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# Patent rights and innovative activity: evidence from national and firm-level data

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**Abstract**

Global standards of patent protection have been strengthened and harmonized in recent years. Despite the heated policy debates and theoretical controversies, empirical studies of the consequences for innovative activity are scant. This paper contributes to the debate by providing an empirical analysis of the effects of patent strength on different aspects of innovative activity, namely firm-level research and development (R&D), domestic patenting, and foreign patenting. The analysis employs an updated index of patent rights. The results show the complexity of evaluating the effects of patent reform on innovative activity, since the effects vary nonlinearly (depending on the initial level of patent strength) and vary by a country's level of economic development. Overall, for developing economies, patent strength negatively affects domestic patent filings and insignificantly affects R&D and foreign patent filings. For developed economies, patent strength positively affects R&D and domestic patent filings, and negatively affects foreign patent filings, after some critical level of patent protection is reached.
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## Introduction

Innovation is an important driver of both firm success and national economic growth (Porter, 1990). The importance of the legal environment for innovation was one of the messages conveyed during the GATT Uruguay Round negotiations to reform global patent and other intellectual property rights standards. To be sure, firms from developed countries (i.e., 'the North') were key beneficiaries of global patent reform since they owned most of the world's patented technologies and were most likely to suffer losses from infringement. However, to the extent that multilateral treaties or agreements are based on *mutual* gains and consent, a case was made that developing countries (i.e., 'the South') would also benefit from reform. Strong property rights in general, and patent protection in particular, would encourage local innovation and inward diffusion of new technologies.

Academically, there has always been controversy surrounding the effects of patent protection on innovation and diffusion, and not just in the context of developing countries. The literature on optimal patent protection (Arrow, 1962; Nordhaus, 1969) long ago recognized both the costs and the benefits of stronger patent protection and the tradeoffs between *static* inefficiencies due to market power and *dynamic* gains due to innovation and diffusion.

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Thus far, however, few empirical studies have been conducted on a broad international scale that allows for an analysis of global patent reform in a North–South context and which incorporates recent developments associated with the formation of the *World Trade Organization* (WTO) and one of its key agreements on *Trade-Related Intellectual Property Rights* (TRIPS). In this paper, we conduct such a study. We assemble two data sets: a panel of national patent applications, and a panel of firm-level research and development (R&D) expenditures. We also utilize an expanded and updated index of patent rights through the year 2000 (developed earlier by Ginarte and Park, 1997 and Park and Wagh, 2002). We then address two main questions. First, what is the relationship between patent strength and firm innovation (i.e., R&D expenditures and domestic patent applications)? Second, what is the relationship between patent strength and innovation diffusion (i.e., foreign patent applications)? How do these relationships vary by level of economic development or by components of patent strength, and what are the larger policy implications?

Thus our contribution to the literature is fourfold: first, we update information about world patent regimes. Many new developments have taken place recently, particularly the TRIPS agreement. It is imperative that research assessing the effects of patent regimes be current in that regard. Second, we examine diverse aspects of innovative activities: R&D, domestic patenting, and foreign patenting. Third, we assess the differential impacts of patent reform on Northern *vs* Southern economies. This enables us to assess whether strong patent rights are appropriate at all levels of economic development. Finally, we allow for 'nonlinear' effects of patent reform. In other words, we do not simply focus on assessing the net effects of patent reform, but we analyze the circumstances underlying these effects. Much of the current debate seems to be concerned with whether strong patent systems have positive or negative effects on innovative activities, without allowing for the possibility that the effects might vary with the existing strength of patent regimes.

As an overview, our results do illustrate that patent rights can have nonlinear relationships with innovation and diffusion, such that the effects of patent reform are rather complex and nuanced. Moreover, the effects of patent reform differ between developed and developing/least developed countries. The results suggest that higher global patent standards and harmonization have largely stimulated Northern innovation and diffusion and not Southern, at least thus far.

The paper is organized as follows. The next section reviews trends in patent reform over the past few decades. After this we provide a literature review, focusing on a theoretical framework and guide to how our empirical work differs from previous studies. The subsequent section discusses our data and empirical methodology, including a description of an updated and extended Patent Rights Index (PRI). This is followed by the empirical analysis, and discussion of the implications of our findings. The final section provides concluding thoughts and suggestions for future research. The Appendix provides further details on the PRI and countries covered in the study.

## Trends in international patent reforms

The past half-century has seen an overall strengthening and harmonization of patent laws worldwide, mostly occurring during the 1990s. Patent rights are governed by a web of national laws and international treaties and agreements. Until 1995, the multilateral treaty with the widest membership was the *Paris Convention* of 1883. The Paris treaty provides for nondiscriminatory treatment, and establishes rules for determining priority of rights. Priority determines who gets to apply for a patent (i.e., the person first to file or first to invent). The 1947 *General Agreement on Tariffs and Trade* (GATT), which later evolved into the WTO, did not deal explicitly with intellectual property rights issues. Provisions were primarily limited to dealing with counterfeit trade. Overall, GATT had no mandate to settle disputes relating to the Paris treaty.

As global trade and innovation progressed, the increased need for international patenting rules and standards led to the 1970 formation of the WIPO (World Intellectual Property Office), an agency of the United Nations. A key treaty that WIPO administers is the *Patent Cooperation Treaty* (PCT), which provides for, among other things, a single filing of an international patent application. Another important treaty is UPOV (*Union for the Protection of Plant Varieties 1961, 1978, and 1991*), which governs biotechnological innovations.

Despite these international treaties, there were divergent levels of patent rights across countries. For example, most developing countries were not signatories to each of these treaties (Paris, PCT, and UPOV). A survey conducted by Gadbaw and Richards (1988) found high rates of piracy in developing countries such as Taiwan, Korea, Singapore, Argentina, Brazil, Mexico, and India. In these countries, the enforcement levels were deemed weak and protection inadequate: for example, the duration of patent rights was short. These countries also practiced compulsory licensing: that is, they mandated patent holders to license to third parties.

In contrast, patent rights in developed countries increased in strength. In the US, landmark Supreme Court rulings in 1972 and 1980 broadened the coverage of patent rights to software and biotechnology. In addition, a specialized appellate court was formed to handle increasingly complex patent cases. This court tended to uphold the validity of existing patent rights (Jaffe and Lerner, 2004). In Japan, major patent reforms were undertaken during the 1980s, for example permitting patents to contain multiple claims. Previously, each patent could make only a single claim. Multiple claims permit a broader scope of rights. In Europe, the European Patent Office (EPO) was formed in 1978 to permit a centralized regional patent filing system. The EPO in effect made it easier to apply for and acquire patent rights.

Thus, prior to 1995, the international distribution of patent rights was very uneven, resulting in adverse trade and financial consequences for patent holders in developed countries, whose innovations were being infringed upon in developing countries where patent rights were weak or nonexistent. The subject of intellectual property was brought up during the Tokyo Round of GATT (1979–1984), but no resolution was reached. The US then took the initiative to get intellectual property issues on the table at the next Uruguay Round of GATT (1986–1994). IP issues were at the top of the agenda (Gervais, 1998). In between the two GATT rounds, the US Congress passed a law (Section 301) in 1984 to allow trade retaliation against nations that provided weak patent rights. In 1988, another law (special 301) was passed to require annual surveillance of foreign countries' practices in IP law.

During the Uruguay Round negotiations two different camps existed. The first consisted of developed countries, which advocated linking GATT to IP issues, as GATT had provisions for trade sanctions against member states in violation of agreements. The second camp consisted of developing countries that opposed linking. They insisted that WIPO was the appropriate forum for negotiating international standards on intellectual property. The two camps had proposed their own draft treaties by 1990. Eventually the developed countries' draft was largely implemented. One reason was that, behind the scenes, the US actually carried out its Section 301 threats, first against Korea in 1985 and then against Taiwan in 1986, with immediate responses. Korea overhauled its patent laws in 1986, as did many other developing countries, such as Mexico and Chile in 1991. Then, as developing countries strengthened their patent laws, they too became advocates for global IP reform, possibly because rights holders in those countries benefited and lobbied their governments. Thus the fervor in opposing the developed-country camp waned.

Hence, in 1995, the WTO formed, and the TRIPS agreement went into effect. This agreement is far-reaching, covering various IPRs (including patents, copyrights, trademarks, trade secrets, etc.), and explicitly states that it builds upon prior intellectual property treaties, such as the Paris Convention, and does not conflict with them. It also states that its provisions are *minimum* standards. Countries are free to provide stronger rights. Thus TRIPS provides for minimum standards for duration (e.g., 20 years), coverage (invention subject matter), and enforcement mechanisms. The WTO also provides a forum for dispute settlement between member states, and allows for trade sanctions against non-complying countries, a power lacking in previous treaties.

While TRIPS generally reflects the developed-country camp's proposal, it offered compromises to win developing country support. For example, it allows for transitional periods for developing and least developed countries, and calls for developed countries to assist in the technology transfer to developing countries (Article 66.2).[1] Furthermore, TRIPS actually provides some restrictions on patent rights, allowing governments to use compulsory licensing, as long as reasonable royalties are paid to rights holders.

## Conceptual framework and previous literature

As the previous section discussed, global standards of patent rights have been raised in recent years. During the multilateral negotiations, one of the cases made for IP reform was that the strengthening of patent rights would stimulate innovation and technological diffusion (Watal, 2000). However, the North–South academic literature presents a diverse range of analyses on the effects of stronger patents. At a minimum, many academic studies recognize that there are both benefits and costs of patent protection (Mazzoleni and Nelson, 1998; Maskus, 2000). Others suggest a need to adjust the strength of protection to recognize countries at different stages of development (Grossman and Lai, 2004; Stiglitz, 2004). In this section, we review the theoretical channels by which stronger patent protection affects innovation and diffusion. We then review the empirical literature and critique existing evidence. We finally outline gaps in previous research and describe how our research fits into the literature.

## Theoretical framework and literature

Table 1 provides an overview of the different channels by which stronger patent protection may positively or negatively affect innovation and diffusion. We break down the potential channels by different levels of country development, resulting in four cases to consider. The net effect of stronger patent rights in many cases is *a priori* ambiguous. Thus, ultimately, the overall effects need to be examined empirically. We discuss the theoretical channels for each case in turn.

Let us first consider the potential impact of stronger patent rights on innovation in a developed region. The standard textbook argument for why innovation may be positively stimulated is that stronger patent rights increase the degree of appropriability of the returns to innovation (Landes and Posner, 2003; Scotchmer, 2004; Allred and Park, 2007). Firms also have alternative means of appropriating the returns to innovation, such as lead-time, trade secrecy, and reputation (Levin *et al.*, 1987). Patent rights can also stimulate innovation, because patent holders are required to disclose their knowledge, as opposed to keeping it secret. The knowledge spillovers should therefore help others to innovate. Additionally, under the prospect theory (Kitch, 1977), a stronger patent system gives pioneers incentives to commercialize and organize the market better for follow-on innovation (via licensing).

Despite these positive influences, patent rights can also negatively affect innovation in developed countries. One possible reason is that patent systems give rise to increased transaction costs in the market for technological exchange, as agents are required to obtain permissions to use patented technologies. Licensing or cross-licensing negotiations are especially burdensome if patent rights are fragmented (i.e., if multiple rights holders own different components of a technology; Heller and Eisenberg, 1998; Bessen and Maskin, 2000; Shapiro, 2000). The transaction costs may particularly harm research and innovation when patentees hold rights to *research tools*, or where innovation is a cumulative and sequential process.

Patent rights may also affect innovation negatively if rights holders use their patent rights for strategic defensive purposes – for example to block rivals from accessing important technologies that are needed to realize their own innovations (Cohen *et al.*, 2000; Ziedonis, 2004). Stronger patent rights

**Table 1** Channels by which stronger patent protection affect innovation and diffusion

| *Region* | *Innovation* | *Diffusion* |
|---|---|---|
| Developed countries (North) | *Positive:* | *Positive:* |
| | Increased appropriability | Market expansion effect |
| | Knowledge pillovers | |
| | Prospect theory | |
| | *Negative:* | *Negative:* |
| | Transaction costs | Market power effect |
| | Defensive patenting | |
| | Reduced rivalry | |
| | *Predicted net effect: ?* | *Predicted net effect: ?* |
| Developing countries (South) | *Positive:* | *Positive:* |
| | Increased appropriability (with qualifications) | Market expansion effect |
| | Knowledge spillovers | Business confidence |
| | *Negative:* | *Negative:* |
| | Inability to imitate and adapt | Market power effect |
| | Traditional knowledge patented | Increased cost of technological inputs |
| | | Limited market size |
| | *Predicted net effect: Likely negative* | *Predicted net effect: Likely negative* |

may also reduce the incentives of patent holders themselves to innovate if they face reduced rivalry, causing a fall in the rate or frequency of innovation (Cadot and Lippman, 1995; Horowitz and Lai, 1996).

Considering developing countries, we see that innovation is likely to be positively influenced by knowledge disclosures from patents and the appropriability effect of patent protection (Siebeck, 1990). Prospect theory may not apply if developing economies engage in adaptive, follow-on innovations (Lerner, 2002). However, the appropriability effect nonetheless needs to be qualified. The early patent literature (Arrow, 1962; Nordhaus, 1969; Scherer, 1972) and more recent work by Grossman and Lai (2004) point out that the optimal level of patent protection depends on the characteristics of a technology or market. In general, developing economies produce less drastic innovations. Thus patent life need not be very long, as there is less innovation investment to recoup. Accordingly, the smaller the market size, and the lower the capacity to innovate, the lower should be the optimal strength of patent protection (Grossman and Lai, 2004). Excessive strength may offset the appropriability benefits by reducing competitive pressures to innovate. More direct negative effects of stronger patent protection on innovation may arise because developing countries tend to perform adaptive or imitative R&D (Evenson and Westphal, 1997). Stronger patents increase the cost of technological inputs and reduce their supply, thereby limiting the ability of local agents to learn by imitation or *learn by doing* (van Elkan, 1996; Glass, 2004). The Commission on Intellectual Property Rights (2002) argues that for developing countries to become world-class innovators and competitors, they need to start with some technological base or skill set. To the extent that stronger IPRs restrict the ability to learn by imitation, this base is not given an opportunity to grow to the necessary critical level.

Another way in which patent rights can have a negative influence is if the *traditional knowledge* of developing countries is patented. Traditional knowledge is that which is common to the local community or part of its heritage but perhaps not in the prior knowledge base of developed-country patentees. A related concern is that of *biopiracy* – the patenting of the genetic or other native resources of local communities by foreign patentees. These introduce transaction costs wherein local agents must pay for access to inputs and knowledge that used to be free. For example, foreign patent rights have been asserted for the neem tree (for pesticide extracts) and turmeric (ginger plant for healing). The reduction in their public domain hinders their ability to engage in invention pursuits. Even if the *traditional knowledge* should not be patentable, on the grounds that it is not novel, it is expensive for developing countries to challenge patent validity and litigate against multinational corporations that hold such patents (Stiglitz, 2004). This makes it difficult to become unencumbered from all the transaction costs due to patent rights.

We next turn to the potential effects of patent protection on the international diffusion of innovations. By diffusion, we are referring to the introduction of new products and processes into a marketplace beyond the resident patent applicant's home market. This can occur through several means, such as trade, international licensing, foreign direct investment, or joint ventures. If the new products or processes are easy to copy and distribute, and meet patentability criteria, firms may file a patent to protect the good. Thus the strength of patent rights could influence diffusion.

In developed countries, patent strength may positively affect diffusion via a *market expansion effect* by reducing the ability of local firms to imitate technologies (Maskus and Penubarti, 1995; Smith, 2001; Yang and Maskus, 2001). Counteracting this effect is the *market power effect* in which stronger patent rights enhance the monopoly power of the rights holder. This leads to less diffusion and higher prices.

Among developing economies, patent strength can also have both positive and negative influences on diffusion. On the positive side, a market expansion effect is also at work (UNCTAD, 1975). Moreover, as Diwan and Rodrik (1991) demonstrate, stronger patent rights in the South give Northern firms a greater incentive to research and introduce technologies appropriate to the South. Similarly, Taylor (1993) argues that weak patent rights in the South would lead Northern firms to introduce less than best practice technologies to the South. Sherwood (1990) identifies another factor encouraging diffusion in the South, namely business climate. Given the special circumstances of developing country regimes (i.e., market distortions and political instability), stronger patent rights help provide a signal that authorities are willing to adhere to commonly held norms that condition business decisions. With increased confidence in the regime, businesses are more apt to engage in technological exchange.

Regarding the negative influences on diffusion in developing countries, stronger patent rights allow foreign patent holders to exploit their market power over existing innovations longer, leading to a slower rate of introduction of new technologies. In addition, stronger patent rights restrict the ability of local agents to freely use and copy technologies. Patent protection thus increases the cost of accessing technological inputs and thereby reduces the diffusion of such inputs (Commission on Intellectual Property Rights, 2002).

The North–South welfare literature on global patent protection discusses another negative influence on diffusion, which pertains to the limited market size of developing countries (Chin and Grossman, 1990; Deardorff, 1992; Helpman, 1993). First, the North–South theoretical models assume that the North conducts invention and innovation, and that technologies diffuse to the South via local imitation. Thus the strength of patent protection in the South affects technological diffusion by affecting Northern incentives to innovate as well as Southern abilities to copy. Because developing-country markets represent a small share of a Northern firm's global market, extending patent protection in small Southern economies adds marginally to the North's incentive to do R&D. Thus stronger patent protection largely reduces technology diffusion to the South by raising the cost and reducing the supply of *existing* technologies to monopolistic levels. This occurs with little or no compensation from any increased quantity of *new* technologies flowing in, since Northern innovation incentives are little affected by the increment in profits from small developing countries.

Thus, to summarize, the net effects of patent protection on innovation and diffusion depend on the interplay of various factors at different levels of economic development. The question is whether we can predict the sign of the net effect, or whether the net effect varies with some other factors, such as the existing level of patent strength. For these questions, the theoretical literature does not provide clear answers. One possibility is that stronger patent protection has negative effects after a high or *excessive* level of protection is reached. On the other hand, it is also plausible that the positive effects should emerge after a certain level of strength is reached. For example, at early or intermediate phases of innovation development, strong patent rights restrict the ability to learn by doing. In this case the positive effects of patent protection come about after a critical level of protection and knowledge base are achieved.

However, for the South, theoretical grounds may exist for predicting a net negative effect on innovation and diffusion of stronger patent rights. Developing and least developed economies are usually characterized by smaller markets and lower technological capabilities. To the extent that patent protection has both benefits and costs, the optimal level of protection for the South is likely to be lower than that for the North. Thus raising patent strength to Northern standards may negatively affect innovation in the South. Furthermore, unless Southern innovation responds significantly to increased patent strength, foreign technology diffusion into the South may also be negatively affected. This is because the increased patent strength enables Northern firms (who hold patents in the South) to enjoy increased market power (so long as it faces limited competition from local innovators) and may thereby reduce the rate of introduction of new technologies. Of course, this increased market power effect could be offset by the increased market expansion effect of deterring local imitation and infringement of Northern technologies. Thus, while some theoretical reasoning can be applied to ascertain the overall effects of patent reform, it is not always clear *a priori* what weight to give the different channels by which patent rights affect innovation and diffusion. We therefore turn to empirical investigations to help resolve some of these issues.

### Previous empirical work

Before getting to our empirical specification, data, and results, we provide a brief review of the evidence thus far on how patent protection affects innovation and diffusion. We turn first to the evidence on innovation, of which there are cross-country and national-based studies. Among cross-country studies, Sherwood (1997) conducted case studies for 18 developing countries and concludes that poor provision of intellectual property rights deters local innovation and risk-taking. Varsakelis (2001) provides a cross-country analysis of patent strength and R&D, and Kanwar and Evenson (2003) provide panel data analysis of the same. Both studies use data prior to the TRIPS agreement and find that R&D/GDP ratios are positively related to the strength of patent rights, conditional on other factors.

In contrast, Lerner (2002) examines 177 events of patent reforms in 51 countries over a 150-year period. The reforms cover the enactment of patent laws, changes in duration of rights and fees, and limitations on patent rights (such as revocation and compulsory licensing). This study finds that residential patent filings were unaffected by patent reforms. This result casts doubt on whether innovation responded significantly to changes in patent strength. Likewise, Branstetter *et al*. (2004) examine patent reforms in 12 developing countries from 1982 to 1999 and find that reforms evoked no significant responses in residential patent filings.

Among single-country studies, Sakakibara and Branstetter (2001) study the Japanese patent reforms of 1988. Amidst the key reforms was a widening of patent scope (i.e., the allowance of multiple claims on a patent application). However, no significant increases were found in the time paths of R&D spending, domestic patenting, or US patent grants to Japanese applicants due to these reforms. Scherer and Weisburst (1995) examine the Italian pharmaceutical industry and find that Italian pharmaceutical innovation activities did not accelerate in response to patent reform. The study conjectures that stringent price controls may have confounded the effects of reform. Using more recent data, Korenko (1999) finds that stronger local patent rights positively affect Italian pharmaceutical R&D and market share (*vis-à-vis* foreign competitors).

Kortum and Lerner (1999) and Hall and Ziedonis (2001) study US patent reforms, focusing on the creation of the specialized appellate court in 1982. Hall and Ziedonis (2001) use evidence from the semiconductor industry and find that patent reform increased firms' incentives to engage in defensive patenting, to pre-empt patents by other rights holders, rather than in innovation *per se*. Conversely, Kortum and Lerner (1999) argue that the rise in US patenting does reflect improved R&D management rather than a friendlier court system.

We next consider evidence on the relationship between patent strength and technology diffusion. Bosworth (1980) studies UK patenting activities abroad and finds that foreign patent strength had no impact on UK technology transfers. In contrast, later works find a stronger positive impact. Mansfield (1994) conducts firm-level surveys and finds that perceptions of strong IP rights abroad had a positive effect on incentives to transfer technologies abroad, but these effects vary by industry, being stronger for the chemical and electronic sectors. In cross-country studies, several works find a positive influence overall of patent protection on trade, FDI, and licensing (Maskus and Penubarti, 1995; Smith, 2001; Yang and Maskus, 2001; Branstetter *et al*., 2004; Park and Lippoldt, 2005). Lerner (2002) and Branstetter *et al*. (2004) find that nonresidential patent filings (e.g., patents filed by foreigners) respond positively to local patent reforms, unlike residential filings.

However, Lerner (2002) qualifies this finding in two ways. First, the effects of patent strength on nonresidential filings are weaker if patent protection is already strong, suggesting an inverted-U relationship between patent strength and nonresidential patent filings. Second, the effects are weaker in poorer countries, supporting arguments that optimal levels of patent protection should take into account the stage of economic development of the reforming countries.

Thus the evidence on innovation is mixed, while the evidence on diffusion generally finds positive effects of patent strength. Our work departs from these previous empirical studies in three key ways. First, we use different measures of patent reform, specifically an index of patent strength.[2] Previous studies have used the dummy variable approach by studying events before and after reform, have relied on surveys of opinions, or have considered only a few characteristics of patent regimes, relatively few countries, and in some cases a single period of time.[3] Our study spans 35 years, contains many more features and nuances of patent systems, and covers 100 countries, including an expanded set of developing economies. Our index incorporates recent developments surrounding the TRIPS agreement, and includes measures of enforcement mechanisms. Second, our study examines the effects of patent strength on both innovation, using domestic patenting and R&D data, and diffusion, using foreign patenting data. Third, our approach explicitly considers the possibility of nonlinear relationships between patent strength and innovative activity, and the possibility that the relationship varies by level of economic development.

## Methodology and data

### Empirical specification and methods

As measures of innovation and diffusion, we use data on international patent applications. We are aware that patent filings are an imperfect measure of innovation, and that not all innovations are patented. Some are not patentable because of subject matter, and some inventors may choose not to patent. While each patent application must declare and embody a new innovation, variations in patent filings do not always reflect variations in innovation. Instead, they may reflect propensities to file. Thus inferences on innovation behavior from patenting activities must be qualified. To provide an independent check, we also examine another often-used measure of innovation, namely R&D spending by firms in different countries. Just as patent applications are the outcome, or an output, of the innovation process, R&D represents investments, or an input, into innovation. Thus examining both kinds of data should give us a broader perspective on the effects of patent strength.

Foreign patent filings represent international technology diffusion to the extent that they correlate with the introduction of new goods and services, through trade, foreign direct investment, joint ventures, licensing, and other modes of market entry. However, problems with using foreign patenting data to measure international technology diffusion also exist. In some situations, foreign patents may represent innovation rather than diffusion. This occurs if the foreign patents are *first filings*. However, most first filings occur in the home country, with subsequent filings made in the rest of the world (Hingley and Park, 2003). Thus most foreign filings can represent the diffusion of patentable ideas, but not perfectly.

We turn now to the models we estimate. For the patenting equation, let $P_{it}$ denote the number of patents filed, whether domestic or foreign. As the *P*s are non-negative integers, we employ *count data* econometric methods. The expected counts are modeled as an exponential function of country-specific effects ($\alpha_i$), which can be fixed or random, and a set of independent variables $X_{it}$:

$$E(P_{it}|\alpha_i, X_{it}) = \exp(\alpha_i + \beta_1 PRI_{it} + \beta_2 PRI_{it}^2 + \beta_3 Z_{it}) \quad (1)$$

where $X_{it}$ includes an index of the strength of patent rights (*PRI*) and other control variables *Z*, to be discussed below. The errors are given by $\varepsilon_{it} = P_{it} - E(P_{it}|\alpha_i, X_{it})$. The parameters in Eq. (1) can be estimated by Poisson regression or by negative binomial regression (to relax a restriction that Poisson models impose, namely the equality of the conditional mean and variance of patent filings). See Cameron and Trivedi (1998) and Hausman *et al*. (1984) for details on count data methods.

Our other dependent variable of interest is R&D. Here our focus shifts from the nation as the unit of analysis to the firm (Allred and Park, 2007). Firm-level R&D is measured as the R&D expenditures of firms headquartered in a given country, and is related to that country's strength of patent rights and other control variables:

$$\ln(R\&D)_{int} = \gamma_0 + \gamma_1 \ln PRI_{nt} + \gamma_2 (\ln PRI_{nt})^2 + \gamma_3 Z_{int} + \varepsilon_{int} \quad (2)$$

where $t = 1 \ldots T$ indexes time, $n = 1 \ldots N$ countries, and $i = 1 \ldots I$ firms. We estimate Eq. (2) using panel data methods (allowing for fixed and random firm-specific effects).

Note that, in both Eqs. (1) and (2), we allow for nonlinear effects of the strength of patent rights on patenting and R&D. As our theoretical section explored, stronger patent rights can have both negative and positive effects on patenting or R&D. Either could dominate on net, or the effects could cancel out, producing a zero effect. Another set of possibilities is that the strength of patent rights can have both negative and positive effects depending on the given level of patent strength. We thus fit this nonlinear specification to the data and examine the implied relationship between patent strength and patenting or R&D.

## Data sources

### *Dependent variables*

National patent data are from the World Intellectual Property Office's *Industrial Property Statistics* and *100 Years of Industrial Property Statistics 1883–1983*. We use the residential filings to represent domestic patenting and non-residential to represent foreign patenting. Our sample covers 1965–2000 (every 5 years) for 100 countries. Prior to 1965, data for few countries are available.

Firm-level data on R&D (in real 1995 US dollars) were collected for three periods (1990, 1995, and 2000) from *Datastream*, a database with international data on a diverse selection of companies. We removed cases with missing data and extreme outliers. These outliers, firms in which the R&D-to-sales ratio exceeded 1000%, occurred in very few cases and were due to firms, such as startups, having little or no sales in a given year. We arrived at a sample of 2,446 companies from 35 countries. The largest share of the data comes from the US (43.4%), followed by Japan (21.6%), and the UK

(8%), India (4.8%), and Korea (3.9%). The data represent firms competing in 10 manufacturing industries.[4] These industries were selected for their broad global coverage, and for their greater consistency in the reporting of innovation investments compared with other industries, such as services or non-profit. Moreover, these industries account for a significant share of patenting. Based on US Patent Office data, an average of 53.1% of all patents granted in 1990–2000 were in the 10 industries represented in this study. A list of countries represented in our samples is found in Appendix B.

### *Independent variables*

We turn now to a discussion of how we measure the strength of patent rights and enforcement effectiveness.

*Patent rights index* The measure of strength of national patent rights is from Ginarte and Park (1997) and Park and Wagh (2002).[5] The updated index covers up to the year 2000 and incorporates recent developments in the global patent system (e.g., patent-related aspects of the TRIPS agreement). As an overview, the PRI ranges from zero (weakest) to five (strongest). The value of the index is obtained by aggregating five components: membership in international treaties, coverage, enforcement mechanisms, loss of rights, and duration. The membership component indicates the extent to which countries are signatories to major international treaties on patent rights. The coverage component refers to the subject matter that is patentable. Enforcement mechanisms refer to the availability of enforcement procedures, such as preliminary injunctions and burden-of proof-reversal for process patents. Loss of rights refers to whether there are restrictions on the use of patent rights, such as working requirements and compulsory licensing. Duration refers to the length of patent protection (in years). Each of these components is scored out of 1. Appendix A provides an overview of the rating methodology and brief definitions.

Note that this index reflects a number of the patent provisions of the TRIPS agreement. Articles 1 and 2 of TRIPS state that the agreement builds on previous international conventions, such as the Paris Treaty (which is included in our membership component). Article 27 of TRIPS requires that patents be 'available for any inventions … in all fields of technology,' thus requiring the patentability of all the subjects identified in our coverage component. TRIPS also requires the availability of such enforcement mechanisms as burden of proof reversals (Article 34) and preliminary injunctions (Article 44), which our index incorporates. In addition, TRIPS requires that infringers pay damages and that offending goods be seized and destroyed (Articles 45 and 46). However, from a data perspective, we do not have information on these enforcement procedures for a wide number of countries or for all the time periods. Article 33 of TRIPS sets the international standard of duration of patent protection as 20 years from the date of patent application, which our duration component uses as a reference point. Note, though, that TRIPS does provide for compulsory licensing (Article 31) as long as reasonable compensation is made to the rights holder. This is one of the compromises made during negotiations in the interests of developing countries that have special public health concerns. However, our index reflects a weakening of patent rights if compulsory licensing is permitted, as is done with TRIPS.

Table 2 provides a summary of the index scores for selected years and different country groupings.[6] The grouping of countries by developed, developing, and least developed nations is based on United Nations classification.[7] Appendix B lists the countries in our sample by country group. Table 2 shows a steady increase in the mean value of the PRI for both developed and developing/least developed countries (hereafter referred to as developing countries). Based on the coefficients of variation, we also observe a general trend towards the convergence of overall patent rights within each country group. The primary drivers of increased global patent strength are the increased duration of protection (as nations adopt the 20-year standard), increased coverage (to incorporate protection for pharmaceuticals), and increased membership in international treaties and agreements.[8] Thus, as we have discussed earlier, global standards of patent rights have steadily increased and become harmonized.

*Control variables* Our empirical analyses control for factors other than patent rights. In the patent sample, we use the natural log of real GDP (in constant 1995 US dollars) to proxy overall market size, which should affect incentives to patent. The growth theory literature has argued that innovation activities are also a function of government size, human capital, health capital, and financial factors (Barro and Sala-i-Martin, 2004). Thus we examine

Table 2 Patent Rights Index: summary statistics

| Year(s) | Country group | Index score |
|---|---|---|
| 2000 | *Developed countries (mean score)* | 4.04 |
| | (standard deviation across countries) | 0.52 |
| | (coefficient of variation) | 0.13 |
| | *Developing/least-developed countries (mean score)* | 3.01 |
| | (standard deviation across countries) | 0.68 |
| | (coefficient of variation) | 0.23 |
| 1995 | *Developed countries (mean score)* | 3.86 |
| | (standard deviation across countries) | 0.58 |
| | (coefficient of variation) | 0.15 |
| | *Developing/least-developed countries (mean score)* | 2.66 |
| | (standard deviation across countries) | 0.74 |
| | (coefficient of variation) | 0.28 |
| 1965–1990 | *Developed countries (mean score)* | 3.02 |
| | (standard deviation across countries) | 0.56 |
| | (coefficient of variation) | 0.19 |
| | *Developing/least-developed countries (mean score)* | 2.11 |
| | (standard deviation across countries) | 0.72 |
| | (coefficient of variation) | 0.34 |

*Notes*: Summary statistics are calculated for the countries in our patent sample.
The coefficient of variation is calculated as the standard deviation divided by the mean.
The classification of developed versus developing/least developed countries is based on UN criteria (see text).

empirical proxies such as government spending to GDP, average years of schooling, life expectancy, and average annual lending rate (which reflects the time preference rate, an important intertemporal decision variable for innovation). All of these data are from the World Bank's *World Development Indicators* (www.worldbank.org).

We also include time dummies and a dummy variable for WTO membership to see whether member states have significantly higher domestic or foreign patent applications. Members not only derive benefits of economic integration, such as trade liberalization, but also can more effectively enforce multilateral obligations through the dispute settlement process and use of trade sanctions against non-compliant members. Thus, while the WTO dummy variable could capture many factors, we are interested primarily in examining whether membership has any additional explanatory power beyond that captured in the PRI.

In the R&D sample, we control for firm size using the natural log of firm sales (in real 1995 US dollars). Firm size helps to account for the effects of potential economies or diseconomies of scale. We also control for national market size, using real GDP, and include time and industry dummies.[9]

## Empirical analysis

In this section, we address two main questions. First, what is the relationship between patent strength and some measure of innovation, namely firm-level R&D expenditures and domestic patent applications? Second, what is the relationship between patent strength and some measure of diffusion, namely foreign patent applications? Furthermore, how do these relationships vary by level of economic development and by the existing level of patent strength, and what are the larger policy implications? The focus of this section is to address these questions. We first present sample statistics on our dependent variables, before presenting our main empirical results. We end with a discussion of the overall implications of the results.

### Sample statistics

In part a of Table 3, we show 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 host country real GDP in 1995 US dollars. Each entry in Table 3a represents the average country value in the respective group. For all countries, there is a rising trend in the number of patents filed by both domestic and foreign agents. Moreover, the rate of patenting, in terms of GDP, has also risen over time, particularly foreign patenting. Similar trends are visible when we split the sample between developed and developing countries, with a couple of noticeable differences. The developed world experienced a large increase in the rate of domestic patenting. However, very little change in the rate of patenting among developing economies has occurred.

Nonetheless, the rate of foreign patenting is much higher in the developing world than in the developed world. What accounts for the higher rate in the developing world can be attributable to two factors. First, the World Intellectual Property Office and other country patent offices have made it easier to designate developing countries on a patent application. For example, the 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

Table 3 Measures of innovative activity: sample statistics

| | Period | Domestic patents | Mean domestic patents per GDP (US$billion) | Foreign patents | Mean foreign patents per GDP (US$billion) |
|---|---|---|---|---|---|
| *(a) Patent data (from World Intellectual Property Office, WIPO)* | | | | | |
| All countries | 1990–2000 | 6,827 | 10.0 | 75,092 | 8,257 |
| | 1960–1990 | 3,614 | 9.3 | 6,439 | 61 |
| Developed economies | 1990–2000 | 22,206 | 18.8 | 145,341 | 1,074 |
| | 1960–1990 | 9,213 | 13.9 | 17,239 | 86 |
| Developing and least developed economies | 1990–2000 | 1,060 | 6.6 | 47,899 | 11,037 |
| | 1960–1990 | 493 | 6.5 | 1,020 | 46 |

| | Year | Mean R&D expenditures | Coefficient of variation | Mean R&D/ Sales | Coefficient of variation |
|---|---|---|---|---|---|
| *(b) Research and development data (from Datastream)* | | | | | |
| All countries | 2000 | 42.24 | 3.95 | 6.69 | 1.31 |
| | 1990 | 45.47 | 3.05 | 4.33 | 1.09 |
| Developed economies | 2000 | 46.14 | 3.78 | 7.20 | 1.23 |
| | 1990 | 49.20 | 2.93 | 4.66 | 1.03 |
| Developing and least developed economies | 2000 | 2.54 | 3.87 | 1.51 | 3.23 |
| | 1990 | 1.33 | 3.21 | 0.43 | 1.21 |

*Notes*: In part a, GDP (US$billion) refers to the destination country's gross domestic product (in real 1995 US dollars). Mean domestic and mean foreign patents refer to the average number of patents filed per country per year, by residents and non-residents, respectively. In part b, R&D refers to firm level investment in research and development, and R&D/Sales refers to firm-level research and development as a percentage of sales for firms headquartered in those economies. The coefficient of variation is the ratio of the standard deviation to the mean.

application is zero. Second, as firms have expanded into international markets, they have often set up branches in developing countries with growing markets and with factor costs that are relatively lower, increasing their demand for patents in those countries. Thus, relative to their demand for patents in developed markets, the demand for patents in less developed markets has increased more quickly.

In part b of Table 3, we show the mean firm R&D expenditures, as well as the mean ratio of R&D to sales for our firm sample. We include the R&D/Sales ratio to give an idea of the increased rate of R&D activity. In our sample for 1990, R&D averaged 4.33% of firm sales, and in 2000 it equaled 6.69%. The ratio of R&D to sales is much higher for firms in developed countries. However, the coefficient of variation of R&D to sales is higher for developing countries. Furthermore, the mean rate of R&D to sales for 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.

## Relationship between national patenting and patent rights

We turn next to estimates of Eq. (1). We focus on reporting the estimates from the fixed effects negative binomial regression. A likelihood ratio test rejects the null hypothesis that the dispersion parameter $\phi$ is zero ($P<0.001$). Second, a Hausman test (Cameron and Trivedi, 1998: 77–78, 293) rejects the null hypothesis that random country effects are not correlated with the regressors ($P<0.01$). In the regressions, we include time dummies but do not report their coefficient estimates to conserve space.

Table 4 reports on the relationship between patent rights and the rate of domestic (resident) patenting. In column 1, we see that patent rights have a statistically insignificant effect on domestic patent filings. Column 2, however, suggests an

**Table 4** Domestic patenting and the Patent Rights Index

| *Variable* | *(1) All countries* | *(2) All countries* | *(3) Developed economies* | *(4) Developed economies* | *(5) Developing economies* | *(6) Developing economies* |
|---|---|---|---|---|---|---|
| Constant | −6.263 | −6.006*** | −2.903 | −2.044 | −1.328 | −1.409 |
| | (1.040) | (1.071) | (2.091) | (2.094) | (1.606) | (1.635) |
| Patent Rights Index | 0.109 | −0.744*** | 0.238* | −0.746† | −0.256* | −0.158 |
| | (0.082) | (0.212) | (0.126) | (0.401) | (0.111) | (0.3911) |
| (Patent Rights Index)$^2$ | | 0.158*** | | 0.147** | | −0.022 |
| | | (0.036) | | (0.057) | | (0.086) |
| WTO dummy | 0.089 | −0.040 | 0.194 | 0.115 | −0.361 | −0.353 |
| | (0.107) | (0.113) | (0.181) | (0.185) | (0.280) | (0.282) |
| ln(gross domestic product) | 0.269*** | 0.303*** | 0.154† | 0.184* | 0.121† | 0.120† |
| | (0.043) | (0.044) | (0.086) | (0.085) | (0.062) | (0.063) |
| Time dummies | Included | Included | Included | Included | Included | Included |
| Log-likelihood | −2511.34 | −2,502.94 | −1290.14 | −1,287.15 | −1172.49 | −1,172.45 |
| Likelihood ratio test statistic | | 16.80*** | | 6.00** | | 0.20 |
| Number of observations | 491 | 491 | 184 | 184 | 307 | 307 |

*Notes*: Estimation is by fixed (country) effects negative binomial regression for 100 countries (data permitting) over the sample period 1965–2000, every five years. Standard errors are in parentheses. The likelihood ratio test is used to test the statistical significance of the quadratic patent rights term.
†$P<0.10$; *$P<0,05$; **$P<0.01$; ***$P<0.001$.

explanation for this finding: the conditional relationship between domestic patenting and patent strength is U-shaped. Indeed, a likelihood ratio (LR) test rejects the null hypothesis that the coefficient of the quadratic patent rights term is zero.[10] Thus this nonlinear relationship indicates that at low levels of the PRI a strengthening of patent rights would negatively affect the rate of domestic patenting. Typically, less developed economies have weaker patent systems. This supports some in the literature who have argued that a stronger patent system may inhibit innovation because it restricts the ability of agents to imitate and copy. According to our finding, this argument particularly applies to situations or countries 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 domestic patenting. Stronger patent rights would increase incentives to innovate by improving appropriability and encouraging knowledge disclosures (rather than trade secrecy). According to the estimates in column 1, the critical turning point is where the PRI equals 2.35.[11] In our sample, 37% 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, Singapore, and Sri Lanka, African economies such as Ghana and Kenya, and European economies such as Greece and Portugal.

The next four columns show the results of splitting the sample between developed countries and developing countries. For each split sample, we estimate the model with and without the quadratic patent rights term. As with the pooled sample, the developed-country sample exhibits a U-shaped relationship between patent rights and domestic patenting, but the U-shape is mildly significant. Indeed, in the model without the quadratic patent rights term, the PRI is statistically significant ($P<0.05$). The LR test, however, still rejects the null hypothesis of no nonlinear effect. In any event, the U-shape is not as pronounced for the developed-country sample because the weak patent rights countries are not in the sample. Here the critical value of the PRI is 2.53. For the developed-country sample, 9% of observations are under this critical value of the Index and are mostly from before 1990.

Within the developing-country sample, patent rights have a significant *negative* influence on domestic patenting ($P<0.05$). There is no statistically strong evidence of a nonlinear effect of patent rights in this subsample. Thus it is by pooling the two split samples that we get an overall U-shaped relationship. The results show that the effects of patent reform depend on the stage of development. Patent rights have a positive effect on domestic patenting after a critical level of protection has been reached.

Throughout the pooled and split samples, national market size (as proxied by real GDP) has a positive influence on domestic patenting, but is most significant as an explanatory factor in the pooled, broader sample. Membership in the WTO has no independent statistically significant contribution to domestic patenting, holding other factors constant. The effects of WTO membership may already be captured in the variables that are explicitly controlled for, such as GDP and PRI. Another possibility is that domestic innovation and patenting respond with a longer lag to institutional and structural changes.

Table 5 repeats the analysis with additional national control variables so as to see whether the inclusion of potential omitted variables reverses any findings. To conserve space, we do not show the estimates of the model without the quadratic patent rights term. Instead, we simply report the LR test results that support a nonlinear effect of patent rights. The additional variables reflect factors that affect the environment in which innovation takes place. The sample size is reduced significantly, since data on these variables are not available for some countries (especially the least developed). The effects of the PRI, WTO membership, and GDP are similar to the earlier results. However, for the split samples, a stronger U-shaped relationship is found for developed countries and a mild inverse U-shaped effect for developing countries. That is, some positive amount of patenting occurs when countries raise patent strength from low levels, or when they start from no system. But for the middle-income developing countries, raising patent strength appears to have a mild negative effect on patenting ($P<0.10$). This would be consistent with the view that such countries largely conduct adaptive, imitative research.

As far as the growth theoretic control variables are concerned, schooling and life expectancy have a positive influence on domestic patenting for the pooled sample but not the split samples. Higher lending rates have a negative effect only in the developed-country sample. Somewhat surprisingly, though, the ratio of government spending to GDP does not have the negative effect that the literature

**Table 5** Domestic patenting and the Patent Rights Index: inclusion of other control variables

| *Variable* | *Domestic patent filings* | | |
|---|---|---|---|
| | *(4) All countries* | *(5) Developed economies* | *(6) Developing and least developed economies* |
| Constant | −9.800** | −1.283 | 0.608 |
| | (3.470) | (23.345) | (6.814) |
| Patent Rights Index | −1.236*** | −1.950*** | 1.783† |
| | (0.380) | (0.542) | (0.941) |
| (Patent Rights Index)$^2$ | 0.226*** | 0.305*** | −0.323† |
| | (0.058) | (0.077) | (0.173) |
| WTO dummy | −0.289 | −0.248 | 0.473 |
| | (0.516) | (0.719) | (0.593) |
| ln(gross domestic product) | 0.229** | 0.283* | −0.018 |
| | (0.074) | (0.122) | (0.132) |
| ln(government spending/GDP) | 0.607* | 0.304 | 0.786† |
| | (0.255) | (0.515) | (0.474) |
| ln(years of schooling) | 0.439** | 0.290 | 0.241 |
| | (0.143) | (0.230) | (0.273) |
| ln(life expectancy) | 1.401* | −0.166 | −1.243 |
| | (0.695) | (5.459) | (1.261) |
| ln(lending rate) | −0.123 | −0.390*** | 0.315* |
| | (0.086) | (0.121) | (0.149) |
| Time dummies | Included | Included | Included |
| Log-likelihood | −1,259.91 | −862.25 | −376.31 |
| Likelihood ratio test statistic | 12.6*** | 15.8*** | 4.0* |
| Number of observations | 248 | 125 | 123 |

*Notes*: Estimation is by fixed (country) effects negative binomial regression for 100 countries (data permitting) over the sample period 1965–2000, every five years. Standard errors are in parentheses. The likelihood ratio test is used to test the statistical significance of the quadratic patent rights term.
†$P<0.10$, *$P<0.05$, **$P<0.01$, ***$P<0.001$.

tends to predict, assuming government size reflects tax burdens or crowding-out effects. Another possibility is that this variable picks up the multiplier effects of government spending on demand, which stimulates firms to innovate and commercialize.

In Table 6, we present the results for foreign patenting. These refer to patent applications by non-residents, aggregated across foreign source countries. The first column shows that domestic patent strength is an important factor in attracting foreigners to file applications for their technology in the domestic economy. Thus stronger patent rights could potentially facilitate technology diffusion. Countries that are members of the WTO also attract more foreign patent filings. Unlike domestic patenting, which may respond to institutional changes with a lag, foreign patenting typically involves the diffusion of technologies that have already been innovated, as long as applications are filed within one year of obtaining priority. Thus foreign filings can more readily respond to institutional changes. Moreover, the WTO dispute settlement procedures are likely to be more attractive to foreign applicants, as they can bring cases against other nationals or residents. For domestic disputes, cases are generally heard in local courts and arbitration systems.

However, column 2 of Table 6 shows an absence of a nonlinear relationship between patent rights and foreign patenting for the pooled sample. We do find an *inverted* U-shaped relationship for the developed-country sample. While patent protection has a significant linear effect (see column 3) as well on foreign patent filings ($P<0.10$), the LR test strongly supports a nonlinear specification (see column 4). Specifically, the estimates suggest that, after patent strength reaches a certain level, the monopoly effect of patent strength tends to overwhelm the market expansion effect. That is, increased market power reduces incentives among rights holders to upgrade or develop new technologies by giving them opportunities to extract more rents from existing technologies. But we need to put some perspective on this. The critical value is $PRI^* = 4.17$, but this is relatively high. Only 12% of developed country observations exceed this, and these are mostly after 1990. Thus market power effects are dominant in a few, high-PRI countries, such as the US, Japan, UK, and Netherlands.

The existence of an inverse-U for foreign patenting but not for domestic patenting may be explained by the fact that firms typically make priority filings first domestically and subsequently internationally. Thus international patent applications are a further source of income or rent to

**Table 6** Foreign patenting and the patent rights index

| *Variable* | *Foreign patent filings* | | | | | |
|---|---|---|---|---|---|---|
| | *(1) All countries* | *(2) All countries* | *(3) Developed economies* | *(4) Developed economies* | *(5) Developing and least developed economies* | *(6) Developing and least developed economies* |
| Constant | −10.069*** | −10.077*** | −12.029 | −13.536*** | −7.734*** | −7.782*** |
| | (0.843) | (0.970) | (1.955) | (1.840) | (1.375) | (1.392) |
| Patent Rights Index | 0.283*** | 0.290† | 0.566*** | 2.670*** | 0.079 | 0.131 |
| | (0.074) | (0.180) | (0.149) | (0.493) | (0.094) | (0.265) |
| (Patent Rights Index)$^2$ | | −0.001 | | −0.320*** | | −0.013 |
| | | (0.033) | | (0.072) | | (0.062) |
| WTO dummy | 0.545** | 0.546† | 0.906*** | 1.353*** | 0.547* | 0.559* |
| | (0.242) | (0.247) | (0.224) | (0.246) | (0.257) | (0.264) |
| ln(gross domestic product) | 0.410*** | 0.409*** | 0.431*** | 0.364*** | 0.338*** | 0.338*** |
| | (0.033) | (0.035) | (0.084) | (0.082) | (0.051) | (0.051) |
| Time effects | Included | Included | Included | Included | Included | Included |
| Log-likelihood | −3,795.9 | −3,795.8 | −1,646.2 | −1,636.5 | −2,115.8 | −2,115.7 |
| Likelihood ratio test statistic | | 0.2 | | 23.6*** | | 0.2 |
| Number of Observations | 536 | 536 | 184 | 184 | 352 | 352 |

*Notes*: Estimation is by fixed effects negative binomial regression for 100 countries (data permitting) over the sample period 1965–2000, every five years. Standard errors are in parentheses. The likelihood ratio test is used to test the significance of the quadratic patent rights term.
†$P<0.10$; *$P<0.05$; **$P<0.01$, ***$P<0.001$.

patent rights holders. International patent protection serves to enhance the market power of the rights holders and augment their ability 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 *n*th country largely yields rent.

For the developing-country sample, we observe (in columns 5 and 6 of Table 6) an insignificant effect of patent rights (whether linear or nonlinear) on foreign patenting. Using our theoretical framework, this result suggests that, overall, the positive (market expansion) effects and negative (market power) effects may cancel for developing countries.

We end this subsection by comparing our results with those in the previous literature. First, our results are consistent with studies employing non-patent measures of innovative activities (such as trade, FDI, and licensing): see, for example, Maskus and Penubarti (1995), Smith (2001), Yang and Maskus (2001), and Park and Lippoldt (2005). In these studies, patent protection is found generally to be positively associated with technology diffusion. In our study we would qualify this finding by indicating that the positive effects occur up to a point, beyond which increased patent protection strength may inhibit diffusion, and that this prediction holds for developed countries. Of course, it is difficult to make fully accurate comparisons with studies that employ alternative measures of technology diffusion.

The two previous empirical studies that do employ international patenting data like ours are Lerner (2002) and Branstetter *et al*. (2004). Of course, our study and theirs differ in terms of sample period, sample size, empirical methodology, and control variables. We can illustrate, however, that our results are generally consistent with their findings, after adjusting for a few of the methodological differences. In Table 7, we show the results of re-estimating Eq. (1) using the same sample of countries as in Lerner (2002) and Branstetter *et al.* (2004). However, we maintain our own measure of patent rights, sample time period, and control variables. In Table 7, we report only the coefficient estimates of the patent rights variable in order to conserve space, and to focus sharply on the importance of the nonlinear effects of patent protection. In rows 1–4 of Table 7, where we restrict our sample of countries to those in Branstetter *et al.* (2004) (not including Taiwan), we find, as they do, that patent protection is not a significant influence on residential patent filings. However, if we include a quadratic patent rights term, which they do not, we observe the same U-shaped pattern as described earlier (see our Table 4). Thus the inference in Branstetter *et al.* (2004) that patent reform does not stimulate domestic patenting ignores the effects of patent rights at different phases of patent reform. On non-residential patent filings, our study is

**Table 7** Estimation of patent model using Branstetter *et al.* (2004) and Lerner (2002) samples

| *Row* | *Dependent variable* | *Patent rights index* | *Patent rights index²* | *Number of observations* | *Likelihood ratio test statistic* |
|---|---|---|---|---|---|
| *Branstetter et al. (2004) sample* | | | | | |
| 1 | Domestic patent filings | −0.19 (0.137) | | 96 | |
| 2 | Domestic patent filings | −1.31 (0.482)** | 0.27 (0.108)** | 96 | 4.00* |
| 3 | Foreign patent filings | 0.43 (0.143)*** | | 97 | |
| 4 | Foreign patent filings | 0.55 (0.344)† | −0.04 (0.089) | 97 | 0.15 |
| *Lerner (2002) sample* | | | | | |
| 5 | Domestic patent filings | 0.12 (0.093) | | 334 | |
| 6 | Domestic patent filings | −0.89 (0.219)*** | 0.18 (0.036)*** | 334 | 21.80*** |
| 7 | Foreign patent filings | 0.37 (0.085)*** | | 335 | |
| 8 | Foreign patent filings | 0.64 (0.203)*** | −0.05 (0.034) | 335 | 2.30 |
| 9 | Foreign patent filings (developed economies) | 2.39 (0.478)*** | −0.28 (0.068)*** | 169 | 18.50*** |

*Notes*: Estimation is by fixed (country) effects negative binomial regression over the sample period 1965–2000, every five years. All of the regressions above include the same control variables as in previous regressions (see Table 4 on domestic patent filings and Table 7 on foreign patent filings). Standard errors are in parentheses.
The likelihood ratio test is used to test the statistical significance of the quadratic patent rights term.
†$P<0.10$; *$P<0.05$; **$P<0.01$; ***$P<0.001$.

consistent with theirs in finding a significant linear relationship between patent rights and foreign patenting (for the pooled sample). The number of countries in Branstetter *et al*. (2004) is too small to permit a separate investigation of developed *vs* developing countries.

In rows 5–9 of Table 7, where we restrict our sample of countries to those in Lerner (2002), we find the same qualitative findings for domestic patenting (insignificant linear effect of patent rights but significant nonlinear effect) and for foreign patenting (significant linear effect of patent rights but insignificant nonlinear effect) for the 'pooled sample'. If we restrict our Lerner sample of countries further to those that are developed nations (see row 9), we obtain the same inverse-U shape relationship between patent strength and foreign patenting as before (see Table 6). These previous empirical studies have not explicitly allowed for a nonlinear effect of patent reform, focusing attention instead on finding net (linear) effects. Moreover, these studies have not used a measure of patent rights, such as our index, that allows for the treatment of nonlinear effects.

## Relationship between firm-level R&D and patent rights

In Table 8, we present the results of estimating Eq. (2). We focus on the fixed effects estimates. For the random effects model, the *Hausman test* rejected the null hypothesis of no correlation between the regressors and the individual effect ($P<0.01$). In preliminary analyses, we estimated Eq. (2) with the log of firm R&D expenditures as the dependent variable, with similar qualitative and quantitative effects. We also include time and industry dummies, but suppress them to conserve space in the tables. We do not include WTO membership as a regressor since all of the countries in the smaller R&D sample are members of the WTO.

Column 1 of Table 8 indicates that patent rights have a significant effect on firm-level R&D in developed countries ($P<0.01$). Column 2 qualifies this finding by indicating that the relationship between patent rights and firm-level R&D in developed countries is U-shaped, meaning that the positive effects arise after some threshold level of patent strength is reached. An *F*-test supports the nonlinear specification (i.e., rejects the null hypothesis of no quadratic term; $P<0.01$).[12]

**Table 8** Firm-level research and development expenditures and the Patent Rights Index

| *Variable* | *ln(firm research and development expenditures)* | | | | |
|---|---|---|---|---|---|
| | *(1) Developed economies* | *(2) Developed economies* | *(3) Developing and least developed economies* | *(4) Developing and least developed economies* | *(5) Developed economies (excluding US)* |
| Constant | 4.287* | 9.183** | 61.800 | 77.067 | 15.135** |
| | (3.086) | (3.086) | (43.395) | (49.177) | (5.896) |
| ln(Patent Rights Index) | 0.912** | −4.389$^{\dagger}$ | 0.361 | 0.517 | −10.585* |
| | (0.366) | (2.527) | (0.813) | (2.407) | (4.630) |
| ln(Patent Rights Index)$^2$ | | 2.051* | | −0.073 | 4.461* |
| | | (0.967) | | (1.723) | (1.815) |
| ln(firm sales) | 0.978*** | 0.977*** | 0.859*** | 0.867*** | 1.002*** |
| | (0.014) | (0.014) | (0.067) | (0.069) | (0.021) |
| ln(gross domestic product) | −0.124$^{\dagger}$ | −0.173* | −2.637 | −2.925 | −0.221 |
| | (0.074) | (0.079) | (1.636) | (1.844) | (0.180) |
| Time dummies | Included | Included | Included | Included | Included |
| Industry dummies | Included | Included | Included | Included | Included |
| Adjusted $R^2$ | 0.893 | 0.893 | 0.857 | 0.863 | 0.867 |
| *F*-test statistic | | 11.9** | | 3.1 | 16.1** |
| Number of observations | 2,143 | 2,143 | 303 | 303 | 1,081 |

*Notes*: Estimation is by fixed effects regression. Gross domestic product, firm sales, and firm research and development expenditures are in real 1995 US dollars. ln denotes natural logs. Standard errors are in parentheses. The *F*-test is used to test the statistical significance of the quadratic patent rights term.
$^{\dagger}P<0.10$; $*P<0.05$; $**P<0.01$; $***P<0.001$.

For developing countries, the results in columns 3 and 4 show no significant linear or nonlinear effect of patent rights on firm-level R&D. The nonlinear results correspond to the results for domestic patenting shown in columns 4 and 6 of Table 4. Owing to the large number of US firms in the sample, we also re-estimate the model without US firms in the sample. This removal affects only the developed-country sample. Column 5 in Table 8 shows the results to be similar to those in column 2 of the same table.

Throughout our study, firm sales have a positive and significant effect on firm-level R&D in all cases. National market size generally has an insignificant effect on R&D, except for a negative influence among developed countries, including the US. GDP here may be picking up effects other than the benefits of a larger market. It may reflect a supply expansion that reduces price levels and profits, although a richer framework is needed to test this, which is beyond the scope of this paper.

We conclude this subsection with a brief comparison of our results with previous studies on the relationship between R&D and patent protection. We confine our comparison to other international studies (rather than single-country studies). While our findings of a positive linear relationship between R&D and patent strength are consistent with previous research (Varsakelis, 2001; Kanwar and Evenson, 2003; Allred and Park, 2007), we do qualify that the effects are U-shaped and apply to developed countries. The significance is that a strengthening of patent rights largely stimulates innovation in countries where patent systems are well developed (e.g., developed economies), not in countries where patent systems are nascent. Our results conflict with Sherwood (1997), whose case study of 18 developing countries documents a positive response of research and innovation to patent reform. The main limitation with the Sherwood study is that it does not conduct regression analyses that allow for a controlling for the influence of other variables.

## Implications of results

We now synthesize our findings to look for common threads. The results offer two main lessons. First, patent reform has potentially varying effects on different stages of the innovation process, from R&D to innovation to the diffusion of innovations worldwide. Second, patent reform can lead to North–South conflicts, in that reform may have opposite effects on Northern and Southern innovation and diffusion.

To help develop these viewpoints, Table 9 provides a quick summary of our results. In our analyses, we illustrated the different dimensions to studying the effects of stronger patent rights: for example, (1) differences between domestic patenting and R&D as measures of innovation, (2) differences between innovation and the diffusion of innovation, and (3) differences between developed and developing countries.

First, on the use of R&D *vs* domestic patents to measure innovation, we find that the two measures agree on a U-shaped relationship between patent strength and innovation for developed countries. For developing countries, patent strength has a negative linear effect on domestic patenting but no significant linear or nonlinear effect on R&D. Of course, the sample of countries is smaller for the R&D panel, which makes the results somewhat harder to compare. However, one way to reconcile the finding that patent strength has a negative impact on patenting but no significant impact on R&D is that, for the latter, a strengthening of patent rights balances the higher cost of R&D with the greater incentives to perform R&D, leaving overall R&D largely unaffected. But a stronger patent system raises the bar as to the nature of R&D outcomes that are patentable: for instance, they must be clearly non-infringing and distinct from prior art. Incremental innovations, which characterize most developing-country technologies, may therefore not meet patentable standards of novelty. Unless patent reforms have a significant impact on developing-country R&D, they could have largely negative impacts on domestic patenting.

**Table 9** Summary of empirical results on the influence of patent rights on innovation and diffusion

| *Innovation* | | | | *Diffusion* | |
|---|---|---|---|---|---|
| *Domestic patenting* | | *Firm-level R&D* | | *Foreign patenting* | |
| 'North' | 'South' | 'North' | 'South' | 'North' | 'South' |
| U-shaped | – | U-shaped | 0 | Inverted-U | 0 |

*Notes*: The above table summarizes the results from Tables 4, 6, and 8. Each entry represents the effect of patent rights on the top row variable by country grouping (North or South).
The top row variables are innovation and diffusion. Innovation is proxied by either domestic patenting or R&D. Diffusion is proxied only by foreign patenting.
'U-shaped' and 'inverted-U' refer to nonlinear effects. '0' indicates statistically insignificant, and '–' generally negative.

Second, in studying innovation *vs* diffusion, we see remarkable differences. Overall patent strength has a U-shaped relationship with domestic patenting but an inverse-U relationship with foreign patenting for developed countries, and no significant relationship for only developing countries. These inverted-U relationships indicate that strengthening patent protection beyond some point generates market power effects that could reduce diffusion, holding other factors constant. Combining the observations that stronger patent rights have on the one hand a U-shaped relationship with domestic patenting, and on the other hand an inverse-U relationship with foreign patenting, suggests that the diffusion rate, or ratio of foreign patents to domestic patents, would eventually decline with increased patent strength. Foreign patenting would level off while domestic patenting increased. Thus excessive patent strength could result in the hoarding of domestic patents as a smaller proportion is diffused abroad. This could happen either because rights holders exercise stronger market power abroad with respect to existing technologies as discussed previously, or because stronger patent rights encourage greater domestic patent filings, including marginally valuable ones. Low-valued innovations are usually not worth filing internationally, where the costs of filing are generally higher than the costs of filing at home owing to foreign agent and translation fees. The concern that stronger patent rights could merely create a glut of marginally valued patents has been expressed elsewhere (Jaffe and Lerner, 2004).

Lastly, we turn to differences between North and South. As Table 9 and previous discussions suggest, there are potential conflicts over which direction patent reform should take to augment innovation and/or diffusion. Domestic patenting and R&D in the North could potentially increase with a stronger patent system while domestic patenting and R&D in the South could decrease or be unaffected. Foreign patenting in the North could rise or fall depending on whether the patent system has reached levels of protection that are too strong. Foreign patenting in the South was theoretically expected to be negative but is actually found to be weakly affected by patent strength. This may be due to the fact that, in practice, developing countries generally have weak patent rights. Thus raising patent strength marginally may not have the same market power effect that it would have in more developed countries.

It would be useful to inquire more generally as to why patent rights are found to have a negative or insignificant impact on innovative activities in the developing world. One perspective simply is that stronger patent protection raises the cost of and restricts access to new technological goods. Another perspective is that the time lag between patent reform and innovative activity is rather long. A third perspective is that proponents of patent reform in the South have not adequately taken into account the historical circumstances in developing and least developed countries. Aside from weak institutions and laws, developing countries have low levels of physical, human, and knowledge capital accumulation. At low levels of such resources, the marginal productivity of research is low. Little innovative activity can be stimulated when these complementary resources are absent. Strengthening patent rights may raise incentives to engage in innovative activity, but the capacity to engage is absent – hence the negative or weak effects of patent reform on innovative activity. The developing world has had to adopt the IP standards of more advanced economies, without fundamental, structural changes having taken place or without much financial or technical assistance to make those changes. Article 66 of TRIPS does require developed countries to provide assistance and to provide means for technology transfer, but so far these obligations have not been fulfilled. Legal and property reforms are no doubt important, but the developing world needs some critical level of technological resources and an adequate research infrastructure.[13]

## Concluding remarks

Stronger patent rights have varied effects on innovative activity, including nonlinear effects, depending on the nature of patent reform and on the level of economic development of the country undertaking reform. For example, patent protection has a U-shaped relationship with domestic patent filings and firm-level R&D (that is, a negative effect at low levels of patent strength and positive at higher levels) in developed countries, and a negative relationship in developing countries. Patent protection has an inverted-U relationship with foreign patent filings (that is, stimulates international diffusion of innovation up to some point) in developed countries, but no significant relationship in developing countries.

We argued that, given the low levels of complementary resources needed for innovation in developing countries, it is not likely that local innovative activity can respond solely or primarily to changes in the legal environment, at least not without some significant time lag. The high global patent protection standards may also not be conducive to developing-country innovation systems that are based largely on incremental, adaptive, and imitative research.

Thus our overall finding is that in developed countries patent reforms have positive effects on innovation and positive effects on diffusion up to some point, beyond which market power effects have net negative effects. But patent reforms do not seem thus far to be a significantly positive influence on innovative activities in developing countries.

We conclude with some suggestions for further study. We would find it desirable to extend the research using firm-level data, particularly since firms make the critical decisions on innovation and commercialization. Further research using firm-level data, though, needs to consider the following challenges. First, broad international firm-level data are generally available primarily for publicly traded companies. While these companies typically represent most of the major firms in a given country, private or national companies are not well represented in current databases. It would be useful to examine whether the findings in this study are applicable to other types of firm. Second, data for firms in the sample do not reflect activities across different business units and countries. There is a continued need for improved data collection in the future that allows researchers to disaggregate the multinational corporation into its business units across countries so that the influence of national-level factors on corporate behavior and outcomes can be better understood. Third, the data in the study are drawn only from manufacturing-oriented industries. While these industries rely heavily on innovation investments to build competitiveness, the findings from this study may not generalize to other types of industry, such as services or non-profit.

Another consideration is that the location of innovation activities of multinational firms may be shifting. While Dunning (1977) found that a high percentage of a multinational firm's R&D activities are undertaken in its home market, recent research and business trends indicate that firms are increasingly relying on foreign operations and subsidiaries for technology (Frost, 2001; Cantwell *et al*., 2004). This trend calls for additional research on the influence of home and host country patent rights on firm-level innovation, especially since foreign subsidiaries may be increasingly relied upon for important technological advances.

Finally, our analysis has treated patent strength and patent reforms as exogenous, focusing on their effects on innovative activity. Future work could explore the determinants of patent strength. This could help determine which countries are likely to implement patent reforms or are capable of complying with international agreement obligations.

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## Notes

[1]For the text of the TRIPS agreement, see http://www.wto.org/english/docs_e/legal_e/27-trips_01_e.htm

[2]The exception is that Yang and Maskus (2001), Kanwar and Evenson (2003), and Park and Lippoldt (2005) use an earlier version of the Patent Rights Index in their studies.

[3]For example, Bosworth (1980) uses dummy variables to indicate whether certain patent law features exist, such as duration, novelty, or compulsory licensing. Ferrantino (1993) uses dummy variables to indicate whether a country was a member of an international patent treaty. Rapp and Rozek (1990) consider additional features of patent systems, but do not incorporate enforcement mechanisms. A disadvantage with these previous measures, for the purposes of our research, is that they are limited to one year of record. Branstetter *et al*. (2004) follow the dummy variable method (giving a value of 1 if a reform has occurred, 0 otherwise). Some pitfalls with this approach are that reforms are not one-shot but ongoing over time, and that there are various magnitudes of reform (from major ones to minor ones). Lerner (2002) also looks at several features of the patent system, but does not aggregate them into an overall measure of the strength of patent rights. Mansfield (1994) and Sherwood (1997) rely on surveys of expert opinion or perceptions of the strength of patent rights. These surveys provide ratings for a few countries and a single time period. Moreover, issues can be raised about the comparability of different interviewees' perceptions, since there is no

information on how to *scale* the responses. How does one expert's rating compare with another's?

[4]The 10 industries are: Beverages (3.6%), Construction Machinery (5.6%), Electrical Components (7.7%), Food (13.8%), Household Appliances (2.2%), Industrial Chemicals (11.4%), Nonferrous Metals (5.8%), Rubber (3.6%), Scientific Instruments (35.7%), and Semiconductors (10.6%).

[5]The Patent Rights Index data are available upon request from Walter Park.

[6]Data on the patent rights index are available from the corresponding author upon request.

[7]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). Only one country switched from the developing to developed group during the sample period – namely Israel in 1978.

[8]For example, membership of the *Paris Convention* grew from 70 members in 1970 to 97 in 1990 and 160 in 2000. Membership of the *PCT* grew from 20 members in 1970 to 123 in 1990 and 175 in 2000. Membership of *UPOV* grew from 4 in 1970 to 19 in 1990 and 46 in 2000. Membership of *TRIPS* grew from 113 in 1995 to 140 in 2000.

[9]In preliminary analyses, 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 insignificant determinants once the industry dummies were included.

[10]The LR test statistic, $-2(\ln L_R - \ln L_U)$, where $L_R$ ($L_U$) is the log-likelihood value of the restricted (unrestricted) model, is distributed as a chi-square distribution (with one degree of freedom).

[11]Bearing in mind that, since Eq. (1) is exponential, the critical value occurs at $PRI^* = -\hat{\beta}_1/2\hat{\beta}_2$. Thus a U-shaped effect arises if $\hat{\beta}_2 > 0$ (and an inverse-U if $\hat{\beta}_2 < 0$), evaluated at $PRI^*$.

[12]The *F*-statistic, $F = (R_U^2 - R_R^2)/[(1 - R_U^2)/(N-K)]$, where ${R_U}^2$ (${R_R}^2$) is the unrestricted (restricted) *R*-squared, is distributed as an *F*-distribution with (1, $N-K$) degrees of freedom, where $N-K$ is the number of observations less the number of RHS variables.

[13]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).

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## Appendix A: Index scoring methods

### Patent Rights Index (PRI)

| | | |
|---|---|---|
| 1. *Membership in international agreements* | *Signatory* | *Non-signatory* |
| Paris Convention | 1/4 | 0 |
| Patent Cooperation Treaty | 1/4 | 0 |
| Protection of New Varieties (UPOV) | 1/4 | 0 |
| Trade-Related Intellectual Property Rights Agreement (TRIPS) | 1/4 | 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. *Enforcement mechanisms* | *Available* | *Not available* |
| Preliminary injunctions | 1/3 | 0 |
| Contributory infringement | 1/3 | 0 |
| Burden-of-proof reversal | 1/3 | 0 |
| 4. *Loss of rights* | *Does not exist* | *Exists* |
| 'Working' requirements | 1/3 | 0 |
| Compulsory licensing | 1/3 | 0 |
| Revocation of patents | 1/3 | 0 |
| 5. *Duration of protection* | *Full* | *Partial* |
| | 1 | $0<f<1$ |

$f$ 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).
Overall score: Sum of (1)–(5).

### Explanatory notes on the Patent Rights Index

#### *Membership in international agreements*

Countries that participate in these international agreements indicate their willingness to provide national, nondiscriminatory treatment to foreigners. In addition, TRIPS obliges member states to make laws, regulations, judicial decisions, and administrative rulings transparent (Article 63). The fact that TRIPS has cross-cutting multilateral statutory and procedural obligations is why we include it under the membership component even though some of its individual provisions are captured in other parts of the index. Participation in each of these agreements receives a score of 1/4, for a total of 1 if the country participates in all four.

#### *Coverage*

Rather than list the universe of technologies that could be patentable, we focus on a few technological fields that provide maximum variability across countries. The score assigned to this component is the fraction of those fields that are patentable under national law.

#### *Enforcement mechanisms*

Preliminary injunctions require individuals to cease alleged infringements prior to a case hearing. Contributory infringement clauses aid in preventing third parties from contributing to infringement. Burden-of-proof reversals shift the burden to alleged infringers to prove non-infringement. Countries receive a score of 1/3 for providing each of these.

#### *Loss of rights*

This category measures whether loss of rights will *not* occur owing 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 occurs. 'Working' requirements require the patent holder to exploit the invention by a certain period of time or forfeit rights. Compulsory licensing requires patentees to share the use of the innovation with third parties. If a country does not impose compulsory licensing within 3 or 4 years from the date of patent grant, it receives credit for this area. Countries that do not revoke patent rights owing to non-working or other reasons also receive credit for this area.

#### *Duration of protection*

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.

## Appendix B: List of countries in the patent sample

| *Developed countries* | *Developing and least developed countries* | |
|---|---|---|
| Australia* | Algeria | Malta |
| Austria* | Argentina | Mauritius |
| Belgium* | Bangladesh | Mexico* |
| Canada* | Bolivia | Morocco |
| Denmark* | Botswana | Mozambique |
| Finland* | Brazil* | Nepal |
| France* | Bulgaria | Nicaragua |
| Germany* | Burundi | Nigeria |
| Greece* | Chile* | Pakistan* |
| Iceland | China* | Panama |
| Ireland* | Colombia | Paraguay |
| Israel* | Costa Rica | Peru |
| Italy* | Cyprus | Philippines* |
| Japan* | Czech Republic | Poland |
| Luxembourg | Ecuador | Romania |
| Netherlands* | Egypt | Russian Federation |
| New Zealand* | El Salvador | Rwanda |
| Norway* | Ethiopia | Saudi Arabia |
| Portugal | Fiji | Sierra Leone |
| Spain | Ghana | Singapore* |
| Sweden* | Grenada | Slovakia |
| Switzerland* | Guatemala | South Africa* |
| United Kingdom* | Guyana | Sri Lanka |
| United States* | Haiti | Sudan |
| | Honduras | Swaziland |
| | Hong Kong* | Syria |
| | Hungary | Tanzania |
| | India* | Thailand |
| | Indonesia* | Trinidad & Tobago |
| | Iran | Tunisia |
| | Jamaica | Turkey* |
| | Kenya | Uganda |
| | Korea* | Ukraine |
| | Liberia | Uruguay |
| | Lithuania | Venezuela |
| | Madagascar | Viet Nam |
| | Malawi | Zambia |
| | Malaysia* | Zimbabwe |

*Country is also in the R&D firm sample.

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