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North–South models of intellectual property rights: an empirical critique

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Abstract Do Southern intellectual property rights (IPRs) affect Northern innovation? There is much theoretical debate on the impact of IPRs in the South on the incentives of Northern firms to innovate and transfer technologies to the South. While empirical research exists on the effects of Southern IPRs on Northern technology transfers, empirical evidence on the effects of Southern IPRs on Northern innovation is absent. This paper seeks to fill that gap. Using a comprehensive micro-database of US multinational firms and their foreign affiliates in developed countries, this study finds that patent protection in the South has statistically insignificant effects on the research and development of these firms. Rather, the patent regimes of *developed countries* matter significantly to the R&D of these firms. Developing countries constitute a relatively small share of the world market so that variations in the patent rights of developing economies have contributed marginally to Northern incentives for R&D.

Keywords Patent protection · North–South models · Research and development · Empirical evidence

JEL Codes O34 · O11 · O31 · F43

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1 Introduction

The Trade-Related Intellectual Property Rights (TRIPS) Agreement of the World Trade Organization (WTO) of 1995 is a global landmark agreement that raised the levels of intellectual property rights around the world, especially in developing countries where intellectual property rights were weak compared to standards in developed countries. While the North (developed countries) stood to benefit from stronger protection of its intellectual property assets, the South (developing countries) also stood to benefit if stronger protection in the South were to foster local innovation, attract inward technology transfers, and/or stimulate Northern innovation, particularly to aid in the development of technologies that could be appropriate for the South.

Indeed, TRIPS has been a motivation for theoretical work on the influence of Southern intellectual property rights (IPRs) on Northern incentives to innovate and transfer technologies to the South. In North–South models of IPRs, the North conducts research and development (R&D), the outcomes of which are embodied in either new goods or the improved quality of existing goods, which the North supplies. The South does not engage in R&D, but it can copy or imitate Northern goods, depending on how weak intellectual property rights are in the South. Upon successful imitation, Southern firms end up producing the goods and exporting them back to the North. The theoretical conclusions of these models concerning the impacts of IPRs are mixed. Some models predict that stronger IPRs in the South discourage Northern investment in R&D and technology transfer; others reach the opposite conclusion, depending on model specifications.

However, empirical work thus far has not tested the strength of the feedback from Southern intellectual property rights to Northern R&D. This feedback is an integral aspect of North–South models. Instead, previous empirical research has focused on whether stronger IPRs in the South help attract Northern technology transfers, such as foreign direct investment (FDI) and licensing, or help foster local innovation.[1] The purpose of this paper is to provide the first empirical analysis of whether Northern innovation responds to Southern IPRs (specifically patent rights) and thus fill a gap in the literature. The issue has important implications for whether an expansion of global intellectual property rights is conducive to world innovation. It also relates to whether stronger IPRs in the South can encourage Northern researchers to target the needs of developing countries, such as treatments for tropical diseases (see Diwan and Rodrik 1991; La Croix and Liu 2008).

To carry out the empirical test, this paper has assembled micro-data on the research and development performed by US multinational firms and their foreign affiliates in developed countries. These firms represent our sample of Northern innovators. The objective is to examine how their R&D relates to patent protection in developing countries, controlling for other factors, including patent protection in other developed (Northern) countries. Measures of foreign patent rights are

[1] For empirical work on IPRs and technology transfer, see Branstetter et al. (2006), Javorcik (2004), Nunnenkamp and Spatz (2004), Park and Lippoldt (2005, 2008), and Primo Braga and Fink (1998). For empirical work on IPRs and innovation, see Allred and Park (2007), Chen and Puttitanun (2005), Kanwar and Evenson (2003), Schneider (2005), and Varsakelis (2001).

constructed by taking the weighted sums of indexes of patent protection in individual countries, where the weights are based on market shares, such as the share of exports accounted for by a foreign country. The empirical investigation is based on a panel of firms surveyed between 1982 and 2004.

The chief, stark finding in this study is that the R&D of these developed country firms responds weakly to Southern patent protection. Instead, their incentives to perform R&D depend on patent protection levels in the North. The underlying intuition is that stronger patent rights expand the market size of innovators; however, in small economies, that expansion accounts for a small percentage change in the innovators' global market. Consequently, variations in patent rights in the South would not substantially affect Northern incentives to conduct R&D.

This paper is organized as follows: the next section provides a brief review of the literature on North–South IPRs. Section 3 discusses the empirical framework, particularly the construction of the measures of foreign patent rights. Section 4 discusses the unique panel data set of firm-level R&D and other variables, and presents some sample statistics. Section 5 presents the empirical results and Sect. 6 concludes.

2 Literature review

The North–South theoretical literature is divided as to the net effect of stronger IPRs in the South on Northern innovation. On the one hand, Helpman (1993) argues that innovation can be lowered because tighter IPRs restrict Southern imitation and shift production back to the North. As a result, the demand for labor in Northern manufacturing increases. Wages in the North rise, which increase the cost of research and reduce the labor available for R&D, hence adversely affecting innovation in the North. Lai (1998), on the other hand, argues that the outcome is different if some Northern firms are multinational firms that produce in the South through local affiliates or subsidiaries. Thus, stronger IPRs attract multinationals to the South (i.e., attract FDI). The resulting shift in production to the South relieves pressure on the labor market in the North. Less demand for Northern labor by the manufacturing sector makes more labor available for research. Hence in this model stronger IPRs are ultimately associated with increased innovation in the North.

Glass and Saggi (2002) also incorporate Northern multinational firms but obtain a different result than Lai (1998). In their model, imitation is not a costless activity. Tighter IPRs force Southern imitators to use up more resources to invent around foreign goods. Thus stronger IPRs in the South result in greater resource scarcity. Less FDI occurs due to the higher costs of production and adaptation. With less FDI, production is shifted back to the North and the result in Helpman (1993) holds. In contrast, Yang and Maskus (2001) introduce Northern licensing instead of FDI as the mechanism for technology transfer to the South. Stronger IPRs in the South help reduce the contractual costs of licensing and increase the Northern licensor's share of the rents. Thus, stronger IPRs in the South increase the returns to licensing so that more production is transferred to the South. As in Lai (1998), this makes more Northern resources available for research.

These studies have been followed by various extensions to the central North–South theoretical framework. For example, Glass and Wu (2007) study the effects of stronger IPRs in the South on the composition of Northern innovation between developing new goods and improving existing goods. Parello (2008) studies how Southern IPRs can affect the incentives of Northern labor to accumulate skills.

A common feature of these theoretical models is that the strength of Southern intellectual property protection feeds back on Northern incentives to invest in R&D. The extent to which Northern R&D will actually respond should depend on the market size of the South, as pointed out in other theoretical models. For example, Deardorff (1992) develops a partial equilibrium model illustrating how the smaller market size of the South may add marginally to Northern incentives to innovate. In this model, where all inventions originate in one country, extending patent protection to more and more foreign countries stimulates the incentive to innovate at a diminishing rate. Angeles (2005) develops a dynamic, general equilibrium model in which the effect of Southern IPRs on Northern innovation becomes insignificant as the size of the Southern market shrinks. Both Deardorff (1992) and Angeles (2005) offer a theoretical explanation as to why patent rights in developing countries are expected to affect the R&D of developed country firms weakly—namely that the South constitutes a relatively small share of the North's world market and returns to R&D.

3 Empirical framework

3.1 Empirical relationship

The measure of innovation focused on in this paper is research and development (R&D) expenditures by firms. The objective here is to analyze the relationship between firm-level R&D in developed countries and the strength of domestic *and* foreign patent rights, controlling for other factors. Consider the following reduced-form equation[2]:

$$R_{ijt} = R\left(\boldsymbol{X}_{ijt}; P_{jt}, P^{*}_{jt}\right) \tag{1}$$

where R_{ijt} denotes R&D investment by the ith firm in the jth developed country at time t, P_{jt} the level of domestic patent protection (i.e., in country j) at time t, P^{*}_{jt} the level of foreign patent protection perceived by researchers in country j at time t, and $\boldsymbol{X}_{ijt}$ the vector of control variables.

The empirical analysis here requires a measure of the level of patent protection that domestic researchers perceive abroad. This measure is defined to be a weighted sum of patent protection levels in other countries:

[2] North–South theoretical models establish this relationship typically through comparative statics (e.g., $\partial R/\partial P^{*}$ using comparable variables). A knowledge production function is specified in which innovation outcomes—for example, new varieties or quality improvements of goods—are a function of R&D resources, such as research labor. IPRs affect the allocation of resources to R&D.

$$P_{jt}^{*} = \sum_{k=1,k\neq j}^{K} \omega_{jkt} P_{kt} \tag{2}$$

where ω denotes the weight and K the number of countries. Note that P^* covers foreign countries and hence excludes the level of domestic patent protection (i.e., the level in country j). The weights can depend on some joint domestic and foreign characteristic and can vary over time. The weighting scheme for ω will be discussed more fully below and the index of domestic patent protection, P, will be discussed in more detail in the next section.

But first, the empirical analysis breaks down the foreign patent protection variable P^* by different foreign groups of countries so as to isolate, for example, the effects of patent strength in the South on Northern R&D. Hence, for each country in the North, the rest of the world is put into two groups: other developed countries (North) and developing countries (South). That is, P^* can be disaggregated as:

$$P_{jt}^{*N} = \sum_{k=1,k\neq j}^{K_N} \omega_{jkt} P_{kt} \quad \text{(Other developed country group)} \tag{3}$$

$$P_{jt}^{*S} = \sum_{k=1}^{K_S} \omega_{jkt} P_{kt} \quad \text{(Developing country group)} \tag{4}$$

where K_N and K_S are the number of developed (Northern) countries and developing (Southern) countries, respectively, and where $K_N + K_S = K$.

3.2 Construction of foreign patent rights indexes

Given a measure of patent protection, P_{kt}, the focus here will be on discussing the derivation of weights, ω. First, the easiest approach would simply be to average the patent protection levels of countries abroad (i.e., $\omega = 1/K$). However, countries abroad vary by market size, and thus may not matter equally to an innovator; that is, the ability to exploit innovation rents varies across markets. Hence, simple averaging treats the patent strength of a small economy the same as that of a large economy, with no consideration of the importance of their markets to the innovating country in question, or to the firms therein. Moreover, another difficulty with the simple averaging method is that each Northern country would face the same level of patent protection in the developing world at a given point in time; that is, there would be no variation in P^{*S} across developed countries.

Thus it would be useful to base the weights, ω, on some function of the *linkage* between domestic and foreign markets. More specifically, the patent protection level of a country abroad should be weighted by some measure of market size. Gross domestic product would be one candidate (e.g., the share of a country's GDP in world GDP). However, a problem similar to that of the simple averaging method arises: each Northern country would face the same level of

patent protection in the developing world since the 'weight' or share of a country's GDP in world GDP is the same from the perspective of each Northern country.

A measure of market size that varies by source country is bilateral exports, which will be used in this paper. For our purposes here, the absolute size of a foreign market is not of interest, but rather the relative share of that market for domestic agents. A limitation, though, is that exports are not the only means by which foreign sales occur. There are also sales from international licensing and overseas subsidiaries of multinational firms. Data on bilateral FDI flows and stocks, though, are not as complete as those on international trade. Nonetheless, as a check for robustness, this paper incorporates data on bilateral FDI positions, despite some gaps in data availability.

Furthermore, national level exports and FDI are used to construct the weights, ω, since firm-level foreign sales in the data set are not broken down by country of destination but mostly by region (for example, Europe, Latin America, and so forth).[3] However, the next section will show that the distribution of firm-level exports by region and the distribution of national exports by region are highly correlated for the firms in the sample. Moreover, aggregate bilateral exports help capture other relevant inter-country interactions; for example, international knowledge spillovers between countries that would make domestic R&D dependent on the IPRs of partner countries (see Coe and Helpman 1995; Coe et al. 2008; Acharya and Keller 2009).

Another concern is that there is likely to be some endogeneity between a country's exports to another country and the latter's patent protection regime. In other words, the level of exports (or FDI and licensing as well) may be low (or high) owing to patent protection levels in the destination country (see Maskus and Penubarti 1995; Smith 1999).[4] As Fig. 1 shows, however, shares of developed country exports to the developing world are relatively stable compared to episodes of patent reforms in developing countries (an index of which will be discussed in Sect. 4). For example, the share of Northern exports going to upper-income developing countries has been about 17%, with a coefficient of variation of 14.5%, while the coefficient of variation of the median level of patent rights in this group of developing countries is greater (about 38%). Thus, the distribution of Northern exports does not appear to change in proportion to patent reforms in the South. Nonetheless, to help avert endogeneity problems, this paper *lags* the export shares used to weight foreign patent protection levels by one period, where the lag length of a period is 5 years, given the structure of the panel data set. Hence, the weights used are:

[3] As for firm-level FDI, the data set in this paper covers the FDI of US parents, but for the FDI of foreign affiliates, it covers a firm's ownership interest only in other affiliates of the *same* parent, not in unaffiliated firms. Consequently, the international distribution of affiliate FDI can only be partially constructed.

[4] A priori, however, the effect of patent protection on exports is ambiguous. Stronger patent rights in a destination country could either expand the markets of exporters (by reducing infringement) or increase the market power of exporters and lead them to restrict output.

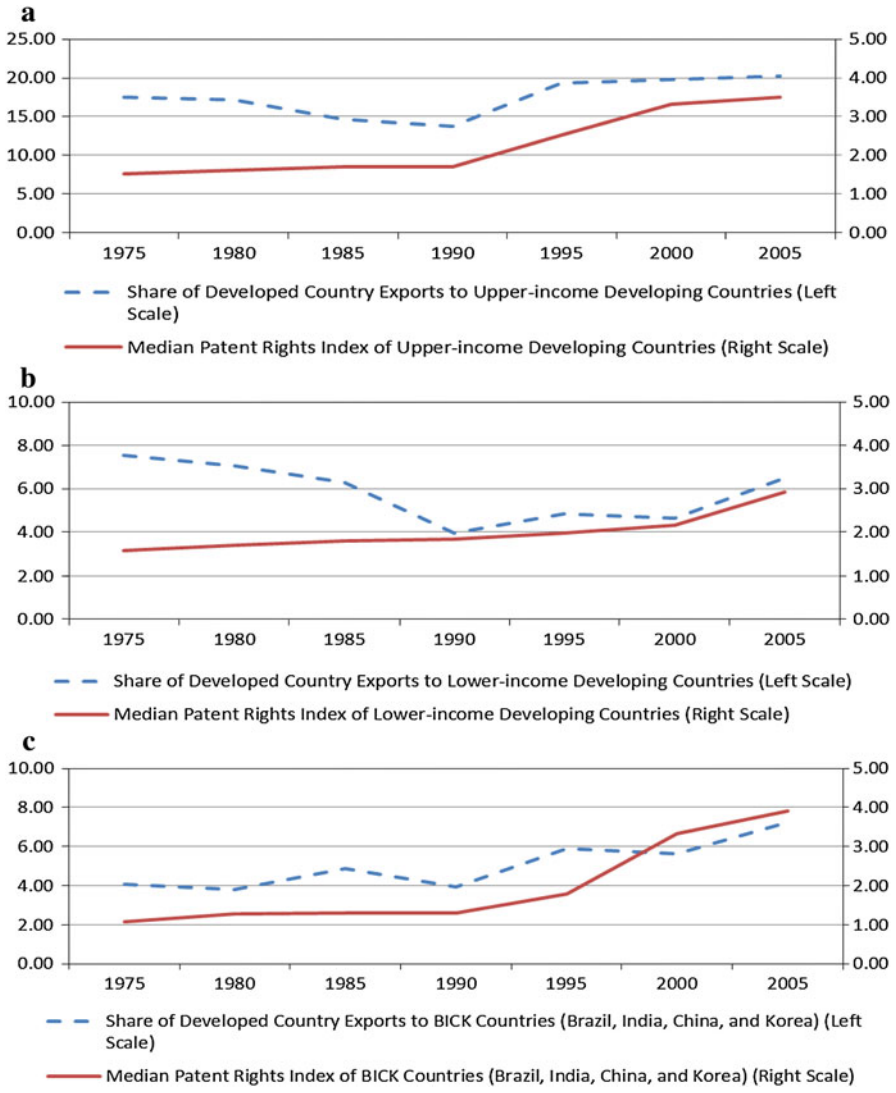

Fig. 1 Trends in foreign market share and patent rights. **a** Upper-income developing countries, **b** Lower-income developing countries, and **c** BICK countries. The notes to Table 2 contain a list of upper and lower-income developing countries

$$\omega_{jkt} = \frac{E_{jkt-1}}{E_{jt-1}} \tag{5}$$

where E_{jkt-1} denotes exports from country j to country k at period $t - 1$ and E_{jt-1} the total exports of country j at period $t - 1$. Lagging the export shares should allow

us to capture variations in foreign patent rights while taking foreign market shares as given.[5]

Before proceeding, it is useful to address other concerns with the construction of the foreign patent rights index. First, in the weights (5), a case could be made that instead of being based on total exports, the weights should depend on manufacturing exports on the grounds that such exports are likely to be more patent sensitive. However, R&D activities also occur in non-manufacturing sectors (e.g., agriculture and services). Nonetheless, as a check for robustness, the empirical analysis will test the effects of recalculating the weights (5) using manufacturing exports. A second concern with the construction of the weights is that the weights do not add up to 100% in each group, but rather across both groups (i.e., other developed and developing countries). However, if the weights were chosen so as to add up to 100% within each group, this would inflate the weight of small countries and work at cross purposes with the intended aim of the construction of the foreign patent rights indexes, which is to incorporate a measure of the market share of foreign markets. Again, as a check for robustness, the empirical section will test the effects of scaling the weights so that they add up to unity within each country group; that is,

$$\sum_{k=1,k\neq j}^{K_N} \omega_{jkt} = 1 \text{ and } \sum_{k=1}^{K_S} \omega_{jkt} = 1$$

A third concern is that exporting, as mentioned earlier, is not the only means of accessing foreign markets. Countries also access foreign markets through FDI. As another check for robustness, the following weights will be examined:

$$\omega_{jkt} = \frac{E_{jkt-1} + F_{jkt-1}}{E_{jt-1} + F_{jt-1}}$$

where F denotes the stock of FDI. As the flows of FDI are much smaller than the levels of exports, the stocks of FDI are used to measure the influence of FDI on foreign market size and share. International licensing is significantly smaller than FDI and exports, so that including it would not significantly affect measures of foreign market shares.

3.3 Empirical plan

In summary, the following log-linear version of Eq. 1 will be estimated with the foreign patent protection variables as defined in 3 and 4:

$$\ln R_{ijt} = \beta_0 = \beta_1 \ln P_{jt} + \beta_2 \ln P_{jt}^{*N} + \beta_3 \ln P_{jt}^{*S} + \beta_4 \ln \boldsymbol{X}_{ijt} + \beta_t + \beta_i + v_{ijt} \qquad (6)$$

[5] An alternative treatment for the endogeneity between bilateral exports and the level of patent rights abroad is to use instruments for exports. In a preliminary version of this paper, the determinants of a gravity model of trade were used as instruments for exports. The fitted exports were then used to construct weights similar to (5), such as $\omega_{jkt} = \frac{\widehat{E}_{jkt-1}}{\widehat{E}_{jt-1}}$, where $\widehat{E}$ denotes the fitted values. The empirical findings were very similar to what are presented in this paper and are available to interested readers upon request. In any event, the endogeneity tests (discussed in Sect. 5.1) indicate that we cannot reject the null hypothesis that the foreign patent rights indexes are exogenous to firm R&D.

$i = 1, \ldots, I$ firms
$j = 1, \ldots, J$ developed countries
$t = 1, \ldots, T$ time periods

where P, P^{*N}, and P^{*S} are the levels of patent protection at home, in other developed countries, and in developing countries, respectively. The vector of control variables, $\mathbf{X}$, will be discussed in the next section. The variables β_t, β_i, and v are the time effects, individual firm effects, and idiosyncratic error, respectively.

As robustness checks, different weighting schemes for foreign patent rights will be examined: (i) using manufacturing exports only; (ii) using the sum of exports and FDI stock; and (iii) scaling within-group weights such that they sum to unity. The empirical analysis will estimate Eq. 6 from different angles. For example, different groups of developing countries will be examined: upper-income developing countries, lower-income developing countries, and a select group consisting of Brazil, India, China, and (South) Korea, to be referred to as the BICK countries. Firms will also be grouped according to their R&D intensities (that is, their R&D/sales ratio) and by selected industries.

4 Data and sample statistics

4.1 Data

This paper utilizes a unique micro-database of US multinational parent firms and their foreign affiliates. The data are from the US Bureau of Economic Analysis (BEA) Survey of US Direct Investment Abroad (USDIA). The surveys are conducted annually by the BEA, with the most extensive data provided in the benchmark years 1982, 1989, 1994, 1999, and 2004. The surveys provide detailed financial and operating data on US parent firms and their foreign affiliates, including their technology-related activities, such as R&D performed. From this source, benchmark year data were gathered on 2,858 R&D performing firms operating in 23 developed countries (including the United States), as listed in the "Appendix".[6] It is this sample of innovators that will be used to test whether Northern investments in R&D respond to Southern patent rights, among other factors. An advantage of this data source is that it provides a large sample of parents and affiliates that innovate and engage in international markets through sales, investment, and licensing of intangible assets. Together, these firms accounted for about 42% of business enterprise R&D performed in the developed OECD countries in 2004.[7]

[6] Each of these firms has had at least one benchmark period of positive R&D expenditures, with most having positive R&D spending in all periods.

[7] This was calculated from BEA data and the *Science, Technology and R&D Statistics* of the OECD. In 2004, total business enterprise R&D in the developed OECD was about $455 billion current purchasing power parity (PPP) US dollars.

About 24% of the firms in the sample are US parent firms. The rest are foreign affiliates of these US parents (see Box 2 in the "Appendix" for the composition). The US parent firms represent the subset of US firms that have direct investment abroad, not all US firms.[8] Along with the amount of R&D performed by a firm (in real 2000 purchasing power parity (PPP) US dollars), data were collected on important control variables, such as the firm's sales (also in real 2000 PPP US dollars), net income, taxes paid, and the number of R&D employees.[9] The sales of firms provide incentives to conduct R&D and to thereby improve or develop new products, while R&D employees represent the human capital resources available for conducting R&D (see Jones and Teegen 2003).[10] Taxes, like the strength of patent rights, have the potential to affect the nature and location of where R&D is conducted (see Bloom et al. 2002; Thomson 2009). In this paper, the tax variable controlled for is the ratio of income taxes paid by the firm to the firm's (pre-tax) net income.[11] Other control variables include the level of public R&D expenditures, which as a public good may provide spillover knowledge benefits to private firms, and the level of parent company R&D (where applicable) to control for any parent-affiliate knowledge spillovers.

Data on patent protection levels come from Park (2008), where an index of patent protection is available for over 120 countries from 1960 to 2005 (every 5 years). The index provides a score that reflects a given country's overall level of patent rights and restrictions at a given point in time.[12] The underlying data are based on statutory and case laws, which interpret and apply the statutes. The index does not measure levels of infringement or the degree to which injured parties obtained redress. These are, of course, critical to the enjoyment of legal rights. Nonetheless, legal codes and regulations are fundamental to asserting rights and conveying national obligations. They serve as a basis for applying the law and settling disputes. Thus shifts in the index over time help track legal developments related to the strength of patent rights, such as the effect of the TRIPS agreement, as well as allow for comparisons between countries regarding the frequency, timing, and intensity of

[8] Note that the level of consolidation in the surveys differs between US parents and their foreign affiliates. While US parents report on a fully consolidated domestic basis, reporting for foreign affiliates is less consolidated. Affiliates of common parents in different industries in a given host country are reported as distinct companies.

[9] The nominal data are deflated by the BEA's private GDP deflator. The firm-level data are in US dollars, as obtained from market exchange rates. But those rates do not take into account differences in the costs of goods and services across countries. Thus, the data are converted here into PPP dollars using the World Bank's PPP conversion factors (see Box 1 in the "Appendix" for the data source).

[10] In North–South models, labor is a key resource which can be allocated to either manufacturing or R&D.

[11] Net income is defined as gross income minus total costs and expenses. The reason the tax base used is net income, rather than gross income, is to obtain a measure of taxable income. Countries vary in terms of their statutory tax rates and regulations on tax deductions, so that gross income would not consistently measure what is taxable.

[12] The strength of patent rights is a composite index measuring the duration of protection, subject matter that is patentable, membership in international treaties, enforcement mechanisms available, and the degree to which limitations on patent holders are not imposed (such as compulsory licensing). The index ranges from 0 (no patent system) to 5 (strongest level of protection).

reforms.[13] As the time periods of the patent rights data set are not synchronized with the BEA benchmark periods, the patent rights index of 1980 is assigned to BEA data for 1982, the index of 1985 to data for 1989, and so on such that the patent rights index of 2000 is matched to BEA data for 2004.[14]

4.2 Sample statistics

The "Appendix" summarizes the data sources. Table 1 presents descriptive statistics and correlations for the variables of interest. In absolute terms, US parent firms conduct more R&D and have more sales and R&D employees than their foreign affiliates, but the data generally exhibit more variability, or higher coefficients of variation, for the foreign affiliate sample. Patent rights in the United States are on average stronger than those in other developed countries.

Patent rights in developing countries are generally weaker than in developed countries. However, through TRIPS reforms, the patent systems of developing economies have increased in strength, as Fig. 1 indicates. As Park (2008) discusses, the key drivers of patent reform in developing countries were increases in the duration of patent protection, increased membership in international patent conventions, expansions in the subject matter that is patentable (e.g., chemicals and pharmaceuticals), and the adoption of stronger enforcement mechanisms. The issue is how influential these developments in the South were on Northern incentives to perform R&D. Table 2 shows that Southern markets are relatively small from the perspective of Northern firms. For example, nearly 80% of developed country exports go to other developed countries. Less than 5% of these exports go to the lower-income developing countries. Data on FDI exhibit the same pattern. The bulk of developed country FDI stock is in other developed countries. These figures provide a rough idea of the weight a foreign patent system gets in a developed country's measure of patent strength abroad.

Table 3 checks to see how closely the distribution of aggregate national exports matches the distribution of firm-level exports across world regions (for the period related to the construction of the weights, 1982–1999). Part A of the table shows a strong match for the United States. In affiliate countries, affiliate firm exports go predominantly to the United States and Europe, as is the case with aggregate national exports. Part B of the table shows the correlation between the regional distribution of firm exports and the regional distribution of aggregate exports for each of the countries in the sample.

[13] An alternative measure of the strength of intellectual property laws is provided in the *Global Competitiveness Reports* (GCR) (see World Economic Forum 2007). This is based on surveys of firms. However, the surveys are based on subjective assessments, are not uniformly measured (in that different respondents rate the regimes of different countries rather than a fixed group of evaluators), and are rather broad in the sense that the surveys cover the perception of intellectual property rights in general, rather than patent rights in particular. Most importantly, longitudinal data are not available before 2000, making it difficult to incorporate data before the agreement on Trade Related Aspects of Intellectual Property Rights (TRIPS). Overall, for 2005, the patent rights index used in this paper has a 0.687 correlation with the GCR intellectual property (IP) ratings. The coefficient of variation of the patent rights index (0.40) is greater than that of the GCR's IP ratings (0.253).

[14] Again, as mentioned before, the foreign patent protection weights ω are lagged one period, so that for 1980s measure of P^*, the weights are constructed from 1975 trade and/or FDI data, for 1985s measure the weights are from 1980 data, and so on such that for 2000s measure the weights are from 1995 data.

Table 1 Descriptive statistics

	Full sample			US parent firms			Foreign affiliates		
	Mean	SD	CV	Mean	SD	CV	Mean	SD	CV
Real R&D	13.4	46.7	3.49	23.6	34.4	1.46	8.7	50.6	5.82
Real sales	745.3	2,535	3.40	1,665	4,009	2.41	344.3	1,326	3.85
R&D employees	97	323	3.33	197	368	1.87	52	289	5.56
Taxes/net income	0.37	2.25	6.08	0.43	2.94	6.84	0.34	1.79	5.26
Patent rights index	3.68	0.78	0.21	4.69	0.21	0.04	3.64	0.76	0.21
Government R&D/GDP (%)	0.5	0.26	0.52	1.02	0.22	0.22	0.47	0.23	0.49

Correlations (Full sample)	Real R&D	Real sales	R&D employees	Taxes/net income	Patent rights	Govt RD/GDP (%)
Real R&D	1					
Real sales	0.370	1				
R&D employees	0.696	0.365	1			
Taxes/net income	−0.001	−0.001	0.007	1		
Patent rights index	0.104	0.125	0.096	0.004	1	
Government R&D/GDP (%)	0.080	0.143	0.168	0.025	0.235	1

R&D and sales are in millions of real 2000 PPP US dollars. Real values are obtained using the BEA's private GDP deflator and PPP dollars are obtained using the World Bank's PPP conversion factor (GDP) to market exchange rate ratio

Sample statistics are calculated for 1982–2004. CV denotes coefficient of variation. Government R&D is gross expenditure on R&D financed by the government sector

Overall, the correlation is over 0.9. Only in three countries (Australia, New Zealand, and Greece) is the correlation less than 0.5. These countries account for just 4.35% of the firms in the sample (see Box 2 in the "Appendix"). Thus, Table 3 shows that most of the firms in the sample sell to other developed countries, and hence the aggregate weights, ω, correspond well to the global market shares of these firms.

Table 4 displays some sample values of the foreign patent rights indexes. The first column shows the domestic patent rights index for comparison, and the remaining columns show the strength of patent protection abroad from the perspective of a Northern country. The foreign countries are grouped by other developed countries and by upper-income and lower-income developing countries.[15] For each country group, the table shows the index created by using export shares, lagged 5 years. It can be seen that after adjusting for export shares, the levels of patent protection in developing countries are low from the perspective of developed countries. For most developed countries, the level of domestic patent protection is higher than the weighted aggregate patent protection in other developed countries. The reverse is the case in seven of these developed countries because their largest foreign markets have higher levels of patent rights than their own (for example, Canada's largest external market is the United States, and the United States has a stronger patent system than Canada has).

[15] The level of patent rights for developing countries as a whole can be obtained by summing the index values for the upper and lower-income developing countries.

Table 2 Distribution of exports and foreign direct investment

Developed country	Share of exports to:			Share of FDI Stock in:		
	Other developed countries	Upper-income developing countries	Lower-income developing countries	Other developed countries	Upper-income developing countries	Lower-income developing countries
Australia	62.3	24.3	13.4	85.4	12.2	2.4
Austria	79.6	17.5	2.9	74.3	25.4	0.3
Belgium	88.6	7.8	3.6			
Canada	91.2	6.2	2.5	90.7	7.7	1.6
Denmark	88.2	8.7	3.1	90.9	8.0	1.1
Finland	73.5	23.2	3.3	95.5	3.8	0.7
France	78.6	15.3	6.1	91.3	7.3	1.5
Germany	76.6	19.6	3.8	87.9	11.3	0.9
Greece	72.1	24.5	3.4			
Ireland	92.3	5.9	1.8			
Israel	81.6	15.6	2.8			
Italy	78.3	17.7	4.0	94.1	5.8	0.1
Japan	55.3	30.6	14.1	66.8	19.6	13.6
Luxembourg	93.1	5.5	1.3	94.4	5.7	0.0
The Netherlands	90.1	6.9	2.9	94.5	4.6	1.0
New Zealand	72.4	20.1	7.5	96.1	1.8	2.1
Norway	91.2	5.6	3.1	93.0	6.2	0.8
Portugal	89.3	5.8	4.9	57.3	40.3	2.4
Spain	78.4	17.4	4.2			
Sweden	85.0	11.7	3.3	97.5	2.3	0.2
Switzerland	80.5	15.9	3.6	86.3	12.5	1.2
United Kingdom	81.6	12.5	5.9	90.5	8.0	1.5
United States	63.6	30.5	5.9	78.9	18.5	2.7
Mean	78.7	16.5	4.8	87.1	10.8	2.1

Shares are annual averages of 1975–2000. Upper-income developing countries are the high and medium-income developing countries, and lower-income are the low-income and least developed countries as classified by the United Nations (see UNCTAD 2006)

Upper-income developing countries: Algeria, Argentina, Bolivia, Botswana, Brazil, Bulgaria, Chile, Colombia, Costa Rica, Czech Republic, Dominican Republic, Ecuador, Egypt, El Salvador, Fiji, Gabon, Grenada, Guatemala, Hong Kong, Hungary, Iran, Jamaica, Jordan, S. Korea, Lithuania, Malaysia, Mauritius, Mexico, Morocco, Panama, Paraguay, Peru, Poland, Romania, Russia, Saudi Arabia, Singapore, Slovak Republic, South Africa, Swaziland, Syria, Taiwan, Thailand, Trinidad & Tobago, Tunisia, Turkey, Ukraine, Uruguay, Venezuela

Lower-income developing countries: Angola, Bangladesh, Benin, Burkina Faso, Burundi, Central African Republic, Chad, China, Congo, Ivory Coast, Ethiopia, Ghana, Guyana, Haiti, Honduras, India, Indonesia, Iraq, Kenya, Liberia, Madagascar, Malawi, Mali, Mauritania, Mozambique, Myanmar, Nepal, Nicaragua, Niger, Nigeria, Pakistan, Papua New Guinea, Philippines, Rwanda, Senegal, Sierra Leone, Somalia, Sri Lanka, Tanzania, Togo, Uganda, Vietnam, Zaire (Dem. Republic of Congo), Zimbabwe, Zambia

Table 3 Relationship between firm exports and aggregate national exports

	Africa	Canada	Europe	Japan	Latin America	Middle East	Other Asia and Pacific	United States
(A) Share of exports by regional destination 1982–1999								
US parent firms	(*)	21.0%	29.2%	12.9%	14.0%	(*)	18.6%	
US aggregate	1.7%	22.6%	27.2%	10.8%	18.3%	2.5%	16.9%	
Affiliate firms	1.0%	1.0%	59.3%	1.3%	1.9%	1.6%	6.6%	27.3%
22 affiliate countries	2.1%	1.1%	60.1%	2.2%	2.5%	1.7%	9.4%	20.9%
(B) Correlation between regional distribution of firm exports and regional distribution of aggregate national exports 1982–1999								
Australia	0.439		Greece	0.493		Norway	0.978	
Austria	0.988		Ireland	0.948		Portugal	0.985	
Belgium	0.996		Israel	0.691		Spain	0.961	
Canada	0.992		Italy	0.878		Sweden	0.952	
Denmark	0.957		Japan	0.782		Switzerland	0.983	
Finland	0.962		Luxembourg	0.999		United Kingdom	0.988	
France	0.987		The Netherlands	0.999		United States	0.968	
Germany	0.998		New Zealand	0.424		Overall	0.913	

Latin America includes Other Western Hemisphere countries. 22 Affiliate Countries refer to the 22 developed countries in which the affiliates are located. Part B shows the correlation between the aggregate firm sales across the eight regions (Africa, Canada, Europe, Japan, Latin America and Other Western Hemisphere, Middle East, Other Asia and Pacific and the United States) and the aggregate national exports across the same regions. (*) indicates less than 3%. The precise percentage figure is suppressed to avoid disclosure of data of individual companies

Table 4 Effective patent protection levels, 1980–2000

	Patent protection levels that developed country faces in:			
	Own country	Other developed countries	Upper-income developing countries	Lower-income developing countries
Australia	3.32	2.55	0.56	0.19
Austria	3.73	3.19	0.34	0.06
Belgium	4.18	3.61	0.15	0.06
Canada	3.67	4.12	0.13	0.04
Denmark	3.98	3.52	0.19	0.06
Finland	3.71	2.94	0.32	0.06
France	4.10	3.16	0.31	0.12
Germany	4.02	3.08	0.31	0.07
Greece	2.99	3.02	0.44	0.06
Ireland	3.11	3.85	0.12	0.04
Israel	3.22	3.49	0.37	0.05
Italy	4.01	3.17	0.35	0.08
Japan	3.96	2.39	0.72	0.23
Luxembourg	3.17	3.77	0.15	0.04
The Netherlands	4.19	3.66	0.14	0.05
New Zealand	3.22	2.91	0.46	0.12
Norway	3.51	3.71	0.12	0.06
Portugal	2.47	3.60	0.10	0.04
Spain	3.50	3.15	0.33	0.08
Sweden	3.92	3.40	0.22	0.06
Switzerland	3.91	3.24	0.33	0.07
United Kingdom	4.21	3.24	0.26	0.12
United States	4.69	2.49	0.65	0.11
Mean	3.68	3.24	0.31	0.08
SD	0.78	0.60	0.23	0.06
Coef of variation	0.21	0.18	0.74	0.75

The index of patent rights varies from 0 to 5, with higher values indicating stronger levels of protection. The foreign patent rights index values are weighted by (5 year) lagged export shares to generate the weights, as discussed in the text. The grouping of countries by level of economic development is based on UN classifications (see UNCTAD 2006). See Table 2 for a list of upper-income and lower-income developing countries

5 Empirical results

5.1 Preliminaries

Before presenting the main results, we discuss some diagnostic tests. Equation 6 is estimated by panel *fixed effects* regression; Hausman tests reject the null hypothesis of no correlation between the regressors and the individual firm effects. In addition, Durbin–Wu–Hausman tests for endogeneity between the indexes of patent rights and firm R&D were also conducted. The motivation for these tests is that policymakers

may choose the strength of the patent regime based on the level of R&D in the economy. As instruments for patent rights, legal origins (British, French, German, and Scandinavian) and an index of governance were utilized, as patent systems are generally the products of existing legal systems and institutions.[16] As Khan (2008) discusses, the historical evolution of patent systems can be characterized by legal origin and institutional environment.[17] Hu and Png (2009) also find a high correlation between the strength of legal systems and the strength of patent rights in developed countries. Moreover, legal origins and governance should be orthogonal to the error term in Eq. 6—that is, not be determined by firm-level R&D. Legal systems, for instance, originated prior to the R&D of US parent firms and their affiliates. Likewise, governance indicators reflect the "traditions and institutions by which authority in a country is exercised" (Kaufmann et al. 2009, p. 5). The culture and traditions underlying the political decision-making process should be established outside the R&D investments of firms in our sample.

Table 5 presents the results of testing for endogeneity. The first-stage regressions for the index of domestic patent rights, index of patent rights in other developed countries, and index of patent rights in developing countries are provided in columns 1–3, respectively. Countries with British legal origin are the reference group. The table also includes some sample statistics for the instrumental variables. The legal origin of most of the developed countries in the sample is French (approximately 35%). The sample correlations show that Scandinavian systems have the relatively highest indexes of governance and the French systems the relatively lowest. The first stage regressions indicate that patent rights in own and other developed countries have a positive association with domestic governance, while patent rights in developing countries have a negative association with domestic governance (due to relatively high governance countries having a lower share of trade with developing countries than do relatively low governance countries). Countries with German legal origins have relatively lower levels of domestic patent rights. Firm sales are positively associated with domestic patent rights and the index of developing country patent rights, but negatively associated with the index of other developed country patent rights; this is due to countries with large domestic firm sales (the United States, Japan, and Germany) having a relatively greater share of trade with developing countries (see Table 2).

The *F*-tests indicate that the instrumental variables are jointly significant. The null hypothesis that the coefficients of these excluded exogenous variables are all zero can be strongly rejected. In addition, the over-identification test indicates that the null hypothesis that the residuals of the second stage estimation of (6) are uncorrelated with the instruments cannot be rejected (p-value = 0.183). Lastly, the Durbin–Wu–Hausman test indicates that the null hypothesis that the coefficients of the residuals of the first-stage regressions are jointly zero in Eq. 6 cannot be rejected (p-value = 0.643);

[16] The index of governance consists of survey measures of regulatory quality, control of corruption, government effectiveness, the rule of law, political stability, and voice and accountability. See Kaufmann et al. (2009) for details.

[17] Legal (or colonial) origins have also been used as instruments for patent rights in Maskus and Penubarti (1995), Hu and Png (2009), and Ivus (2010), and studied as a determinant of intellectual property enforcement in Montoro Pons and Cuadrado Garcia (2008). The data sources for the instruments are provided in the "Appendix".

Table 5 First stage regressions and test of simultaneity

Dependent variable[a,b]	ln P (1)	ln P^{*N} (2)	ln P^{*S} (3)
Constant	0.657***	3.256***	−10.14***
	(0.025)	(0.059)	(0.250)
Governance indicator index	0.029***	0.092***	−0.158***
	(0.003)	(0.007)	(0.033)
Legal origin: French	0.024***	0.055***	0.133***
	(0.003)	(0.007)	(0.028)
Legal origin: German	−0.015***	−0.017***	0.364***
	(0.002)	(0.006)	(0.024)
Legal origin: Scandinavian	0.030***	−0.055***	0.505***
	(0.004)	(0.009)	(0.037)
ln sales	0.0014***	−0.006***	0.016***
	(0.000)	(0.001)	(0.005)
ln R&D employees	−0.0002	−0.003**	0.021***
	(0.0004)	(0.001)	(0.004)
ln (1+income tax rate)	0.0005	−0.0002**	0.0001
	(0.004)	(0.0001)	(0.0004)
ln (public R&D)	0.025***	−0.065***	0.297***
	(0.001)	(0.002)	(0.006)
Time effects (1999, 2004)	Yes	Yes	Yes
Number of observations	5,088	5,088	5,088
F-Statistic, $F(4,5077)$, p-value	0.00***	0.00***	0.00***

Sample statistics	Mean	SD	Correlation with governance index
(i) Governance index	1.595	0.389	1
(ii) Legal origin: British	0.304	0.465	0.161
(iii) Legal origin: French	0.348	0.482	−0.381
(iv) Legal origin: German	0.174	0.383	0.064
(v) Legal origin: Scandinavian	0.174	0.383	0.394

[a] Hansen J statistic, for test of overidentification, $\chi^2(1)$ p-value 0.183

[b] Durbin–Wu–Hausman, F-test for test of endogeneity, p-value 0.643

***, **, and * denote significance levels of 1, 5, and 10%, respectively. The sample consists of US parent firms and their foreign affiliates in 22 developed countries (as listed in the "Appendix") over the period 1994, 1999, and 2004. The shorter sample period, compared to the main results, is due to the data availability of the instrumental variables. The F-tests in columns 1–3 test the null hypothesis that the coefficients of the excluded instrumental variables (i)–(v) are all zero. Legal origins are dummy variables. The Governance Index ranges from −2.5 (weakest) to 2.5 (strongest), and is the average of its underlying components. ln P denotes the natural log of *domestic patent rights*, ln P^{*N} the natural log of foreign patent rights in *other developed* countries, and ln P^{*S} the natural log of foreign patent rights in *developing* countries

in other words, the null hypothesis of no simultaneity between firm R&D and patent rights at home or abroad cannot be rejected. One reason domestic patent rights, P_{jt}, are exogenous to R_{ijt} is that patent rights at the national level are not significantly influenced by an individual firm's R&D and because the patent rights data precede R&D data by a few years (e.g., the 2004 R&D data are matched to the 2000 year level

of patent rights, and so on, as indicated earlier). Patent rights abroad may also be exogenous to domestic R&D because foreign policymakers are not likely to choose the level of their patent rights based on R&D performed outside their country.

5.2 Main results

Table 6 presents the results of estimating Eq. 6. The reported standard errors are all robust and clustered at the country-year level in order to account for unobserved correlations within countries over time (due, say, to other institutional factors). The results confirm that Southern patent protection has a statistically insignificant influence on the R&D of US parent firms and their foreign affiliates in developed countries. In column 1, all developing countries in the sample are included in the measure of Southern patent rights. In column 2, only the upper-income developing countries, and in column 3, only the lower-income developing countries are considered in the measure. In column 4, only the patent rights in Brazil, India, China, and South Korea (BICK) are considered in the measure of Southern patent rights. These countries have been singled out for their recent fast growth performances. The levels of patent protection in these countries should therefore be of interest to researchers in the North. Still, the aggregate weighted patent protection of these four countries has a statistically insignificant influence on the R&D of US parents and their foreign affiliates in developed countries. As Fig. 1, part C shows, the BICK account for a relatively small percentage of Northern exports; for example, slightly over 7% in 2005. Patent protection in the BICK countries may matter to inward technology transfer and innovation within the BICK, but it does not seem to have a strong feedback effect on the R&D of our Northern firms.[18]

Instead, controlling for other factors, the R&D of US parents and their foreign affiliates is strongly and positively associated with patent protection levels in the developed world; that is, with own-country patent rights and the aggregate weighted patent rights of other developed countries. The coefficient estimates of domestic patent protection indicate a measured elasticity—that is, the percentage change in firm R&D due to a percentage change in the strength of patent rights—of about 0.92. The elasticities associated with patent protection in other developed countries are higher—about 1.8—but it should be noted that these estimates represent a measure of *group elasticity*.[19] That is, they approximately represent the percentage

[18] See Park and Lippoldt (2005, 2008) and Xu and Chiang (2005) for empirical analyses of inward technology transfer in developing countries, including the BICK countries.

[19] That is, from Eqs. 6 and 3, the elasticity of firm R&D in a developed country j with respect to patent strength in another developed country k equals (omitting time subscripts):

$$\varepsilon_{ijk} = \frac{dR_{ij}}{dP_k}\frac{P_k}{R_{ij}} = \widehat{\beta}_2 \frac{\omega_{jk}P_k}{\sum_{k=1,k\neq j}^{K_N}\omega_{jk}P_k}$$

where $\widehat{\beta}_2$ is the coefficient estimate of $ln\ P_{jt}^{*N}$ and P_{kt} the patent protection level of country k. In other words, the coefficient estimate is adjusted by the share of country k's weighted patent index in P_{jt}^{*N}. In the extreme case where each country in the group contributes equally to the group's patent strength (i.e., $\omega_{jm}P_m = \omega_{jk}P_k$), the elasticity is just the coefficient estimate divided by the number of countries in the group; that is, $\varepsilon_{ijk} = (\frac{\widehat{\beta}_2}{K_N - 1})$.

Table 6 Main results using lagged export-weighted foreign patent rights

	Dependent variable: ln (R&D)					
	Full sample (1)	Full sample (2)	Full sample (3)	Full sample (4)	Foreign affiliates (5)	Foreign affiliates (6)
Constant	−9.83**	−9.82**	−9.93**	−9.82**	−9.64**	−9.79**
	(4.067)	(4.107)	(3.934)	(4.214)	(3.709)	(3.877)
ln sales	0.352***	0.352***	0.351***	0.349***	0.317***	0.287***
	(0.057)	(0.057)	(0.057)	(0.058)	(0.089)	(0.094)
ln R&D employees	0.513***	0.513***	0.514***	0.513***	0.562***	0.550***
	(0.029)	(0.029)	(0.029)	(0.029)	(0.038)	(0.037)
ln (1 + income tax rate)	−0.028	−0.028	−0.029	−0.03	−0.017*	−0.021**
	(0.041)	(0.041)	(0.041)	(0.041)	(0.009)	(0.010)
ln (domestic patent rights)	0.891***	0.939***	0.887***	0.946***	0.833***	0.726**
	(0.256)	(0.254)	(0.277)	(0.263)	(0.310)	(0.350)
ln (foreign patent rights in other developed countries)	1.808***	1.765***	1.872***	1.727***	1.186***	1.051**
	(0.460)	(0.455)	(0.495)	(0.462)	(0.402)	(0.447)
ln (foreign patent rights in developing countries)	−0.108				0.008	−0.031
	(0.109)				(0.111)	(0.115)
ln (foreign patent rights in upper-income developing countries)		−0.061				
		(0.099)				
ln (foreign patent rights in lower-income developing countries)			−0.136			
			(0.150)			
ln (foreign patent rights in BICK countries)				0.074		
				(0.094)		
ln (public R&D)	0.264**	0.264**	0.261**	0.277**	0.292**	0.275**
	(0.133)	(0.134)	(0.131)	(0.139)	(0.129)	(0.132)
ln (parent R&D)						0.117***
						(0.038)
Time effects	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.4004	0.4003	0.4005	0.4004	0.4126	0.4028
Number of observations	6,253	6,253	6,253	6,253	3,846	3,649

Estimation is by panel fixed effects regression. Robust standard errors clustered at the country-year level are in parentheses. ***, **, and * denote significance levels of 1, 5, and 10%, respectively. The sample consists of US parent firms and their foreign affiliates in 22 developed countries (as listed in Box 1 of the "Appendix") over the period 1982, 1989, 1994, 1999, and 2004 (i.e., BEA Survey Benchmark Years). BICK refers to Brazil, India, China, and S. Korea. Both R&D and sales are in real 2000 PPP US dollars

change in firm R&D if all of the countries in a foreign country group increase their patent protection levels by 1% each. Each foreign country's patent system therefore has a relatively small quantitative impact on domestic R&D but collectively the patent system of other developed countries has a greater quantitative impact on it than the domestic patent system has.

Columns 5 and 6 of Table 6 show the results of estimating Eq. 6 for foreign affiliates only. Again, controlling for other factors, R&D has a significant positive association with patent rights in the domestic economy and in other developed countries, but not with those in developing countries. The measured elasticities associated with developed country patent rights are smaller for the affiliate sample—that is, about 0.8 for domestic patent protection and about 1.1 for patent protection in other developed countries.

The control variables in Table 6, such as sales and R&D employees, have the expected signs and are strongly significant. Tax rates have a negative association with R&D performed; however, the variable is statistically significant at conventional levels for foreign affiliates only, indicating that taxes have some locational influence on affiliate R&D, but not on parent R&D (since its location is fixed). Public R&D funding is a statistically significant determinant of private R&D in both the full and foreign affiliate samples. For the foreign affiliate sample, parent R&D is also controlled for, the motivation for which is that certain foreign affiliates of US parent firms may be performing greater levels of R&D because of their association with high R&D parents. But the inclusion of this variable leads to similar results.

5.3 Sensitivity to alternative weighting methods

The sensitivity of the results to alternative weighting schemes is now examined. Alternative ways to construct the weights were discussed in Sect. 3. Three different weights for foreign patent rights are considered here based on: (i) shares of lagged manufacturing exports; (ii) shares of lagged total exports, as before, but where the within-group weights sum to unity; and (iii) shares of lagged exports plus the lagged stock of FDI. Table 7 shows the results of using these alternative indexes. The table also provides some sample correlations to show how the three newly constructed foreign patent rights indexes correlate with one another and with the previously constructed indexes, as based on lagged total export shares. The foreign patent rights indexes created using manufacturing exports are highly correlated with those using total exports, so the empirical results shown earlier should not be affected too much. Combining FDI stocks and exports also leads to foreign patent rights indexes that are highly correlated with those using exports only. This reflects the fact that shares of outward FDI stock mimic those of exports, as developed country FDI is also mostly concentrated in other developed countries.

The main point to take away from this table is that the earlier results remain largely intact. Controlling for other factors, the R&D of US parents and their foreign affiliates in developed countries depends positively and significantly on domestic patent rights and on the patent rights of other developed countries, not on Southern (developing country) patent rights. As expected, the results are similar if manufacturing exports are used or if FDI stock is added. When the scaled indexes are used, again the patent rights indexes of other developed countries are statistically significant, while those of developing countries are not. As pointed out earlier, scaling inflates the weights of smaller economies. The weights no longer reflect market share. Even so, variations in the patent rights of developing countries do not explain variations in the R&D of these developed country firms.

Table 7 Sensitivity of results to alternative weighting methods

Weighting method[a]	Dependent variable: ln (R&D)		
	Manuf (1)	Exports scaled (2)	Exports plus FDI (3)
Constant	−8.912**	−9.433**	−5.632
	(4.224)	(4.315)	(5.549)
ln sales	0.351***	0.365***	0.365***
	(0.057)	(0.057)	(0.058)
ln R&D employees	0.513***	0.510***	0.513***
	(0.029)	(0.028)	(0.029)
ln (1 + income tax rate)	−0.027	−0.026	−0.027
	(0.041)	(0.041)	(0.042)
ln (domestic patent rights)	1.145***	1.869***	1.271***
	(0.277)	(0.342)	(0.361)
ln (foreign patent rights in other developed countries)	1.795***	3.348***	1.854***
	(0.409)	(0.722)	(0.650)
ln (foreign patent rights in developing countries)	0.029	0.178	0.14
	(0.111)	(0.325)	(0.503)
ln (public R&D)	0.233*	0.131	0.114
	(0.136)	(0.135)	(0.161)
Time effects	yes	Yes	Yes
R-squared	0.4006	0.4016	0.3955
Number of observations	6,253	6,253	6,200

	Exports	Manuf	Exports scaled	Exports plus FDI
(A) Correlation among indexes of patent rights derived for other developed countries:				
Exports	1			
Manuf	0.973	1		
Exports scaled	0.700	0.729	1	
Exports plus FDI	0.720	0.717	0.578	1
(B) Correlation among indexes of patent rights derived for developing countries:				
Exports	1			
Manuf	0.967	1		
Exports scaled	0.581	0.560	1	
Exports plus FDI	0.705	0.681	0.560	1

[a] The above estimates are from the full sample (of US parent firms and their foreign affiliates in 22 other developed countries). Estimation is by panel fixed effects regression over the period 1982, 1989, 1994, 1999, and 2004. Robust standard errors clustered at the country-year level are in parentheses. ***, **, and * denote significance levels of 1, 5, and 10%, respectively. Manuf indicates that shares of manufacturing exports are used as weights. Exports Scaled indicates that the shares of exports sum to unity within each country group and Exports plus FDI indicates that the shares of the sum of the values of exports and FDI are used as weights. The above shows the corre lations among these alternative indexes by country group, where exports refer to the base index used thus far

Note that the estimated coefficients of the patent rights of other developed countries are rather large when the index is scaled. This may arise because the scaled index exhibits less data variability than do the non-scaled ones. The coefficient of variation of the scaled index for the patent rights of other developed countries is 11% compared to 18% for the non-scaled version (see Table 4).

5.4 Variations of main results

Table 8 shows the results of splitting the sample into two groups: firms that are above median R&D intensity and those that are below or equal to the median. R&D intensity is defined here as the ratio of R&D to sales. The purpose is to see if we might at least pick up the effects of Southern patent rights on the R&D of firms that are especially R&D intensive. The table reports the results for the full sample and the foreign affiliate sample. The median R&D/sales ratio is just over 1% for the full sample and 0.8% for the sample that excludes US parent firms.

The full sample results reveal that the significant positive association between R&D and patent rights in developed countries is driven by the sample of highly R&D-intensive firms. This finding is intuitive in that firms with higher rates of R&D performance are more likely to desire strong protection for their intellectual properties. The R&D of firms whose R&D intensity is below or equal to the median is insignificantly associated with the level of patent protection in the domestic economy or in other developed countries. But again Southern patent rights are a statistically insignificant determinant of the R&D of our developed country firms, whether they are highly R&D intensive or not.

The affiliate sample results are similar, except that local patent protection is not a statistically significant determinant of R&D performed locally. For highly R&D intensive affiliates, this suggests that the incentive to conduct R&D is affected marginally by a strengthening of domestic patent rights, where such rights are already relatively strong (as they are in the high R&D countries of Japan, Germany, and the United Kingdom). Instead, this incentive rises more significantly with an increase in the strength of patent rights in other developed countries. The latter represents, to the firm, an expansion in its 'effective' global market. A stronger patent system abroad extends the economic territory of the firm's innovations beyond its domestic market, and thus provides a commensurate increase in incentive for innovation. This is especially the case for an affiliate since one of its key foreign country markets is the United States.

Table 9 presents results by selected industries, in particular the chemical industry, which covers basic chemicals, pharmaceuticals, medicines, agricultural chemicals, synthetic materials, and other chemical products. This provides yet another check to see if the more R&D-intensive firms have greater sensitivity to foreign patent rights. Chemical firms account for about 20% of the firms in the sample and have an above average R&D/sales ratio, namely 1.53% compared to 1.18% for all firms. But another reason to examine this sector is that it performs R&D on technologies, such as drugs and agricultural innovations, that could especially be relevant for developing countries and thus it may be more sensitive to Southern patent rights. Of course, this industry conducts R&D for the Northern

Table 8 Firms grouped by R&D intensity

	Dependent variable: ln (R&D)			
	Full sample		Foreign affiliate sample	
	Above median R&D/sales ratio (1)	Below median R&D/sales ratio (2)	Above median R&D/sales ratio (3)	Below to median R&D/sales ratio (4)
Constant	−6.256	−5.232	−9.873***	−3.227
	(4.039)	(8.681)	(3.663)	(10.697)
ln sales	0.436***	0.676***	0.355***	0.791***
	(0.062)	(0.056)	(0.088)	(0.089)
ln R&D employees	0.314***	0.381***	0.352***	0.258***
	(0.023)	(0.028)	(0.031)	(0.049)
ln (1 + income tax rate)	−0.005	−0.003	−0.018**	−0.033
	(0.046)	(0.003)	(0.008)	(0.047)
ln (domestic patent rights)	0.812***	0.156	−0.389	0.564
	(0.305)	(0.359)	(0.278)	(0.714)
ln (foreign patent rights in other developed countries)	1.368***	1.031	0.966**	0.449
	(0.473)	(0.660)	(0.427)	(0.701)
ln (foreign patent rights in developing countries)	0.01	−0.134	0.071	−0.164
	(0.114)	(0.172)	(0.109)	(0.180)
ln (public R&D)	0.181	0.031	0.331**	−0.144
	(0.134)	(0.259)	(0.129)	(0.327)
ln (parent R&D)			0.130***	0.196**
			(0.033)	(0.097)
Time effects	Yes	Yes	Yes	Yes
R-squared	0.5914	0.3243	0.6411	0.3505
Number of observations	3,799	2,454	2,463	1,186

The median R&D/sales ratio for the entire sample is 1.1% and for the foreign affiliate sample 0.8%. Estimation is by panel fixed effects regression. Foreign patent rights are weighted by (5-year) lagged export shares. Robust standard errors clustered at the country-year level are in parentheses. ***, **, and * denote significance levels of 1, 5, and 10%, respectively. The time periods are 1982, 1989, 1994, 1999, and 2004

market as well and predominantly so. Moreover, the industry classification is still too aggregated to identify specific technologies or research projects intended for developing markets.[20] There may well be narrower classes whose product developments are better linked to the Southern market. It is with these caveats in mind that the results are presented. Columns 1–2 of Table 9 show, nevertheless, that Southern patent rights are insignificantly associated with the R&D of chemical firms. As before, the latter are positively and significantly associated with domestic

[20] Here, four-digit North American Industry Classification System (NAICS) codes (the 2002 version) were used to classify sectors.

Table 9 Firms grouped by selected sectors

	Dependent variable: ln (R&D)			
	Chemical industry		Mixed industry	
	Full sample	Foreign affiliates	Full sample	Foreign affiliates
	(1)	(2)	(3)	(4)
Constant	−3.246	−5.673	−18.18***	−20.42***
	(7.822)	(7.590)	(6.825)	(7.439)
ln sales	0.201*	0.124	0.199	0.111
	(0.106)	(0.128)	(0.126)	(0.163)
ln R&D employees	0.519***	0.587***	0.538***	0.587***
	(0.049)	(0.058)	(0.055)	(0.068)
ln (1 + income tax rate)	−0.019	−0.04	−0.018	−0.054
	(0.015)	(0.042)	(0.025)	(0.057)
ln (domestic patent rights)	0.922**	1.629**	1.360***	1.140**
	(0.453)	(0.681)	(0.370)	(0.552)
ln (foreign patent rights in other developed countries)	1.703***	1.234*	2.382***	1.808***
	(0.618)	(0.643)	(0.556)	(0.655)
ln (foreign patent rights in developing countries)	−0.164	0.044		
	(0.166)	(0.171)		
ln (foreign patent rights in lower income developing countries)			−0.105	0.032
			(0.197)	(0.229)
ln (public R&D)	0.112	0.159	0.545**	0.645**
	(0.250)	(0.252)	(0.220)	(0.253)
ln (parent R&D)		0.136**		0.133**
		(0.056)		(0.058)
Time effects	Yes	Yes	Yes	Yes
R-squared	0.4240	0.4417	0.4712	0.4587
Number of observations	1,532	958	1,592	1,050

The chemical industry includes basic chemical, pharmaceuticals, medicines, agricultural chemicals, cleaning compounds, synthetic materials, and other chemical products. Mixed industry consists of pharmaceuticals, medicines, agricultural chemicals, medical equipment/supplies, food, and agriculture. Estimation is by panel fixed effects regression. Foreign patent rights are weighted by (5-year) lagged export shares. Robust standard errors clustered at the country-year level are in parentheses. ***, **, and * denote significance levels of 1, 5, and 10%, respectively. The time periods are 1982, 1989, 1994, 1999, and 2004

and other developed country patent rights, among other factors. This is the case for both the full and foreign affiliate samples.

Columns 3–4 of Table 9 show the attempt to custom select industries whose R&D may be relatively more relevant to developing economies. This sample mixes firms that conduct R&D on pharmaceuticals, medicines, medical equipment and supplies, food, and agriculture. Thus there is some overlap between this sample and the chemical industry sample. However, as another twist, instead of examining the

patent rights of all developing countries, columns 3–4 focus on the patent rights of lower-income developing countries, where basic necessities (health and food) are of relatively greater importance. But, consistent with the earlier findings, patent rights in lower-income developing countries do not significantly explain the R&D of this mixed group of firms; rather, patent rights in the developed world, along with government R&D funding, and other factors, better explain their R&D.

5.5 Future implications

The results in this paper are based on data from 1982 to 2004. During this period, developing countries accounted for a small share of the market for Northern products. This is a key factor behind why patent rights in the South have been a weak influence on the R&D of US parent firms and their affiliates. However, the South may not remain a weak influence on Northern R&D. As developing country markets expand over time, their patent regimes should assume more prominence in Northern innovation. This section discusses how the findings in this paper may be affected if more recent data are incorporated. At least for the near term, the findings in the paper should remain robust.

Table 10 presents some indicators of interest. First, it shows that, from the perspective of most developed countries, patent rights in developing countries have increased in strength; that is, the ratio of the index of developing country patent rights to the index of domestic patent rights has risen during 2000–2005. Developing economies are gradually catching up to the developed countries in terms of patent strength. Furthermore, the share of manufacturing exports from developed countries to developing countries has increased over the period 2004–2009. In Japan, almost 70% of its recent manufacturing exports are going to developing countries; in the United States, it is over half. (Manufacturing exports are examined since they are typically more patent-sensitive than total exports as a whole.) Thus, developing countries are becoming a more significant share of the market for Northern products. Holding other factors constant, this helps increase the overall strength of patent protection in the South.

However, a positive impact on Northern R&D would be better detected if the R&D of firms had increased recently. Instead, due to the global economic downturn of the late 2000s, the firms in our sample have mostly experienced declines in the real growth of R&D. For example, Table 10 shows that the growth rate of aggregate firm R&D is lower (and even negative) in the 2004–2008 period than it was in the 1999–2004 period for most countries.[21] Moreover, for 13 of the 23 developed countries, the R&D/sales ratio of firms (as a whole) is lower in 2008 than it was in 2004. Thus, including data for 2008 would likely not affect the results that have been found thus far on the effects of Southern patent rights on Northern R&D, controlling for other factors. But for the longer term, there is scope for Southern patent protection to matter more importantly to the R&D of US parent firms and

[21] Since firm-level R&D data cannot be disclosed, only the aggregate firm R&D by country is shown. Furthermore, since 2008 is not a benchmark year, R&D and sales data are available for just 83% of the firms in the sample. Thus Table 10 calculates the growth rate of R&D and the R&D/sales ratio for the truncated sample of firms.

Table 10 Recent developments in northern firm R&D and Southern patent rights

	R&D growth rate (%)		Ratio of R&D to sales (%)		Ratio of southern patent rights to domestic patent rights		Manufacturing exports to South (% of total manufacturing export)	
	1999–2004	2004–2008	2004	2008	2000	2005	2004	2009
Australia	113.8	92.4	1.90	2.69	0.34	0.39	36.3	45.7
Austria	76.2	78.2	4.22	5.92	0.14	0.18	4.7	4.9
Belgium	350.8	192.9	3.02	8.18	0.08	0.10	9.2	12.1
Canada	94.4	−16.1	2.29	1.88	0.05	0.04	11.3	17.5
Finland	119.8	24.0	3.04	3.48	0.16	0.20	18.2	18.8
France	102.1	−26.9	3.71	3.04	0.12	0.14	11.4	13.7
Germany	48.6	4.3	4.04	3.98	0.15	0.17	15.0	17.7
Greece	206.8	306.8	1.12	2.60	0.21	0.32	14.9	21.4
Ireland	560.8	25.2	2.35	1.43	0.05	0.08	12.8	13.7
Israel	144.1	−8.8	19.03	12.40	0.19	0.22	23.6	29.2
Italy	126.5	−7.8	2.16	1.78	0.16	0.17	14.0	17.9
Japan	14.5	−20.6	4.16	3.93	0.35	0.36	62.1	69.0
The Netherlands	133.4	18.2	1.57	1.25	0.08	0.09	24.5	28.2
New Zealand	321.4	−18.5	0.65	1.65	0.26	0.27	25.0	35.5
Portugal	211.0	97.6	0.88	2.04	0.05	0.06	7.0	9.4
Spain	153.5	−12.3	1.15	0.81	0.12	0.14	11.6	16.6
Sweden	103.6	−6.1	6.78	5.89	0.10	0.15	8.3	10.8
Switzerland	406.8	4.1	2.15	1.71	0.14	0.15	7.2	7.2
United Kingdom	121.4	−33.9	5.64	3.88	0.12	0.12	18.6	21.9
United States	17.2	8.3	1.49	1.40	0.27	0.32	47.5	54.4

R&D and sales refer to the aggregate research and development and sales of the firms in our sample. Growth rate of R&D refers to real growth in constant 2000 PPP dollars

Southern patent rights refers to foreign patent rights in developing countries, from the perspective of the Northern (row) country. Manufacturing exports to South … refer to the row country's manufacturing exports to developing countries as a share of the total manufacturing exports of the row country

their affiliates, given the growth in trade between North and South. Even then, the impacts of Southern patent rights on Northern innovation will be conditional on further reforms of patent rights in the South and on the future direction of the TRIPS agreement.

6 Conclusion

North–South models of intellectual property rights make important predictions about how Southern IPRs affect Northern incentives to innovate and transfer

technologies to the South. However, using a sample of US multinational firms and their foreign affiliates in developed countries to represent Northern innovators, this paper finds no supportive evidence that patent protection in developing countries influences the research and development of these firms—even the R&D of highly research-intensive firms. Instead, the dependence of their R&D on patent protection is confined to the strength of patent rights in the developed region. This evidence is robust to different ways of constructing or weighting the levels of patent protection abroad.

A key reason behind the evidence is that the Southern market has thus far accounted for a relatively small share of the North's market. Stronger patent rights expand the turf of rights holders, but in small economies, that expansion accounts for a small percentage change in the rights holders' global market and contributes marginally to Northern rents from innovation.

The policy implications of these results are at least threefold. First, they raise issues about whether Northern researchers have adequate incentives to conduct research on technologies suitable for Southern needs. Second, Northern countries, particularly the United States, were leading advocates for global patent reform. The evidence here suggests that their advocacy was motivated more by the desire to access Southern markets and to protect existing Northern intellectual property assets abroad rather than to create incentives for knowledge creation at the point of origin. Third, as it turns out, the weak linkage between Northern R&D and Southern patent rights suggests that Northern innovation was not especially harmed by the weak levels of patent rights that prevailed in the South.

As extensions to this research, it would be useful to determine if the results can be replicated for the multinational firms and affiliates of other developed economies, such as Japan and Europe. Second, the analysis could be repeated using patent data to further examine the effects of foreign patent rights on Northern innovation. Third, a case study of specific technologies or innovations, such as a specific drug treatment, could better illuminate the factors that influence Northern firms to choose lines of research relevant to developing country interests, including factors beyond patent rights.

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Appendix: data sources and coverage

See Boxes 1, 2.

Box 1 Variables and sources of data

Research and development (R&D), sales, R&D employees, income taxes, and net income	US Bureau of Economic Analysis (2008), *US direct investment abroad*, BE-10 Benchmark Surveys
Index of patent rights	Park (2008)
Bilateral exports	United Nations (2010), *Commodity trade statistics database (Comtrade)*
Bilateral foreign direct investment	Organization for Economic Co-operation and Development (OECD 2010a), *International direct investment statistics* database
Gross domestic expenditure on R&D (by sector of financing and performance)	Organization for Economic Co-operation and Development (OECD 2010b), *Science, technology, and R&D statistics* database
Real GDP, population, and purchasing power parity (PPP) conversion factor	World Bank (2009), *World development indicators*
Governance indicators	Kaufmann et al. (2009) and http://www.govindicators.org
Legal origins	La Porta et al. (2008) (legal origins)

Box 2 Percentage distribution of firms by country (sample size = 2,858 firms)

Australia	3.43%	Japan	4.62%
Austria	0.95%	Luxembourg	0.14%
Belgium	3.12%	The Netherlands	4.76%
Canada	7.56%	New Zealand	0.67%
Denmark	1.05%	Norway	0.49%
Finland	0.95%	Portugal	0.63%
France	7.46%	Spain	3.22%
Germany	11.06%	Sweden	1.89%
Greece	0.25%	Switzerland	2.35%
Ireland	2.21%	United Kingdom	13.41%
Israel	1.16%	United States	23.73%
Italy	4.89%		100%

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