3.52	1
Mean	*2.08*	*2.40*	*2.63*	*0.54*
Std. Dev.	*0.95*	*0.94*	*0.90*	*0.51*
All Countries:				
Mean	*2.31*	*2.75*	*3.07*	*0.74*
Std. Dev.	*0.82*	*0.91*	*0.86*	*0.44*

Notes: *For WTO Membership, 1 = Member, 0 = Non-Member. The mean gives the percentage of countries that are members. Countries are grouped into Developed, Developing, and Least Developed, according to United Nations Classification. The patent rights index varies from 0 to 5 (see Appendix for overview of scoring method).*

Table 2. Index of Enforcement Effectiveness -- Select Countries

Country	1990	1995	2000
Australia*	1	1	1
Austria*	1	1	1
Belgium*	0.5	0.5	1
Canada*	1	1	1
Denmark*	1	1	1
Finland*	1	1	1
France*	1	1	1
Germany*	1	1	1
Hong Kong*	0.5	0.5	1
Japan*	1	1	1
Netherlands*	1	1	1
New Zealand*	1	1	1
Norway*	1	1	1
Sweden*	1	1	1
Switzerland*	1	1	1
United Kingdom*	1	1	1
United States*	1	1	1
Argentina	0	0	0.5
Brazil*	0	0	0.5
Bulgaria	0	0	0.5
Chile*	0	0	0.5
China*	0	0	0.5
Greece*	0.5	0.5	0.5
Ireland*	0.5	0.5	0.5
Israel*	0.5	0.5	0.5
Italy*	0.5	0.5	0.5
Korea*	0.5	0.5	0.5
Malaysia*	0.5	0.5	0.5
Mexico*	0	0	0.5
Peru	0	0	0.5
Philippines*	0	0	0.5
Poland	0	0.5	0.5
Singapore*	0	0	0.5
South Africa*	0	0	0.5
Turkey*	0	0	0.5
Colombia	0	0	0
Egypt	0	0	0
Guatemala	0	0	0
India*	0	0	0
Indonesia*	0	0	0
Pakistan*	0	0	0
Romania	0	0	0
Thailand	0	0	0
Uruguay	0	0	0
Venezuela	0	0	0
Correlation with Index of Patent Rights:	*0.73*	*0.67*	*0.72*

Notes: See Appendix for scoring method. * indicates country in DataStream Sample (see Table 4)

Table 3. Sources of Changes in the Index of Patent Rights (IPR)

A. Variance and Covariances of Patent Rights Index and its Components:

	Period:	Variance of IPR:	Covariance of IPR and: COV	ENF	RIG	MEM	DUR
ALL COUNTRIES	1960-2000	0.786	*0.107*	*0.202*	*0.148*	*0.207*	*0.124*
	1960-1990	0.708	*0.090*	*0.178*	*0.152*	*0.172*	*0.117*
	1990-2000	0.752	*0.110*	*0.115*	*0.121*	*0.213*	*0.195*
DEVELOPED COUNTRIES	1960-2000	0.456	*0.068*	*0.147*	*0.068*	*0.141*	*0.032*
	1960-1990	0.365	*0.041*	*0.124*	*0.070*	*0.112*	*0.020*
	1990-2000	0.311	*0.035*	*0.069*	*0.072*	*0.109*	*0.026*
DEVELOPING & LEAST DEV. COUNTRIES	1960-2000	0.621	*0.132*	*0.125*	*0.137*	*0.110*	*0.118*
	1960-1990	0.558	*0.129*	*0.089*	*0.139*	*0.070*	*0.132*
	1990-2000	0.551	*0.115*	*0.054*	*0.111*	*0.118*	*0.156*

B. Granger Tests of Temporal Precedence:

Summary of Vector Autoregression Results:

i. Patent Rights Components

	COV	ENF	RIG	MEM	DUR
COV	L1	L1		L2	
ENF		L1, L2		L1	L1
RIG		L1, L2*	L1, L2		
MEM		L1, L2*		L1, L2	L1, L2*
DUR		L1, L2*		L1	L1, L2

ii. Indexes of Patent Rights & Enforcement Effectiveness

	IPR	Enf_Effect
IPR	L1	
Enf_Effect	L1	L1

Notes:
IPR denotes index of patent rights, COV coverage, ENF enforcement, RIG loss of rights (inverse), MEM membership in international treaties, and DUR duration. Enf_Effect denotes the index of enforcement effectiveness.

In part B, Li denotes the statistical significance of the ith lag of the column variable in explaining the row variable (using the conventional significance level of 5%). The superscript * on Li indicates that the coefficient sign is negative.

Table 4. Measures of Innovation – Sample Statistics

A. Patent Data (from World Intellectual Property Office (WIPO))

	Period	Domestic Patents	Domestic Patents per billion GDP	Foreign Patents	Foreign Patents per billion GDP
All Countries	1960-1990	3614	9.3	6439	61
	1990-2000	6827	10.0	75092	8257
Developed Economies	1960-1990	9213	13.9	17239	86
	1990-2000	22206	18.8	145341	1074
Developing & Least Dev.	1960-1990	493	6.5	1020	46
	1990-2000	1060	6.6	47899	11037

B. Research and Development Data (from Datastream)

	Year	Mean R&D/Sales	Coefficient of Variation
All Countries	1990	4.33	1.09
	2000	6.69	1.31
Developed Economies	1990	4.66	1.03
	2000	7.20	1.23
Developing & Least Dev.	1990	0.43	1.21
	2000	1.51	3.23

Notes: In part A, billion GDP refers to the destination country's Gross Domestic Product (in real 1995 U.S. dollars). Domestic and Foreign patents refer to the number of patents filed by residents and non-residents respectively. In part B, R&D/Sales refers to firm level research and development as a percentage of sales, and the coefficient of variation is the ratio of the standard deviation to mean.

Table 5. R&D sample: Composition by Country and Industry

Country	Number of Observations	Percent
Australia	33	1.4
Austria	3	0.1
Belgium	4	0.2
Brazil	2	0.1
Canada	42	1.7
Chile	7	0.3
China	9	0.4
Denmark	21	0.9
Finland	24	1.0
France	41	1.7
Germany	44	1.8
Greece	12	0.5
Hong Kong	9	0.4
India	118	4.8
Indonesia	1	0.0
Ireland	14	0.6
Israel	6	0.2
Italy	17	0.7
Japan	529	21.6
Korea	96	3.9
Luxembourg	1	0.0
Malaysia	14	0.6
Mexico	2	0.1
Netherlands	24	1.0
New Zealand	4	0.2
Norway	11	0.5
Pakistan	6	0.2
Philippines	2	0.1
Singapore	9	0.4
S. Africa	16	0.7
Sweden	21	0.9
Switzerland	37	1.5
Turkey	13	0.5
UK	195	8.0
USA	1064	43.4
Total	2451	100

INDUSTRY	Number of Observations	Percent
Beverages	87	3.6
Construction Machinery	138	5.6
Electrical Components	188	7.7
Food	339	13.8
Household Appliances	55	2.2
Industrial Chemicals	280	11.4
Nonferrous Metals	142	5.8
Rubber	88	3.6
Scientific Instruments	874	35.7
Semiconductors	260	10.6
Total	2451	100

Source: Datastream (Thomson Financial Inc.)

Table 6. Role of WTO/TRIPS in Patenting

Distribution of:	(1) Developing Countries Member vs. Non-member	(2) Least Developed Countries Member vs. Non-member
i. Domestic Patents	Significant Difference p-value = 0.037	Insignificant Difference p-value = 0.96
ii. Domestic Patents Per GDP	Moderate Difference p-value = 0.09	Insignificant Difference p-value = 0.80
iii. Foreign Patents	Insignificant Difference p-value = 0.69	Insignificant Difference p-value = 0.78
iv. Foreign Patents Per GDP	Moderate Difference p-value = 0.14	Insignificant Difference p-value = 0.93

Notes: These are the results of the rank-sum tests where the null hypothesis is that no difference in distribution exists between two groups. The lower the p-value is the greater the confidence in rejecting the null hypothesis. Column 1 compares the distribution of the row variable (e.g. domestic patents) between developing countries that are members of the WTO and those that are not. Column 2 compares the same for least developed countries.

Table 7. Domestic Patents and Patent Rights

Dependent Variable: ln Patents/GDP

	All Countries (1)	All Countries (2)	Developed Economies (3)	Developing & Least Dev. Economies (4)
Constant	-31.7***	-47.0***	-32.6***	-38.0***
	(4.96)	(11.9)	(6.36)	(7.30)
ln IPR	-2.34***	-4.41***	-3.86*	-1.15
	(0.65)	(0.95)	(2.14)	(0.91)
$(\ln \text{IPR})^2$	1.21***	1.69***	2.12***	-0.061
	(0.39)	(0.54)	(0.95)	(0.67)
ln GDP	0.59***	0.69**	0.64***	0.87***
	(0.21)	(0.46)	(0.25)	(0.32)
ln Govt_Size		0.19		
		(0.43)		
ln Education		0.25		
		(0.22)		
ln Life_Exp		3.54*		
		(1.94)		
ln Lend_Rate		-0.19*		
		(0.11)		
Time Dummies	Included	Included	Included	Included
Adjusted R^2	0.17	0.20	0.21	0.20
No. of Obs.	466	233	187	279

Notes: The dependent variable is the natural log *(ln)* of the ratio of resident patents to GDP. *IPR* denotes index of patent rights, *GDP* real gross domestic product (1995 dollars), *Govt_Size* ratio of government spending to GDP, *Education* average years of schooling (tertiary level), *Life_Exp* average life expectancy, and *Lend_Rate* the lending rate. ***, **, and * indicate significance at the 1%, 5%, and 10% levels respectively. The method of estimation is *fixed effects* regression over the sample period 1965-2000 (every five years) and 100 countries (where data permit).

Table 8. Domestic Patenting and the Components of the Patent Rights Index

	Dependent Variable: ln Patents/GDP		
	All Countries (1)	Developed Economies (2)	Developing & Least Developed Economies (3)
Constant	-39.9***	-47.4***	-40.5***
	(4.88)	(8.54)	(7.04)
ln COV	0.48***	1.29***	0.17
	(0.19)	(0.40)	(0.35)
$(\ln COV)^2$	0.052***	0.46***	0.023
	(0.021)	(0.18)	(0.036)
ln ENF	0.12	0.38*	-0.47
	(0.20)	(0.22)	(0.43)
$(\ln ENF)^2$	0.024	0.057***	-0.035
	(0.021)	(0.023)	(0.043)
ln RIG	0.98***	0.69**	1.84***
	(0.32)	(0.32)	(0.58)
$(\ln RIG)^2$	0.098***	0.07**	0.18***
	(0.031)	(0.032)	(0.056)
ln MEM	-0.234	-0.26	-0.64**
	(0.18)	(0.20)	(0.33)
$(\ln MEM)^2$	-0.017	-0.021	-0.056*
	(0.018)	(0.02)	(0.033)
ln DUR	-0.19	2.69	-0.17
	(0.22)	(1.74)	(0.36)
$(\ln DUR)^2$	-0.022	9.39*	-0.021
	(0.023)	(5.72)	(0.036)
ln GDP	0.90***	1.19***	0.93***
	(0.20)	(0.33)	(0.29)
Time Effects	Included	Included	Included
Adjusted R^2	0.27	0.33	0.32
No. of Observ.	466	187	279

Notes: COV denotes coverage, ENF enforcement, RIG loss of rights, MEM membership in treaties, and DUR duration. ***, **, and * are statistical significance levels of 1%, 5%, and 10% respectively. Standard errors are in parentheses. Estimation is by *fixed effects*.

Table 9. Foreign Patents and the Patent Rights Index

Dependent Variable: ln Foreign Patents/GDP

Destination Countries:	All Countries (1)	Developed Economies (2)	Developing & Least Dev. (3)	Developed Economies (4)	Developing & Least Dev. (5)
Constant	-16.8***	-37.7***	-18.0***	1.31	-17.7***
	(3.68)	(8.38)	(7.75)	(9.94)	(6.98)
ln IPR	-1.35	11.9***	-2.5**		
	(1.06)	(2.92)	(1.36)		
$(\ln IPR)^2$	2.30***	-4.86***	3.29***		
	(0.62)	(1.29)	(0.97)		
ln COV				0.12	-0.66
				(0.42)	(0.42)
$(\ln COV)^2$				0.023	-0.08*
				(0.19)	(0.046)
ln ENF				0.13	2.93***
				(0.24)	(0.61)
$(\ln ENF)^2$				-0.03	0.29***
				(0.03)	(0.059)
ln RIG				-0.23	-0.51
				(0.48)	(1.31)
$(\ln RIG)^2$				-0.04	-0.04
				(0.05)	(0.13)
ln MEM				0.045	1.04***
				(0.21)	(0.42)
$(\ln MEM)^2$				-0.022	0.103***
				(0.022)	(0.042)
ln DUR				4.98***	2.57***
				(1.79)	(0.39)
$(\ln DUR)^2$				20.0***	0.25***
				(6.0)	(0.039)
ln GDP	-0.04	0.54*	0.03	-0.68*	0.14
	(0.26)	(0.32)	(0.34)	(0.39)	(0.30)
Time Effects	Included	Included	Included	Included	Included
Adjusted R^2	0.23	0.61	0.23	0.75	0.46
No. of Observ.	452	163	289	163	289

Notes: The dependent variable is the natural log of the ratio of non-resident patents to (resident) GDP. For other variable definitions, see Tables 7 and 8. ***, **, and * are statistical significance levels of 1%, 5%, and 10% respectively. Standard errors are in parentheses. Estimation is by *fixed effects*.

Table 10. Firm Level R&D and Patent Rights

Dependent Variable: ln R&D/Sales

	All Countries (1)	Developed Economies (2)	Developing & Least Dev. Economies (3)
Constant	1.58	6.32**	136.8**
	(1.84)	(2.89)	(66.0)
ln IPR	-0.71	-4.31*	2.66
	(0.55)	(2.59)	(3.44)
$(\ln IPR)^2$	0.68***	1.97**	-0.72
	(0.28)	(0.99)	(2.09)
Enforcement Effectiveness	0.992***	1.659***	-1.488
	(0.341)	(0.483)	(1.345)
ln Firm Size	-0.036***	-0.031**	-0.015
	(0.014)	(0.014)	(0.111)
ln GDP	-0.041	-0.14**	-5.29**
	(0.069)	(0.077)	(2.49)
Time Dummies	Included	Included	Included
Industry Dummies	Included	Included	Included
Adjusted R^2	0.33	0.22	0.16
No. of Observations	2440	2229	211

Notes: The dependent variable is the natural log *(ln)* of the ratio of research and development expenditures to sales. *Firm Size* is the sales of a firm (relative to the industry average), *GDP* real gross domestic product (in 1995 dollars), and *Enforcement Effectiveness* a rating of the effectiveness of the enforcement of patent laws. ***, **, and * indicate significance at the 1%, 5%, and 10% levels respectively. The method of estimation is *fixed effects*, where the individual effect is firm-country specific.

Table 11. Firm Level R&D and Patent Rights – By Components of Patent Rights

	Dependent Variable: ln R&D/Sales		
	All Countries (1)	Developed (2)	Developing & Least Developed (3)
Constant	-0.118 (2.05)	4.29* (2.29)	-1041.7*** (328.6)
ln COV	-0.725** (0.37)	0.23 (0.46)	n/a
$(\ln COV)^2$	-0.49** (0.24)	0.27 (0.36)	-25.1*** (5.27)
ln ENF	0.38*** (0.13)	0.48*** (0.14)	-14.6*** (3.97)
$(\ln ENF)^2$	0.037*** (0.012)	0.042*** (0.014)	-1.32*** (0.37)
ln RIG	0.094 (0.093)	0.33** (0.14)	0.79 (4.15)
$(\ln RIG)^2$	0.009 (0.009)	0.032** (0.014)	0.0002 (0.392)
ln MEM	0.25** (0.12)	0.20 (0.13)	-4.12*** (1.36)
$(\ln MEM)^2$	0.030*** (0.011)	0.015 (0.014)	-0.328*** (0.124)
ln DUR	-0.25 (0.22)	1.48 (1.60)	-10.2*** (3.33)
$(\ln DUR)^2$	0.027 (0.022)	3.06 (4.31)	-0.97*** (0.33)
Enforcement Effectiveness	0.978*** (0.388)	1.743*** (0.498)	-11.9*** (2.29)
ln Firm Size	-0.035** (0.015)	-0.029** (0.014)	0.006 (0.109)
ln GDP	0.036 (0.076)	-0.136 (0.086)	41.0*** (12.5)
Time Effects	Included	Included	Included
Industry Effects	Included	Included	Included
Adjusted R^2	0.35	0.24	0.50
No. of Observ.	2440	2229	211

Notes: ***, **, and * are statistical significance levels of 1%, 5%, and 10% respectively. Estimation is by *fixed effect*. COV denotes coverage, ENF enforcement, RIG loss of rights (inverse), MEM membership in international treaties, and DUR duration. n/a indicates not measured due to singularity.