THE IMPACT OF PATENT PROTECTION ON R&D. EVIDENCE USING EXPORT MARKETS.*

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ABSTRACT

We examine whether stronger patent protection promotes private-sector R&D, using changes in the patent rights regime of export-destination countries as a quasi-exogenous source of variation. Constructing an export-weighted index of trade partner patent rights by country-industry-year, we find that R&D responds strongly to trade partner patent rights, and this after including country-industry, country-year, and industry-year fixed effects. This relationship is present in industries where patents are an effective way to protect innovation, but not in patent insensitive industries. Our results suggest a causal link between patent rights and firm R&D investments and support the inclusion of patent rights provisions in trade agreements.

1. Introduction

Intellectual property rights, and patents in particular, are among the key institutions that influence private innovative activity. They allow agents to appropriate their creations, thereby providing increased incentives to innovate. Yet even as strong patenting regimes have spread, they have come under increased criticism amid speculation that, in their current form, they may be stifling innovation (Jaffe and Lerner, 2011). In an influential paper, Boldrin and Levine (2013) begin by stating that "the case against patents can be summarised briefly: there is no empirical evidence that they serve to increase innovation." Indeed, the existing evidence is mixed at best and this lack of strong evidence is often referred to as the "patent puzzle." Determining whether patent rights promote innovation therefore remains an important question with significant policy implications.

The challenge in addressing this question is that patent protection is endogenous. A positive correlation between R&D and domestic patent rights could arise because firms that expect to ramp up R&D expenditures lobby the government for increased patent rights so as to better protect their investment. Alternatively, governments may enact stronger patent protection in response to some expectation of increased domestic R&D. One could envision a number of other scenarios where unobserved variables might influence both domestic patent strength and R&D.

In this paper, we test this relationship between patent rights and private R&D, using changes in the patent rights regime of export destination countries as a quasi-exogenous source of variation. The premise is that a firm considering whether to undertake the development of a new product compares the costs of R&D with the profit stream that the product is expected to earn, not just domestically but also in foreign markets.[1] To the extent that the firm will enjoy a stronger or longer monopoly in its export markets, it has a greater expected foreign income stream associated with the innovation and will therefore have a stronger incentive to perform R&D.

Further, because within a given country different industries export to different destinations, they will effectively face different incentives to innovate. For example, Singapore's largest export industry in 1987, Chemicals, had Japan, Malaysia and Indonesia as its three biggest destination countries, while its second largest export industry, Communications Equipment, exported the most to the United States, Malaysia and the United Kingdom (see Figure 1). Because between 1990 and 1995, patent rights were significantly strengthened in the United States and the United Kingdom, but less so in Japan and Indonesia, ceteris paribus we would expect that if stronger patents indeed foster innovation, the Singapore Communications Equipment industry would have increased R&D expenditures more than the Chemical industry over that period.

More formally, we test whether R&D responds to the patent regime of export markets by constructing an export-weighted foreign patent rights measure at the country-industry-year level for a sample of 20 mostly OECD countries. Controlling for numerous covariates, as well as fixed effects including country, industry, year, and their interaction, we find evidence that R&D responds strongly not only to the domestic patent regime but also to changes in the patent regime of export markets. The latter result provides strong evidence that firms do indeed perform more R&D in response to stronger patent rights in that it is not subject to the same endogeneity concerns.

[1] Under the Paris Convention's provision on national treatment, countries must provide foreign nationals the same intellectual property protection afforded to domestic nationals.

To be sure, we are not proposing that foreign patent regimes are completely exogenous. Firms could lobby foreign countries either directly or through their own government. The TRIPS agreement is a case in point. It was pushed most fervently by the United States following prolonged domestic lobbying by Pfizer and others (Braithwaite and Drahos, 2000). We suggest that foreign patent rights are subject to fewer endogeneity concerns than domestic patent rights. And for the large majority of countries that are too small to effectively lobby on the world stage, foreign patent rights are plausibly exogenous. Importantly, we show that our results are robust to restricting the subsample to these smaller countries.

We also examine whether the relationship between patent protection and R&D is non-monotonic and whether it is stronger for patent-sensitive industries. Overall, we find that firms indeed perform more R&D in response to stronger patent protection, though only up to a point. Further, this relationship is strongest in patent-sensitive industries.

The remainder of this paper is organised as follows. Section 2 briefly outlines the previous literature, while section 3 discusses our methodology, our data, and summary statistics. Section 4 presents and discusses our empirical results and section 5 concludes.

2. Literature Review

The theoretical case for patent protection begins with the understanding that innovation and knowledge are unlike other goods. Innovations are non-rival and only partially excludable. To the extent that the knowledge underlying an innovation is a public good, innovation will be underprovided by the market due to a positive information externality. Patent protection seeks to address this problem by allowing inventors to exclude others from using the innovation for a period of time. The theoretical literature on optimal patent protection has long recognised that a policy of stronger patent rights trades off static welfare losses (due to the temporary monopoly) with dynamic welfare gains (due to increased incentives for innovation) (Arrow, 1962; Nordhaus, 1969).[2] Crucially, then, any argument in favour of stronger patents rests on the case that it will result in a significantly higher level of innovation.

Yet the empirical evidence in this regard remains mixed. In a survey of U.S. patent reforms and their impact on innovation, Jaffe (1999) concludes that little empirical evidence supports the theory that stronger patents increase innovation. Park and Ginarte (1997) examine a panel of countries and find that the strength of a country's patents is positively correlated with R&D, though only for developed countries. Kanwar and Evenson (2003) and Allred and Park (2007), using a similar methodology to that of Park and Ginarte (1997), also find a positive correlation between patent strength and R&D expenditures. However, in a paper that exploits the 1988 expansion of patent scope in Japan, Sakakibara and Branstetter (2001) find no effect of stronger patent protection on R&D. Qian (2007) controls for a country's innovative potential using nonparametric matching and finds that stronger patents do not increase the R&D of pharmaceutical firms except at higher levels of economic development, and then only up to a point. Kyle and McGahan (2012) exploit cross-country variation in the prevalence of diseases and the time that TRIPS was adopted in these countries to determine whether stronger patent protection impacts pharmaceutical R&D spending. They find that increased patent

[2] More recent models examine situations where innovation is cumulative and/or complementary (Green and Scotchmer, 1995; Lemley and Shapiro, 2006; Bessen and Maskin, 2009). In such cases, patent protection could result in lower rates of innovation due to such issues as holdup and coordination problems.

protection in developed countries is associated with increased R&D on the diseases that are most prevalent in those countries, but the same is not true for developing countries.

While the primary contribution of this paper is to use foreign patent rights as a more exogenous source of variation to show that private-sector R&D responds to the patent regime, the relationship between domestic R&D and trade partner patent protection is also interesting in and of itself, and constitutes a second contribution of this paper. A significant theoretical literature addresses the topic, primarily within the context of a North-South model (Helpman, 1993; Lai, 1998; Glass and Saggi, 2002; Branstetter and Saggi, 2011; Dinopoulos and Segerstrom, 2010). Although for the most part these models predict a positive relationship between Northern innovation and Southern patent rights, the result depends on the channel being examined and the particulars of the model. For example, Glass and Saggi (2002) find that stronger foreign patent rights result in imitation being more difficult, which leads to resource wasting, lower levels of foreign direct investment, and reduced domestic innovation.

The empirical literature examining how innovation responds to foreign patent rights is relatively newer. Qiu and Yu (2010) find that U.S. patenting rates increased in response to the implementation of the TRIPS Agreement. However, they do not find U.S. patenting rates to be affected by the strengthening of patent protection by individual or small groups of countries. Most recently, in a paper employing a similar methodology to ours, Park (2012) examines whether Southern patent regimes affect Northern innovation using a micro-database of U.S. multinationals and their foreign affiliates. He finds that the R&D expenditures of these U.S. firms do not respond significantly to the level of patent rights in developing countries, instead responding to the strength of patents in other developed countries. To arrive at this result, he separately constructs a trade-weighted index of foreign patent rights for developing and developed partner countries using the U.S. national share of exports to any particular country as weights (because firm-level exports were unobserved).

Our paper has a different focus in that foreign patent rights are used as an exogenous source of variation to establish a causal relationship between patent regimes and R&D. In addition, our data allows us to use a more robust methodology. We merge private-sector R&D, production, and trade data at the level of the country-industry-year for 20 countries, 42 industries, and the years 1988 to 2005. We examine the relationship between private-sector R&D and the export-weighted foreign patents regime, both of which vary by country, industry, and year. As such, we are able to include in our regressions, not only a number of controls, but also fixed effects for the country, industry, year, and their interaction. We therefore identify the relationship based on differences across countries, industries, and time. For example, we find that otherwise similar industries in the same country exhibit different changes in their level of R&D as a function of having exports that are tilted towards markets with different changes in the level of patent protection. As discussed in the next section, we also address the potential issue of endogeneity in the choice of export partners (and hence of the export-weighted foreign patent rights measure) by fixing the country-industry's export shares at pre-sample levels.

3. Data and Methodology

To examine the impact of patent regimes on investment in innovation, we combine country-year-level data on patent rights with data on business R&D expenditures, industrial output, and imports, each of which are across countries, industries, and time.

The two most commonly used proxies for measuring innovation are patent counts and R&D expenditures. While neither is perfect, R&D is a better choice for our purposes since a positive relationship between patent protection and the number of patents could have been due to firms altering how they protect their innovations (shifting, for example, from using trade secrets to using patents in response to patent rights). We obtain our measure of business enterprise R&D expenditure (BERD) from the OECD Main Science & Technology Indicators (MSTI) database. The data spans 20 countries, 45 industries defined at either the two- or four-digit ISIC rev. 3 classification, and the years 1988 to 2005. However, the data is incomplete; national statistical agencies prevent the publication of R&D expenditures for industries with too few firms. Our panel is therefore unbalanced.[3]

We use the UNIDO Industrial Statistics Database to obtain value-added output by country-industry (at the level of two- and four-digit ISIC rev. 3 classification) for the years 1988 to 2005. We use this variable to normalise R&D by the size of the industry. In particular, we construct our key dependent variable, R&D intensity, as the ratio of business enterprise R&D expenditures and value-added output; it varies at the level of the country-industry-year.

[3] Our final sample consists of all country-industry combinations for which we have observations in at least three of the five periods. Alternatively, we could have balanced the sample and performed the analysis on the 606 remaining observations. Doing so yields results that are fully consistent with those presented in this paper.

The UN Comtrade Database provides a reliable measure of imports by country-product-year, which we use to compute exports by country, product (at the two- and four-digit SITC rev. 3 classification), and year (1987 to 2005). We convert from products to industries using a Euro Stat concordance table linking SITC rev. 3 to ISIC rev. 3 to obtain exports at the country-industry-year level.[4]

Our measure of patent rights is the index of patent protection (IPR) developed by Ginarte and Park (1997) and updated in Park (2008). The index provides scores for 122 countries at five-year intervals between the years 1960 to 2010. It measures the strength of national patent rights as an aggregate score of five factors:

1) Membership in International Treaties,
2) Coverage,
3) Enforcement Mechanisms,
4) Loss of Rights,
5) Duration.

Each factor has a value ranging between zero and one. The range of the aggregate score is therefore from zero (weakest) to five (strongest). Ginarte and Park (1997) provide a more extensive description of this index and its creation. Figure 2 presents the net change in IPR score over our sample period (1988-2005) for a selection of countries.

< Figure 2 >

In order to determine whether business R&D responds to the patent regime in export destination markets, we construct an export-weighted IPR (EIPR). EIPR is computed as

[4] While some product codes map to more than one industry, none of these is in our sample. For instance, SITC product code 57.91 (melons and papayas, fresh) corresponds to both ISIC codes 112 (the growing of vegetables, horticultural specialties) and 113 (growing of fruit, nuts, and beverages) industries, but neither of these industries is in our sample.

the weighted average of the export partners' IPR, where the weights are the share of a country-industry-year's exports to a particular destination country. More formally, defining X_{ijkt} as the value of exports of country i's industry k at time t to destination country *j,* we have:

$$EIPR_{ikt} = \sum_{j \neq i}^{J=122} \frac{X_{ijkt} * IPR_{jt}}{\sum_{j \neq i}^{J=122} X_{ijkt}},$$

where subscript *i* refers to the country of origin, *j* the destination country, *k* the industry, and *t* the year. The summation is over all export destination countries for which we have an IPR.[5]

EIPR is comprised of two components that vary over time: dynamic trade flows and the IPR of the export country. These dynamic trade flows are endogenous in that exports may flow to countries with high levels of IPR for reasons that are related to the R&D intensity in the exporting country. In particular, we might expect that industries that increase their R&D expenditures (i.e., develop higher quality products) would shift exports toward more developed (and higher IPR) export markets. It would be incorrect, therefore, to interpret a positive relationship between R&D intensity and EIPR as evidence that firms respond to increases in the IPR of foreign partners by increasing R&D expenditures. More generally, we are concerned that an omitted variable correlated with R&D may be influencing the export dynamics.

[5] While the Ginarte and Park (1997) IPR index covers the majority of countries, it does not cover all export destinations. The weights are therefore exports as a share of total exports to countries with an IPR score. In our sample, 83% of exports flow toward the 122 countries covered in the Ginarte and Park (1997) IPR index.

We address this concern by fixing export shares at pre-sample (1987) levels.[6] By constructing an index that only varies with changes in partner IPR (and not with changes in trade flows), we address this source of endogeneity and facilitate interpretation of the results. We define partner IPR (PIPR) as:

$$PIPR_{ikt} = \sum_{j \neq i}^{J=122} \frac{x_{ijk87} * IPR_{jt}}{\sum_{j \neq i}^{J=122} x_{ijk87}}.$$

A further consideration in the design of our empirical methodology is the delay with which we can expect domestic R&D intensity to respond to changes in partner IPR. To account for any lags and given that we only observe IPR at five-year intervals, we calculate the forward average of R&D intensity over a five-year period. For instance, we determine the relationship between 1990 PIPR and the average R&D intensity for the years 1990 to 1994, inclusive.[7]

Our specifications also include a number of controls. Following the literature, we control for the size of government by including total *government expenditure*[8] (as a percentage of GDP). We also control for a key input to the innovative process, *human capital*, which we measure as the total enrolment in tertiary education as a percentage of the population. We obtain both variables from the World Development Indicators (WDI) database. These control variables, both country characteristics that vary over time, serve primarily to generate a more reasonable estimate on the effect of domestic IPR on R&D

[6] A similar methodology has been proposed by Park (2012), who uses five-year lagged export shares. Park suggests a further alternative: using as instruments the determinants of a gravity model of trade.
[7] For the year 1988, we use the average R&D intensity values for the years 1988 and 1989. Our results, are robust to excluding this 1988 period from the analysis.
[8] Ideally we would have controlled for the role of government in innovation, but data on government R&D expenditure is notoriously incomplete.

intensity since, in our preferred specification examining the relationship between R&D intensity and partner IPR, we will be including interacted country-year fixed effects.

We also control for the *export partner GDP per capita*. Our concern is that, in the absence of this control, our PIPR index could be measuring the level of development of export partners and not their IPR (since a country's IPR and GDP per capita are correlated). We therefore construct, at the country-industry-year level, an export-weighted partner GDP per capita index in the same way that we have constructed the PIPR index, using 1987 export shares as the weights. We also obtain our GDP per capita variable from the WDI database.

Lastly, we control for an industry's trade openness. The trade orientation of specific industries and countries can be an important determinant in the propensity to innovate. It may be that relatively open industries/countries face more competition and are thus more likely to invest in R&D to remain competitive. Using data from the UN Comtrade and the UNIDO database, we construct our country-industry-year measure of trade openness as the ratio of exports to total production output. We note that this measure of trade openness is subject to significant measurement issues. For instance, the period when goods are produced may not coincide with the period when they are exported if firms carry inventory. It may also be the case that goods are imported and re-exported without undergoing further processing in the country. This likely explains the trade openness value of 194 for Portugal in the manufacturing of office, accounting, and computing machinery in 2005.

Our final dataset is comprised of an unbalanced panel with 1556 observations across 20 developed countries[9], 42 manufacturing sectors[10], and the years 1988, 1990, 1995, 2000, and 2005.

3.1 Descriptive Statistics

Table 1 presents descriptive statistics for our dependent and explanatory variables as well as for the control variables. As expected, the average domestic IPR score (DIPR) is relatively high for our sample of 20 OECD countries, although there is significant variation, from a low of 1.66 for Portugal in 1990 to a high of 4.88 for the U.S. in the years 1995 and 2000. EIPR and PIPR are similar both in terms of their mean and the variance, although the mean of EIPR is slightly lower because the export share to low-IPR developing markets has increased over time for the countries in our sample. PIPR exhibits a higher mean than domestic IPR largely because a number of the larger export markets (e.g., USA, Japan, and Germany) are among the highest IPR countries, with IPR scores (as of 2005) of 4.88, 4.67, and 4.50, respectively. Our key explanatory variable, PIPR, ranges from a low of 1.62 for Australia in 1988 (which had a significant share of exports to developing countries) to a high of 4.9 for Canada in 2005 (which exported mainly to the USA).

< Table 1 >

[9] The countries in our sample are: Australia, Austria, Canada, Denmark, Finland, France, Greece, Hungary, Iceland, Israel, Italy, Japan, Korea, Norway, Portugal, Singapore, Spain, Sweden, U.K., and U.S.A

[10] The comprehensive list can be found in the appendix

3.2 Estimating Equation

Our estimating equation for jointly determining the effect of domestic and foreign partner IPR takes the following form:

$$\ln\left(\frac{R\&D}{Output}\right)_{ikt} = \beta_1 DIPR_{it} + \beta_2 PIPR_{ikt} + \gamma_1 \boldsymbol{X}_{ikt} + \gamma_2 \boldsymbol{X}_{it} + \delta_{\mathrm{i}} + \delta_{\mathrm{k}} + \delta_{\mathrm{t}} + \epsilon_{\mathrm{ikt}} \ ,$$

where our dependent variable is the natural logarithm of R&D intensity (R&D/Output). β_1 measures R&D intensity's responsiveness to domestic IPR and β_2 the responsiveness to export partners' IPR (both DIPR and PIPR are expressed in natural logs). $\boldsymbol{X}$ represents our vector of control variables that vary either by country-industry-year (partner GDP per capita and trade openness) or by country-year (government expenditure and human capital). Our specification also includes country, industry, and year fixed effects to account for additional factors that could affect R&D intensity.

As discussed, we are concerned that domestic IPR is endogenous because firms planning to increase R&D may lobby governments for increased protection or governments may proactively increase domestic IPR in the face of higher expected R&D to better protect the investment of home firms. Since we can't observe the occurrence of such scenarios, they result in an omitted variable bias. In more formal terms, the error term could contain a component that varies by country-year (e.g., firm lobbying) and is correlated with domestic IPR. Thus, our estimate of the coefficient on domestic IPR is likely (upward) biased and should be interpreted accordingly.

Therefore, a more reliable way to determine whether stronger patent rights indeed promote increased firm R&D is to examine the effect of PIPR. To the extent that most firms cannot effectively lobby foreign governments and governments do not strive to promote the interests of foreign innovating firms, we would not expect a correlation between this omitted variable and PIPR.

To further ensure the robustness of our results, some of our specifications include interacted country-year, industry-year, and country-industry fixed effects. Country-year fixed effects control for factors such as the country's level of development, government R&D expenditure, educational attainment, population, and the domestic intellectual property rights regime.[11] Industry-year fixed effects control for any industry characteristics that are changing over time such as whether an industry is evolving to become more or less R&D dependent. Finally, country-industry fixed effects capture any industry characteristics that are particular to a country, such as, for example, whether the industry is more capital intensive in the focal country than it is in other countries. As will be shown, adding any or all of these fixed effects does not significantly change the results.

4. Results and Discussion

Table 2 presents the results of these empirical models. Column 1 presents the regression for our first estimating equation with domestic IPR, export partner IPR, the full set of control variables, and country, industry, and year fixed effects as regressors. Column 2 adds industry-year interacted fixed effects, while Column 3 further adds country-year fixed effects. Column 4 includes the full set of interacted fixed effects.

< Table 2 >

[11] This interacted fixed effect also rules out the lobbying omitted variable bias considered above. Together, the three interacted fixed effects rule out any potential omitted variable bias except where the omitted variable varies by country-industry-year.

Column 1 suggests that both domestic and foreign partner IPR positively impact firm R&D. Both coefficients are significant at the 5% level. However, we need to exercise caution in this interpretation, particularly in the case of domestic IPR, since the estimate likely suffers from an omitted variable bias. The relative magnitudes of the coefficients on DIPR and PIPR are perhaps surprising until we consider that, according to our measure of openness, an average of 81% of productive output is exported. Therefore, it is not unexpected that for this sample of countries foreign IPR has a larger impact on firm R&D than domestic IPR. Among the control variables, only the degree of trade openness is significant. As expected, the coefficient is positive, at least until country-industry fixed effects are introduced, at which point the coefficient is indistinguishable from zero. This is not surprising since most of the variation in the trade openness variable is across different country-industries.

Adding industry-year fixed effects (Column 2) lowers our estimate of the coefficient on both DIPR and PIPR, though they remain large and significant at the 5% level under this more robust specification. Column 3 adds country-year fixed effects, and therefore we drop variables that vary by country-year from the specification (domestic IPR, government expenditure, and human capital). The coefficient on foreign partner IPR is significant at the 1% level.

Our preferred specification, which includes all three interacted fixed effects, is presented in Column 4. We find that export partner IPR still maintains a positive and significant effect (at the 10% level) on domestic R&D. Specifically, we see that a 1% increase in foreign-partner IPR is associated with a 1.271% increase in domestic R&D

investment. Taken together, our results suggest that patent protection has a significant impact on firm R&D.

4.1 Non-Monotonicity between IPR and R&D

Previous theoretical and empirical studies have proposed the possibility that there may be diminishing returns to strengthening IPR. For instance, Helpman (2003) develops a dynamic general equilibrium model and finds that stronger IPR may in fact inhibit innovation in the long run. Murray and Stern (2007), Williams (2013), and Galasso and Schankerman (2014) find that IPR can stifle follow-on innovation. The reason is that when patent rights are too broad, new innovators will frequently be subject to hold-up by previous innovators and may therefore choose not to pursue otherwise profitable innovation projects in the first place. This is especially true in the face of information asymmetries and innovative uncertainties, so that ex-ante licensing agreements are not possible.

Following Allred & Park (2007), we examine the possibility that the effect of foreign partner IPR on R&D is not monotonic by including a quadratic IPR term. The results are presented in Table 3, which presents the same specifications as in Table 2 but with the additional quadratic domestic and foreign partner IPR terms.

< Table 3 >

The addition of the quadratic term has very little effect on our previous results from Table 2. The coefficient on the linear IPR and PIPR terms remains significant across all specifications, and the magnitudes are relatively unchanged.

Consistent with the literature, the quadratic IPR and PIPR terms are always negative (though only significant in the specification with no interacted fixed effects), suggesting a decreasing marginal impact of both domestic and foreign partner IPR on R&D. The point estimates suggest that the optimal level of IPR, in terms of encouraging R&D, lies to the right of the actual observed range of IPR. That is, our coefficients suggest that, keeping everything else constant, R&D expenditures would be highest for IPR scores of 6 or higher, depending on the specification. As shown in Table 1, the highest domestic and foreign partner IPR scores in our sample are 4.88 and 4.85, respectively. This, of course, does not imply that strengthening patent rights would be welfare improving, since our analysis does not account for the deadweight losses that patents generate.

4.2 Industry Sensitivity to Patent Rights

Firms could employ numerous approaches, other than patents, to appropriate the value of their innovation. Alternative methods include secrecy, copyrights, trademarks, a first-mover advantage, or complementary assets in manufacturing or distribution. We would therefore expect the effect of IPR as an incentive to perform R&D to vary by industry. In particular, industries where patents are an effective way to appropriate the value of innovations should exhibit a stronger R&D response to changes in export market IPR.

We classify our 42 industries into more and less sensitive to patent rights and conduct our analysis on each of the two subsamples. Our classification is based on the work of Cohen, Nelson, and Walsh (2000), who surveyed 1478 U.S. R&D labs in the manufacturing sector and determined, by industry, the mean percentage of product innovations for which patents were deemed to be an effective mechanism for appropriation. The mean patent effectiveness score in our sample was 32.0, therefore industries with a score above that were classified as patent sensitive, and those below as less patent sensitive. For six of our industries, Cohen et al. did not provide a patent effectiveness score (either due to their use of a different industry classification or because they did not survey any firms in that sector) and we therefore classified the industry based on how similar industries had been classified.[12] The full classification of industries is presented in the appendix.

The first three columns of table 4 present the results for the set of industries that are most patent sensitive. Across all three specifications we find the effect of export partner IPR on R&D to be highly significant and much larger than what we found for the full sample. In the specification with the full set of interacted fixed effects (column 3) we find that a 1% increase in PIPR contributes a 1.933% increase in R&D (compared to 1.148% for the full sample). For the less patent sensitive industries (columns 4-6) we find much smaller effects of PIPR on R&D. In particular, for our specification with the full set of interacted fixed effects (column 6) we find that a 1% increase in PIPR generates essentially no change (an insignificant 0.053% decrease) in R&D.

4.3 Country Size and Foreign Partner IPR

As a robustness check of our results, we conduct the analysis on the subset of smaller countries that are unlikely to be able to influence foreign IPR. For this set of countries, it

[12] In particular, "Apparel" (18) and "Leather" (19) were classified as patent insensitive like "Textiles" (17), "Wood products" (20) was classified as sensitive like "Paper and paper products" (21), and "Boat building and repairing" (351), "Transport Equipment n.e.c." (359), and "Railway locomotives" (3520) were classified as sensitive like both "Motor vehicles" (34) and "Aircraft and spacecraft" (3540).

is more plausible that changes in the IPR of their foreign partners is exogenous, since neither their firms nor their government are likely to have enough clout to significantly influence IPR in their major export markets (which tend to be the larger countries). The TRIPS agreement, for example, was pushed most fervently by the U.S., Japan, and the larger European countries.

We estimate our empirical models separately on the subsample of the ten smallest and the ten largest countries, as categorized by population in 2005. The results are reported in Table 5.

< Table 5 >

On the whole, the results continue to hold for the subsample of smaller countries. In fact, in the first two specifications for the subsample of small countries (columns 1 and 2), the coefficient on foreign partner IPR is significant and much larger than both the coefficients presented in Table 2 and the corresponding coefficient for the subsample of larger countries (Table 5 columns 4 and 5). In the third specification, however, the coefficient is estimated very inaccurately and is not significant, likely due to the sample not being large enough given the large number of interacted fixed effects.

For completeness, it is worth noting that for small countries the coefficient on government expenditure is positively correlated with R&D and significant. Part of these government expenditures may be subsidies to R&D. Alternatively, we may view this result as governments providing public goods that promote innovation. Or it could be that in smaller countries more innovation results in higher growth and increased government expenditures. The surprising result is that in smaller countries higher levels of enrolment in tertiary education are negatively correlated with R&D. We do not have a good explanation for this apparent correlation, which is not evident for larger countries or for the whole sample.

5. Conclusion

The primary objective of this paper was to determine whether stronger patent rights encourage private-sector investment in R&D. Our results provide new and compelling evidence that they indeed do, at least for the relatively developed set of countries in our sample. We arrive at this conclusion not by directly examining the relationship between domestic firm R&D and domestic IPR, which could be endogenous, but by using export partner IPR as a more exogenous source of variation in the incentives faced by firms. A second advantage of our approach is that this foreign partner IPR measure that we constructed varies by country, industry, and time (unlike domestic R&D); we can therefore control for a broader set of unobservables through the use of interacted fixed effects. This more robust analysis finds a strong relationship between R&D and IPR, particularly for the set of industries where patents are an effective method for appropriating the value of an innovation.

It is important to note, however, that we cannot conclude from these results that stronger patent rights are merited. These results address an important, yet unresolved, piece of the discussion on the merits of patents. To the extent that patents do in fact encourage private sector R&D, it becomes possible that strong patent regimes are warranted, but only if this benefit outweighs the deadweight losses associated with increased market power and the transaction costs associated with patent applications and enforcement. If anything, our finding of diminishing R&D returns to increasing IPR suggests that it may not be optimal to have stronger patents.

Further, from a societal perspective the objective is to foster innovation, not R&D, and while higher levels of R&D are generally associated with increased innovation, this may not always be the case. In particular, one can envision a scenario where stronger patents increase the costs of inventing around previous patents, increasing R&D but not affecting innovation (or even affecting innovation adversely). Thus, it is entirely possible that patents promote R&D but not innovation, and therefore that patents are welfare destroying.

Beyond contributing to the discussion on whether stronger patents encourage private-sector innovation, our results also highlight the fact that the R&D incentives of firms are framed not only by the patent regime in their home country but also by the regime in their export markets. As such, and to the extent that countries have an incentive to free-ride off the patent regimes of trade partners, there exists a rationale for bundling patent protection with trade agreements.

We foresee two important avenues for future work. First, we believe that firm-level studies are warranted, ideally for relatively small open economies where firms are more likely to be export-oriented and hence responsive to changes in foreign IPR. The challenge is to obtain firm-level data that includes both firm R&D expenditures and firm exports by destination country, and this over a long enough time horizon. Second, and most importantly, we must strive towards a welfare analysis of the merits of patent rights. While it might be difficult to directly pursue this agenda, hence the numerous studies examining the different pieces of the puzzle, it is only by addressing the larger welfare question that we may satisfactorily answer the crucial question of how and in what direction we should reform patent regimes.

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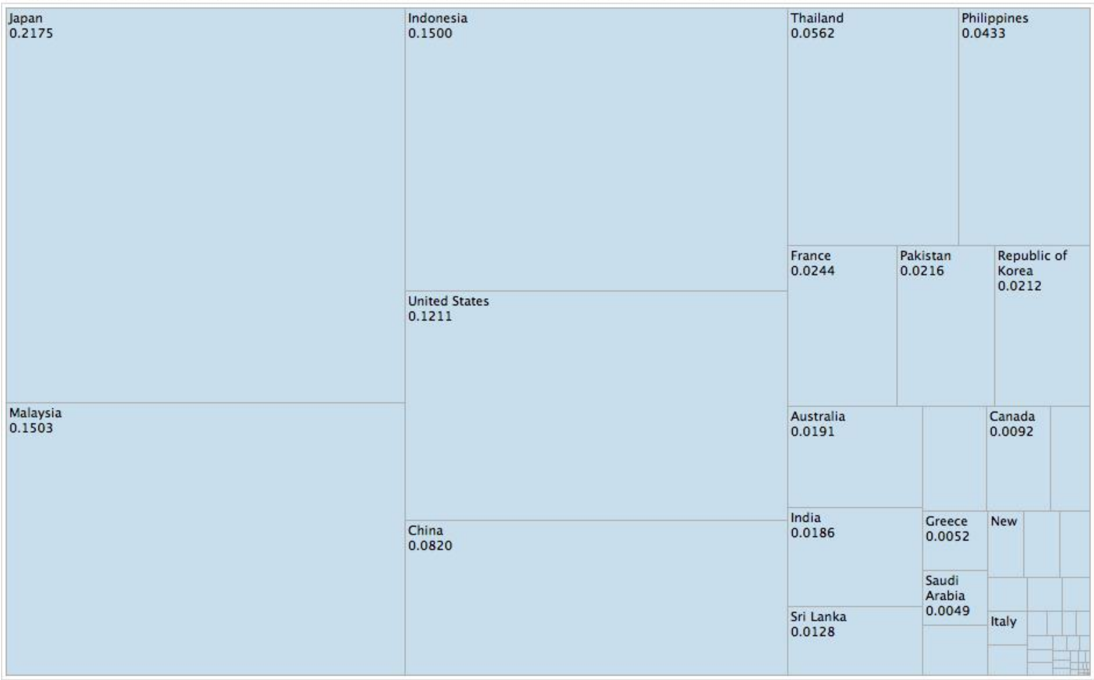
Figures

Figure 1: Fraction of exports by destination for Singapore's two biggest export industries in 1987.

Singapore Manufacture of Chemicals and Chemical Products (ISIC 24) Export Destination Shares



Singapore Manufacture of Radio, Television, and Communication Equipment and Apparatus (ISIC 32) Export Destination Shares

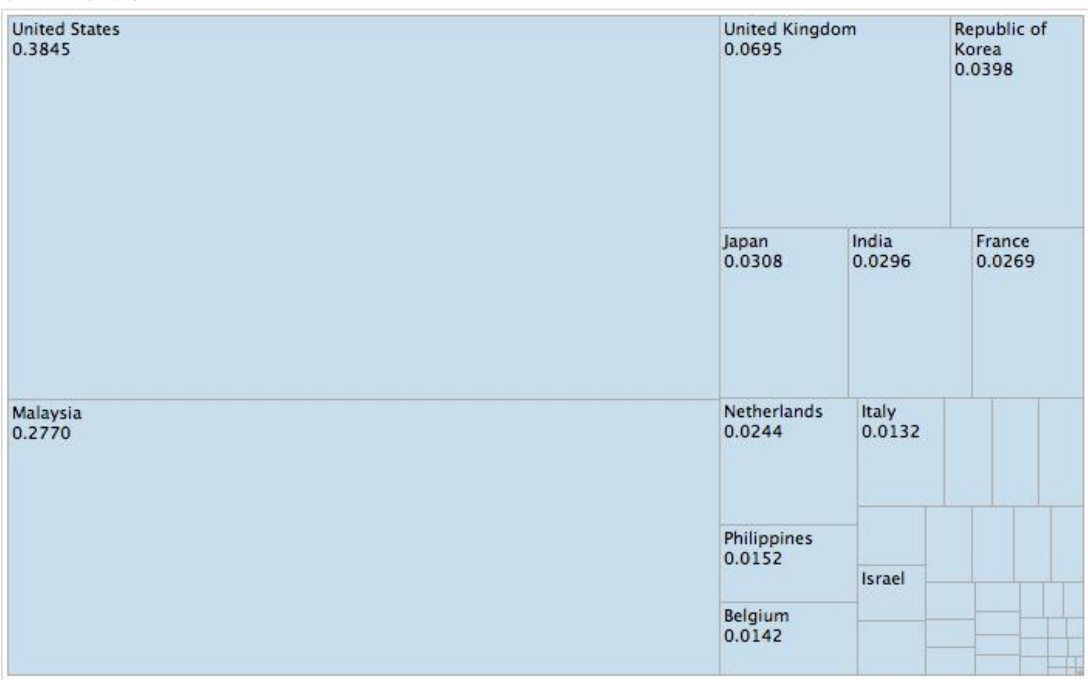
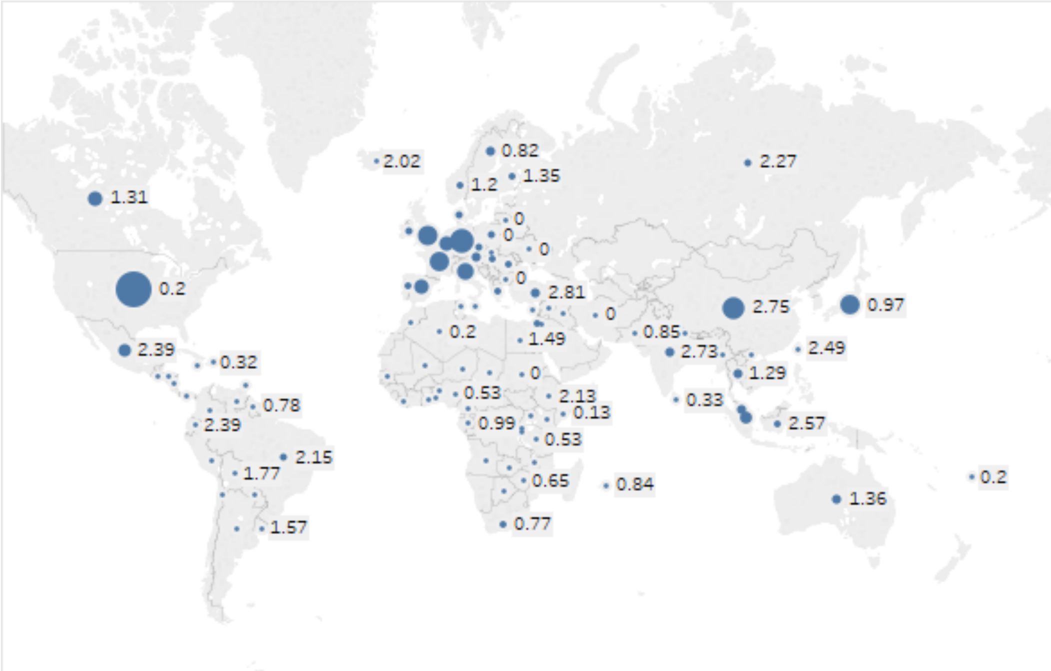


Figure 2: Total imports in 2005 and 1988-2005 change in IPR for a selected set of Countries.



Notes: The size of the markers (circles) represent the magnitude of total imports to the country in 2005. The U.S. had the most imports at 1.73 Trillion U.S. dollars, followed by Germany at 0.78, China at 0.66, the U.K. at 0.53, and Japan at 0.52. To the right of the marker is the change in the IPR between 1988 and 2005 for each country. Slovakia experienced the largest increase in IPR at 3.00, followed by Turkey with 2.81, Papua New Guinea with 2.77, China with 2.75, and India with 2.73.

Tables

Table 1: Descriptive statistics for dependent, explanatory, and control variables.

Variable	Obs.	Mean	SD	Min	Max
ln(R&D Intensity)	1551	-5.05	2.70	-13.65	0.14
DIPR	1551	4.01	0.60	1.66	4.88
EIPR	1551	4.00	0.44	2.16	4.84
PIPR	1551	4.04	0.53	1.39	4.85
Control Variables					
Export Partner GDP Per Capita	1551	23995	7721	2722	55854
Trade Openness	1551	0.81	5.03	5.18e-06	194.22
Government Expenditure	1551	19.49	3.72	10.29	27.82
Human Capital	1551	5.24	1.17	1.98	8.00
Population	1551	3.68e+07	4.95e+07	260685	2.88e+08

Table 2: OLS Estimates of impact of partner IPR on R&D Intensity

Dependent Variable: ln of R&D Intensity

	(1)	(2)	(3)	(4)
ln(DIPR)	0.738**	0.599**		
	(0.302)	(0.263)		
ln(PIPR)	1.148**	1.005**	1.509**	1.271*
	(0.461)	(0.447)	(0.615)	(.679)
Trade Openness	0.013*	0.013**	0.010*	-0.002
	(0.007)	(0.006)	(.005)	(.005)
ln(Partner GDP)	-0.246	-0.177	-0.270	-0.545
	(0.315)	(0.320)	(0.324)	(0.378)
ln(Gov. Expenditures)	0.270	0.396		
	(0.392)	(0.363)		
ln(Human Capital)	-0.381	-0.396		
	(0.340)	(0.305)		
Industry FE	Yes	No	No	No
Country FE	Yes	Yes	No	No
Year FE	Yes	No	No	No
Industry-Year FE	No	Yes	Yes	Yes
Country-Year FE	No	No	Yes	Yes
Country-Industry FE	No	No	No	Yes
R-squared	.9105	.9191	.9248	.9773
No. Obs.	1551	1551	1551	1551

Note: Robust standard errors clustered by country. Sample size consists of 20 countries and 42 industries for the years 1988, 1990, 1995, 2000, and 2005.
* p < .10 , ** p <.05, ***p < .01

Table 3: OLS Estimates of impact of partner IPR on R&D Intensity with quadratic term

Dependent Variable: ln of R&D Intensity

	(1)	(2)	(3)	(4)
ln(IPR)	0.680**	0.542*		
	(0.320)	(0.280)		
ln(IPR^2)	-0.026*	-0.022		
	(0.013)	(0.014)		
ln(PIPR)	1.228**	1.064**	1.552**	1.445*
	(0.447)	(0.435)	(0.595)	(0.720)
ln($PIPR^2$)	-0.096*	-0.088	-0.098	-0.046
	(0.052)	(0.062)	(0.058)	(0.054)
Trade Openness	0.013*	0.013**	0.010*	-0.002
	(0.007)	(0.006)	(0.005)	(0.005)
ln(Partner GDP)	-0.357	-0.276	-0.367	-0.586
	(0.290)	(0.292)	(0.303)	(0.385)
ln(Gov. Expenditures)	0.252	0.379		
	(0.385)	(0.355)		
ln(Human Capital)	-0.394	-0.409		
	(0.332)	(0.298)		
Industry FE	Yes	No	No	No
Country FE	Yes	Yes	No	No
Year FE	Yes	No	No	No
Industry-Year FE	No	Yes	Yes	Yes
Country-Year FE	No	No	Yes	Yes
Country-Indus. FE	No	No	No	Yes
Observations	1551	1551	1551	1551
R-Square	.9112	.9197	.9252	.9773

Note: Robust Standard Errors clustered by country. Sample size consists of 20 countries and 42 industries for the years 1988, 1990, 1995, 2000, and 2005.
* p < .10 , ** p <.05, ***p < .01

Table 4: Results for subsample of industries that are more and less sensitive to patent rights. OLS Estimates of impact of partner IPR on R&D Intensity.

Dependent Variable: ln of R&D Intensity

	Patent Sensitive Industries			Less Patent Sensitive Industries		
	(1)	(2)	(3)	(4)	(5)	(6)
ln(IPR)	0.620			0.882**		
	(0.391)			(0.374)		
ln(PIPR)	1.409***	1.825**	1.933**	0.522	1.045	-0.053
	(0.472)	(0.664)	(0.899)	(0.938)	(1.379)	(0.993)
Trade Openness	0.010*	0.008**	-0.001	0.146***	0.140**	0.122
	(0.005)	(0.004)	(0.004)	(0.032)	(0.047)	(0.072)
ln(Partner GDP)	-0.522*	-0.632*	-0.654	0.141	0.150	-0.365
	(0.287)	(0.309)	(0.435)	(0.515)	(0.540)	(0.919)
ln(Gov. Expenditures)	0.187			0.558		
	(0.289)			(1.070)		
ln(Human Capital)	-0.442			-0.198		
	(0.317)			(0.591)		
Industry FE	Yes	No	No	Yes	No	No
Country FE	Yes	No	No	Yes	No	No
Year FE	Yes	No	No	Yes	No	No
Industry-Year FE	No	Yes	Yes	No	Yes	Yes
Country-Year FE	No	Yes	Yes	No	Yes	Yes
Country-Indus. FE	No	No	Yes	No	No	Yes
Observations	1015	1015	1015	536	536	536
R-Square	.9056	.9198	.9762	.9299	.9474	.9832

Note: Robust Standard Errors clustered by country. Sample size consists of 20 countries and the years 1988, 1990, 1995, 2000, and 2005. Each of the 42 industries is classified as either patent sensitive or insensitive and the analysis is conducted separately on each subsample. Patent sensitive industries are those where the percentage of product innovations that can be effectively protected by patents is higher than the mean across all industries as reported in Cohen, Nelson, and Walsh (2000). The classification of industries is reported in the appendix.
* p < .10 , ** p <.05, ***p < .01

Table 5: Results for subsample of smaller and larger countries. OLS Estimates of impact of partner IPR on R&D Intensity.

Dependent Variable: ln of R&D Intensity

	Sample of Smaller Countries			Sample of Larger Countries		
	(1)	(2)	(3)	(4)	(5)	(6)
ln(IPR)	0.128			0.535		
	(0.529)			(0.641)		
ln(PIPR)	2.331***	1.859**	0.765	1.020	1.448*	1.096
	(0.705)	(0.796)	(1.692)	(0.618)	(0.728)	(0.962)
Trade Openness	0.012	0.013***	0.000	0.216**	0.152	0.230
	(0.007)	(0.004)	(0.004)	(0.084)	(0.097)	(0.137)
ln(Partner GDP)	-0.326	-0.082	-0.802	-0.443	-0.565	-0.338
	(0.448)	(0.472)	(0.864)	(0.271)	(0.325)	(0.455)
ln(Gov. Expenditures)	3.704**			0.287		
	(1.551)			(0.483)		
ln(Human Capital)	-2.761**			-0.318		
	(1.021)			(0.355)		
Industry FE	Yes	No	No	Yes	No	No
Country FE	Yes	No	No	Yes	No	No
Year FE	Yes	No	No	Yes	No	No
Industry-Year FE	No	Yes	Yes	No	Yes	Yes
Country-Year FE	No	Yes	Yes	No	Yes	Yes
Country-Indus. FE	No	No	Yes	No	No	Yes
Observations	724	724	724	827	827	827
R-Square	.8972	.9195	.9741	.9323	.9442	.9849

Note: Robust Standard Errors clustered by country. Sample size consists of 42 industries for the years 1988, 1990, 1995, 2000, and 2005. Countries are divided into one of two subsamples according to their population. The analysis is performed separately on the subsample of small countries (Iceland, Singapore, Norway, Finland, Denmark, Israel, Austria, Sweden, Hungary, Portugal) and large countries (USA, Japan, France, Italy, UK, Korea, Spain, Canada, Australia, Greece).
* p < .10 , ** p <.05, ***p < .01

Appendix

Industries in our sample and their patent sensitivity classification

Industry	ISICr3 Code	Patent Sensitive
Food and beverages	15	I
Textiles	17	I
Wearing apparel, fur	18	I
Leather, leather products, and footwear	19	I
Wood products (excl. furniture)	20	S
Paper and paper products	21	S
Printing and publishing	22	I
Coke, refined petroleum products, nuclear fuel	23	S
Chemicals and chemical products	24	S
Rubber and plastics products	25	S
Non-metallic mineral products	26	I
Basic metals	27	I
Fabricated metal products	28	S
Machinery and equipment n.e.c.	29	S
Office, accounting, and computing machinery	30	S
Electrical machinery and apparatus	31	S
Radio, television, and communication equipment	32	I
Medical, precision, and optical instruments	33	S
Motor vehicles, trailers, semi-trailers	34	S
Other transport equipment	35	S
Special purpose machinery	292	S
Building and repairing of ships and boats	351	S
Transport equipment n.e.c.	359	S
Pharmaceuticals, medicinal chemicals, etc.	2423	S
Basic iron and steel	2710	I
Basic precious and non-ferrous metals	2720	I
Engines & turbines (not for transport equipment)	2911	S
Machine tools	2922	S
Weapons and ammunition	2927	S
Electric motors, generators, and transformers	3110	I
Lighting equipment and electric lamps	3150	S
Other electrical equipment n.e.c.	3190	S
Electronic valves, tubes, etc.	3210	I
TV/radio transmitters; line comm. apparatus	3220	I
TV and radio receivers and associated goods	3230	S
Medical, surgical, and orthopaedic equipment	3311	S
Measuring/testing/navigating appliances, etc.	3312	I
Optical instruments & photographic equipment	3320	I
Railway/tramway locomotives & rolling stock	3520	S
Aircraft and spacecraft	3530	S
Furniture	3610	S
Other manufacturing n.e.c.	3699	S