DO FIRMS RESPOND TO STRONGER PATENT PROTECTION BY DOING MORE R&D?*

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Abstract

We examine whether stronger intellectual property rights (IPR) promote firm R&D, using changes in the IPR of export-partner countries as an exogenous source of variation. Constructing an export-weighted index of trade partner IPR by country-industry-year, we find that R&D responds strongly to trade partner IPR, and this after including industry, year, country, and interacted fixed effects. We further find evidence of this relationship at the level of the establishment, using a unique Canadian dataset. Our results suggest a causal link between IPR and firm R&D investments.

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1. Introduction

IPR and Intellectual property rights (IPR) are among the key institutions that influence private innovative activity. They allow firms to appropriate their creations, thereby providing increased incentives to innovate. Given the importance of IPR in an increasingly knowledge-based economy, it is perhaps not surprising that IPR regimes have been strengthened across the globe. Yet IPR, and patent protection in particular, are coming 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 summarized 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 such an empirical relationship exists therefore remains an important question with significant policy implications. In this paper, we develop a robust methodology to test this relationship, using export partner country IPR as an exogenous source of variation, and find strong evidence that patent protection promotes private-sector R&D.

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 recognized that a policy of stronger IPR trades off static welfare losses (due to the temporary monopoly) with dynamic welfare gains (due to increased incentives for innovation) (Arrow, 1962; Nordhaus, 1969).[1] Crucially, then, any argument in favor of stronger IPR 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 IPR increases innovation. Park and Ginarte (1997) examine a panel of countries and find that the strength of a country's IPR 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 a country's IPR and R&D. 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. Focusing on the pharmaceutical industry, Qian (2007) finds that stronger IPR do not increase the R&D of firms except at higher levels of economic development and then only up to a point.

A concern common to all the above papers is the possibility of an omitted variable bias that could account for some of the positive findings. For example, the correlation between IPR and R&D could arise because firms that expect to ramp up R&D expenditures lobby the government for increased IPR so as to better protect their investment. Alternatively, governments may enact stronger IPR protection in response to some expectation of increased domestic R&D. One could envision myriad other scenarios

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[1] 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.

where unobserved variables might influence both IPR and R&D. Qian (2007) partially addresses such scenarios by employing a nonparametric matching method that controls for some of the covariates that could be associated with a country's innovative potential.

In this paper, we propose to address endogeneity using the IPR regime of a country's trade partner as an 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.[2] To the extent that the firm will enjoy stronger patent protection 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.

We test whether R&D responds to the IPR regime of export markets by constructing an export-weighted foreign IPR measure. In Section 2, we construct this variable at the country-industry-year level for a sample of 20 countries. Controlling for numerous covariates as well as fixed effects including country, industry, year, and their interaction, we find unambiguous evidence that firm R&D responds strongly not only to the domestic IPR regime but also to the IPR regime of export markets. The latter result, since it is not subject to the same concerns of endogeneity, provides strong evidence that firms do indeed perform more R&D in response to stronger IPR. Notwithstanding, we do find diminishing returns to stronger IPR in terms of its positive impact on R&D. To provide additional evidence on the relationship between IPR and R&D, in Section 4 we perform a similar analysis on a sample of Canadian export-oriented firms, constructing the export

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

partner IPR measure at the establishment-industry-year level, and obtain consistent results.

While the primary contribution of this paper is to use foreign IPR as an exogenous source of variation to show that firm R&D responds to the IPR regime, the relationship between domestic R&D and trade partner IPR 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 IPR, the result depends on the channel being examined and the particulars of the model. For example, Glass and Saggi (2002) find that stronger foreign IPR results in imitation being more difficult, which leads to resource wasting, lower levels of FDI, and reduced domestic innovation.

In contrast to the theoretical literature, empirical work in this area is in its relative infancy. In perhaps the first empirical paper examining how innovation responds to foreign IPR, 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. While these are important findings, the use of patents as a measure of innovation could potentially be problematic in this context. For instance, the findings are consistent with U.S. firms responding to stronger global IPR, not by increasing innovation but by maintaining the same level of innovation and switching to protecting their intellectual property through patents instead of trade secrecy or other means. Hence, it would seem that for the purpose of analyzing the relationship between innovation and IPR, R&D expenditures (an input measure of innovation) are a better measure.

Most recently, in a paper employing a related methodology to the one presented here, Park (2012) examines whether Southern intellectual property rights 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 IPR in developing countries, instead responding to the level of IPR in other developed countries. To arrive at this result, he separately constructs a trade-weighted index of foreign IPR 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).

Relative to Park (2012), our paper has a different focus in that foreign IPR are used as an exogenous source of variation to establish a causal relationship between IPR 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 IPR regime, both of which vary by country, industry, and year. As such, we are able to include in our regressions, not only numerous 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 perform different levels of R&D as a function of having exports that are tilted towards different markets with different levels of IPR. We also address the potential issue of endogeneity in the choice of export partners (and hence of the export-weighted foreign IPR measure) by fixing the country-industry's export shares at pre-sample levels. In addition, we repeat our analysis on a unique micro-dataset of Canadian firms and find consistent results, although these should be interpreted as suggestive because of the small size of the dataset and our limited access to it. Overall, we find that firms indeed perform more R&D in response to stronger IPR.

The remainder of this paper is organized as follows. Section 2 discusses our methodology, the primary dataset, and presents summary statistics, Section 3 presents and discusses our empirical results for the full sample of countries, and Section 4 discusses our micro-dataset of Canadian firms and presents our results for that analysis. Finally, Section 5 concludes.

2. Dataset and Methodology

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

[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

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), and for the years 1988 to 2005. We use this variable to normalize 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.

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 IPR is the patent protection index developed by Ginarte and Park (1997) and updated in Park (2008). The IPR index provides scores for 122 countries at five-year intervals between the years 1960 to 2010. The IPR index 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.

the 606 remaining observations. Doing so yields results that are fully consistent with those presented in this paper.

[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.

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.

In order to determine whether business R&D responds to the IPR regime in export destination markets, we construct an export-weighted IPR (EIPR) index. EIPR is computed as 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 index.[5]

EIPR is comprised of two components that vary over time: dynamic trade flows and the IPR regime of the export country. These dynamic trade flows are endogenous in that exports may flow to countries with high levels of IPR protection 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

[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.

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.

We address this issue 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 final dataset is comprised of an unbalanced panel with 1556 observations across 20 developed countries, 42 manufacturing sectors, and the years 1988, 1990, 1995, 2000,

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[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.

and 2005. We present the list of countries and industries in our sample in Tables 8 and 9 in the appendix.

2.1 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 >

Two of our control variables are country characteristics that vary over time. 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 enrollment in tertiary education as a percentage of the population. We obtain both variables from the World Development Indicators (WDI) database. These control variables serve primarily to generate a more reasonable estimate on the effect of domestic IPR on R&D 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 potentially significant measurement issues. For instance, the period when goods are produced may not coincide with the period when they are exported if

[8] Ideally we would have controlled for the role of government in innovation, but data on government R&D expenditure is notoriously incomplete.

firms carry significant 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 194.22 for Portugal in the manufacturing of office, accounting, and computing machinery in 2005. We therefore draw on the fact that smaller economies tend to be more open, to propose an alternative measure of trade openness: population (varying at the level of the country-year). The principal results, presented below, include trade openness as the control variable. However, these results are unaffected by its exclusion or by the use of population as an alternative measure.

2.2 Estimating Equation

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

$$\ln\left(\frac{R\&D}{Output}\right)_{ikt} = \beta_1 DIPR_{it} + \beta_2 PIPR_{ikt} + \gamma_1 \boldsymbol{X}_{ikt} + \gamma_2 \boldsymbol{X}_{it} + \delta_i + \delta_k + \delta_t + \epsilon_{ikt} ,$$

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 intellectual property 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. Nonetheless, it is possible that other types of omitted variables could bias our results. Thus, we adopt a more rigorous specification. To rule out biases introduced by any omitted variables (except possibly by ones that vary by country, industry, and year), we introduce interacted country-year, industry-year, and country-industry fixed effects. Our preferred specification for determining the impact of (foreign partner) IPR on domestic R&D is therefore:

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

This specification controls for any country factors that vary over time, such as the country's level of development, government R&D expenditure, educational attainment, population, and domestic IPR regime. In addition, the 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 intensive. Lastly, our country-industry interaction fixed effect captures any industry characteristics that are particular to a country. For example, it controls for the fact that shoe manufacturing is more capital intensive in some countries than it is in others.

To the best of our knowledge, this is the first paper to estimate whether intellectual property rights influence firm R&D using this robust a specification.

3. 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 interaction fixed effects, while Column 3 further adds country-year fixed effects. Column 4 is our preferred specification, which includes the full set of fixed effects and their interactions, as described by our second estimating equation.

< Table 2 >

Column 1 suggests that both domestic and foreign partner IPR positively impact firm R&D. Both coefficients are significant at the 1% 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 remarkable 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. Our coefficients nonetheless remain 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 each of the fixed effects and their interactions, is presented in Column 4. We find that export partner IPR still maintains a positive and significant effect (at the 5% level) on domestic R&D. Specifically, we see that a 1% increase in foreign-partner IPR is associated with a 1.3% increase in domestic R&D investment.

3.1 Trade Openness and Foreign Partner IPR

It is important to note that the coefficient reported above is the mean across all countries, including some of the larger countries that export smaller fractions of their output. The principal premise behind this paper is that firm R&D responds to the IPR regime of trade partners because stronger protection in the markets where they sell their products will yield them higher returns to innovation. Therefore, we would expect that the R&D of country-industries that rely more on export markets would respond more strongly to the export partner IPR index.

We test this prediction by adding a *population x PIPR* interaction term to our regression.[9] As discussed, countries with smaller populations tend to be more open to trade. Therefore, we expect the coefficient on the interaction term to be negative (smaller countries respond more to PIPR). Table 3 confirms this is the case.

< Table 3 >

Countries with smaller populations (which are typically more open) respond strongly to partner IPR. These results are statistically significant for all specifications and suggest a large variation in how responsive countries are to foreign partner IPR as a function of population, from a large response for small countries to essentially no response for the largest countries. Our preferred specification (Column 4) finds the largest variation across country size. The coefficients predict that a 1% increase in foreign partner IPR is associated with a 5.5% increase in domestic R&D for Iceland (our smallest country, with a population of 261,000), while for the U.S. (our largest country with a population of 288 million), it is associated with a 1.5% decrease. Of course, the coefficients estimate average effects and are best interpreted as predicting the response of countries that are not

[9] Ideally, we would employ an interaction between the trade openness variable and PIPR to test this implication. However, as previously discussed, our trade openness variable is subject to extreme values that are likely due to measurement problems. Using this variable results in strong collinearity: the *trade openness x PIPR* interaction variable and the *trade openness* variable have a correlation coefficient of 0.9999. Another proxy for openness is the country's GDP. Using an interaction with GDP instead of population yields similar results to the ones presented.

outliers (which explains the negative result for the U.S.). For our mean sized country (with a population of 36.8 million), a 1% increase in foreign partner IPR is associated with a 0.6% increase in domestic R&D investment.

As an aside, this result that R&D in smaller countries responds more to foreign IPR also helps to allay the concern that foreign IPR is not exogenous because countries (and their firms) are, through trade agreements, influencing foreign IPR. We would expect larger countries such as the U.S. to exert the most influence on foreign IPR through agreements such as TRIPS, and yet the R&D of large countries responds the least strongly to foreign IPR. Conversely, small countries such as Singapore and Iceland are unlikely to exert much influence on foreign IPR, and their R&D responds most strongly.

For completeness, it is worth noting the coefficients on the control variables. Columns 1 and 2 show a significant positive correlation between population and R&D. Perhaps it is because a larger home market makes it more attractive to undertake the fixed costs of innovating. An alternative explanation could be that countries with increasing innovation experience population growth. The coefficient on government R&D is also as expected if we assume that governments provide public goods that promote innovation or alternatively if we assume that more innovation results in higher growth and increased government expenditures. The surprising result is that higher levels of enrollment in tertiary education are negatively correlated with R&D. We do not have a good explanation for this apparent result, although given the marginal significance of the coefficient here, and the fact that the same coefficients are insignificant in Tables 2 and 4, it may simply be a spurious finding.

3.2 Non-Monotonicity between IPR and R&D

Previous theoretical and empirical literature has addressed 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 4, where Column 4 gives the results of the fully specified model and Column 5 adds the population interaction term.

< Table 4 >

The addition of the quadratic term has very little effect on our previous results from Tables 2 and 3. The coefficient on the linear IPR term remains significant across all specifications, and the magnitudes are largely unchanged. Similarly, Column 5 shows that the coefficient on the population interaction term is unchanged.

The fact that the quadratic IPR term (both domestic and foreign partner) is significant in all but one specification indeed suggests that the relationship between IPR and R&D is non-monotonic. As expected, we find a decreasing marginal impact of both domestic and foreign partner IPR on R&D. However, in all specifications, our estimates suggest that the optimal level of IPR, purely 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 mean that the higher the IPR score the better, since we have not considered the welfare cost of deadweight losses that are associated with IPR.

4. Evidence from Canadian Firms

The previous section provides evidence that R&D, at the level of the country-industry, responds strongly to foreign partner IPR. A natural next step is to determine whether we observe the same relationship at the level of the firm. In particular, do a firm's R&D expenditures respond positively to changes in the IPR of the countries to which it exports? To the best of our knowledge, this question has yet to be addressed, likely due to the dearth of firm-level data that includes both firm R&D expenditures and firm exports by destination country. Moreover, such a dataset would have to be from a relatively small, open country where firms are more likely to be export-oriented and hence responsive to changes in foreign IPR.

Through an internship at Industry Canada, we have been able to gain limited access to such a unique dataset: the T2-LEAP-Export Registry Database linked to the Research & Development in Canadian Industry (RDCI) database. We note, however, that for reasons of confidentiality we were not given direct access to the data, but instead were able to submit a limited number of batch analyses to be performed by Statistics Canada staff. Also, as discussed below, the data spans a limited period of time and there is limited variation in foreign export partner IPR since more than three quarters of Canadian exports are destined for the U.S.A.. As such, this section should be seen as a first firm-level analysis of this question, and the results should be interpreted as suggestive and complementary to the main findings in section 3.

The dataset includes all incorporated export-oriented business enterprises in Canada that have also pursued R&D investments and comprises both key financial information (including R&D expenditures[10] and sales) as well as detailed values of exports by the eight-digit Harmonized System (HS) code, export destination country, and year. The data is at the level of the establishment, with many firms having more than one establishment, and covers the years 2000 to 2008, inclusive. Table 5 summarizes the manufacturing product categories in our sample, where for parsimony of presentation we group the products covered at the two-digit Harmonized System (HS) level.[11]

< Table 5 >

Canada represents a good test bed for the analysis in question in that it is a relatively small and very open economy. Specifically, in 2008, Canada's total imports and exports represented over two thirds (67.2%) of GDP. However, the use of Canada also poses certain concerns. Chief among these is that Canada has one major trade partner: the

[10] R&D expenditures include both current and capital expenditures on R&D, where current expenditures refer to wages, salaries, and other current costs, such as contracts and services required to carry out R&D, while capital expenditures refer to the costs of land, buildings, and equipment.

[11] We exclude food, vegetables, beverages, as well as articles of leather, fur, and imitation jewellery.

United States. In 2008, 78% of all Canadian exports were destined for the U.S. The concern is that a single country's IPR could have a large influence in the average levels of foreign partner IPR in our sample. For this reason, and because U.S. IPR was unchanged between 2000 and 2008, we exclude from our sample establishments that export exclusively to the U.S. (such establishments would have no variation in foreign partner IPR).

A second concern is that many of the firms in our sample are large multinationals with complex international organizational structures. For these firms, it is not clear that product research and production would be collocated and hence that there should be a link between export market IPR and R&D. For example, such firms might develop new products in a centralized location and serve foreign markets through horizontal FDI instead of exports. Alternatively, a product might be developed in one country and produced and exported by an affiliate in another. Our data does not allow us to observe the organizational structure of the firm, and thus we are unable to address these issues beyond restricting our sample to the smaller firms that are least likely to be multinational organizations. We therefore limit our sample to firms that have on average fewer than 100 employees; our results should be interpreted accordingly. The final dataset is comprised of 455 establishments across 341 product categories (at the four-digit HS level) that cumulatively export to 117 countries.

The short time span of our data (2000 to 2008) may also present challenges in that there is limited change in the IPR of countries over this time. Our timeframe falls after the period of rapid IPR change that followed the 1994 inclusion of the TRIPS Agreement into the WTO framework. The TRIPS Agreement was largely implemented in three phases. The first transition period (1995-2000), by the end of which WTO member countries were required to implement the agreement, falls before our sample. However, certain (developing) countries were allowed to delay implementation of TRIPS until 2005 in technological areas where they did not previously have patent protection. This is likely an important source of the variation in IPR that we observe between 2000 and 2005. The third implementation phase (post 2005) applied to the least developed countries and also falls outside our sample.

As expected, we observe an increase in IPR scores between 2000 and 2005: 69 of 122 countries had increases in their IPR score over this period, with only Iraq showing a decline. In most of these cases (42 of 69 countries), the IPR index increase was relatively modest (less than 20%). The largest increases in IPR were primarily in Africa and Latin America, neither of which is a major destination of Canadian exports. To the extent that there is little variation in the foreign partner IPR of Canadian firms, it may be difficult to observe a strong relationship between partner IPR and R&D.

4.1 Methodology

As a first step, we construct for each establishment an export-weighted IPR index (EIPR) similar to the index we constructed in Section 2 for each country-industry. This index is the weighted average of the establishment's export partners' IPR, where the weights are the proportion of the establishment's exports that are destined for each partner country. More formally, defining X_{ejt} as the value of exports from establishment *e* at time *t,* to country *j*, we have:

$$EIPR_{et} = \sum_{j=1}^{J} \frac{X_{ejt} * IPR_{jt}}{\sum_j X_{ejt}}.$$

To avoid endogeneity issues related to the choice of export destinations, we define as before our "fixed" export share partner IPR (PIPR) index as:

$$PIPR_{et} = \sum_{j=1}^{J} \frac{X_{ej99} * IPR_{jt}}{\sum_j X_{ej99}}$$

As before, we construct five-year intervals. Since domestic R&D intensity (measured as the ratio of R&D expenditure to sales) is unlikely to respond immediately to changes in export partners' IPR, we examine the relationship between year 2000 PIPR and the *forward* average of R&D intensity over the years 2000 to 2004, as well as year 2005 PIPR and average R&D intensity over the years 2005 to 2008.

To examine the relationship between export-partner IPR and Canadian innovation, we use OLS to estimate the following econometric model:

$$Log\left(\frac{R\&D}{Sales}\right)_{ikt} = \beta_0 + \beta_1 PIPR_{ikt} + \delta_i + \delta_k + \delta_t + \epsilon_{ikt} ,$$

where β_1 is the coefficient of interest, capturing the degree to which the establishment's R&D responds to export-partner IPR. Our model includes firm (δ_i) and product (δ_k) fixed effects to account for time invariant firm and product unobservables. It also includes time fixed effects (δ_t). We note that Canada's domestic IPR index is not included as a control variable in this model because it would be absorbed in the time fixed effects.

It should be noted that in order to include a product fixed effect, each establishment must be assigned a single export product. While the assignment of exported product is unambiguous for the large majority of establishments since they only produce and export a single four-digit Harmonized System (HS) product, a small portion of establishments export more than one product. For these, we assign the product with the largest total exports.

4.2 Descriptive Statistics

Tables 6 provides descriptive statistics for R&D intensity, EIPR, and PIPR in the Canadian sample. As before, PIPR exhibits a higher mean than EIPR, presumably because Canadian firms have, over time, increased the share of exports to developing countries. Table 7 shows that EIPR and PIPR are positively correlated, as expected.

< Table 6 >

< Table 7 >

4.3 Results

Table 8 presents our results, where we control for year, industry, and establishment fixed effects. These establishment level results are consistent with the country-industry level analysis, although not surprisingly, they are weaker. While they suggest a positive relationship between partner IPR and R&D, these results are statistically significant only at the 18% level. As previously mentioned, there are several issues with the potential to severely attenuate our Canadian results and make it difficult to observe a significant relationship between R&D and partner IPR. In particular, our results could be weaker because Canadian firm R&D might be driven largely by Canadian and U.S. market conditions, while export partners other than the U.S. are the only source of variation in the partner IPR measure over the observed period. For example, the product categories of recording apparatuses and electric motors (HS 852 and 850 respectively) export close to 80% of their goods to the U.S. and the next largest export market is Mexico, whose IPR was also relatively stable between the years 2000 and 2005 (it increased by 5%). By way of example, if we exclude the five establishments that export recording apparatuses, our results become significant at the 12% level. If we exclude both (15 establishments in all), our coefficient is significant at the 5% level.

< Table 8 >

Overall, while the results are as expected weaker for the Canadian case, they still suggest a relationship between R&D and partner IPR, and they are thus consistent with our international findings from Section 3.

5. Conclusion

The primary objective of this paper is to determine whether stronger IPR encourages firm investment in R&D. Our results provide new and compelling evidence that they indeed do. We arrive at this conclusion not by directly examining the relationship between domestic firm R&D and domestic IPR, which is highly endogenous, but by using export partner IPR as an exogenous source of variation in the IPR 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 fixed effects for the country, industry, year, and their interactions. This more robust analysis finds a strong relationship between R&D and IPR, particularly for open economies.

In addition, in what we believe to be the first analysis of its kind, we use a unique Canadian dataset to determine whether, at the level of the product/establishment, R&D responds to changes in the IPR regime of its export markets. The results we obtain are weaker but still consistent. That is, Canadian establishments increase R&D in response to stronger partner IPR, but the estimated effect is an order of magnitude weaker than it is for the industry level analysis, perhaps due to attenuation associated with Canada's strong trade ties with the IPR-invariant U.S. and the limited time span of the sample.

It is important to note, however, that we cannot conclude from these results that stronger IPR is merited. These results address an important yet unresolved piece of the IPR discussion, whether managers respond to stronger IPR by increasing the R&D budget. But they do not address the net welfare effects of IPR. In particular, while this paper finds benefits to IPR in the form of increased firm R&D (which we tend to believe is undersupplied by the market), it in no way compares these benefits to the welfare losses associated with increased market power. If anything, our finding of diminishing returns to increasing IPR suggests that strong IPR might not be optimal. Further, the objective of IPR is to encourage 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 IPR increase the costs of inventing around previous patents, increasing R&D but not affecting innovation (or even affecting innovation adversely). Thus, examining how IPR affect R&D and innovation (perhaps measured by patent counts) jointly is an important avenue for future work.

Beyond contributing to the discussion on whether stronger IPR encourage private-sector innovation, our results also highlight the fact that the R&D incentives of firms are framed not only by the IPR regime in their home country but also by the IPR in their export markets. As such, they offer a rationale for the inclusion of TRIPS into the WTO or the adoption of the controversial Anti-Counterfeiting Trade Agreement (ACTA).

We foresee two important avenues for future work. First, we believe that additional firm-level studies are warranted, ideally with larger data sets and a longer time horizon. As outlined, the use of Canada as the test case brings both advantages and disadvantages, and it would be useful to replicate the analysis for other countries, for longer time periods, and with full access to the data. Second, and most importantly, we must strive towards a welfare analysis of the merits of IPR. While it might be difficult to directly pursue this agenda, hence the numerous studies examining the different pieces of the problem, 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 IPR policy.

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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

	Full Sample			
	(1)	(2)	(3)	(4)
Ln(DIPR)	0.788***	0.599**		
	(0.281)	(0.282)		
Ln(PIPR)	1.148***	1.005**	1.509***	1.271**
	(0.419)	(0.437)	(0.518)	(.572)
Trade Openness	0.012**	0.013**	0.009**	-0.001
	(0.005)	(0.005)	(.004)	(.006)
Partner GDP	-0.245	-0.176	-0.270	-0.544
	(0.185)	(0.184)	(0.199)	(0.395)
Gov. Expenditures	0.269	0.395		
	(0.408)	(0.399)		
Human Capital	-0.381	-0.396		
	(0.271)	(0.262)		
Industry FE	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
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 correcting for heteroskedasticity. 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 population interaction term

Dependent Variable: Ln of R&D Intensity

	Full Sample			
	(1)	(2)	(3)	(4)
Ln(IPR)	.283	0.121		
	(0.319)	(0.306)		
Ln(PIPR)	9.643***	9.642***	11.415**	18.064**
	(2.991)	(2.907)	(4.55)	(7.862)
Ln(Pop) x Ln(PIPR)	-.508**	-.518**	-.597**	-1.005**
	(.171)	(.165)	(.265)	(.458)
Population	2.235**	2.464**		
	(1.12)	(1.12)		
Trade open	.012**	.013**	.009**	-.001
	(.006)	(.005)	(.005)	(.006)
Partner GDP	-.246	-.168	-.260	-.531
	(.187)	(.186)	(.204)	(.389)
Gov. Exp.	1.040**	1.220***		
	(.481)	(.463)		
Human Capital	-.6304**	-.651**		
	(.278)	(.265)		
Industry FE	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Industry-Year FE	No	Yes	Yes	Yes
Country-Year FE	No	No	Yes	Yes
Country-Industry FE	No	No	No	Yes
R-squared	.911	.919	.925	.977
No. Obs.	1551	1551	1551	1551

Note: Robust Standard Errors correcting for heteroskedasticity. 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: OLS Estimates of impact of partner IPR on R&D Intensity with quadratic term

Dependent Variable: Log of R&D Intensity

	Full Sample				
	(1)	(2)	(3)	(4)	(5)
Panel A					
Ln(IPR)	.679**	.5421**			
	(.284)	(0.284)			
Ln(IPR^2)	-.025**	-.022*			
	(.013)	(0.013)			
Ln(PIPR)	1.228**	1.064**	1.552**	1.445**	18.84**
	(.411)	(0.432)	(0.499)	(0.577)	(7.457)
Ln($PIPR^2$)	-.095**	-.088**	-.097**	-.046	-.058*
	(0.035)	(0.038)	(0.043)	(0.033)	(0.034)
Trade Open	.013**	.013**	.010	-.002	-.0017
	(.005)	(.006)	(.005)	(.006)	(.006)
Partner GDP	-.356	-.276	-.367	-.585	-.5808
	(.186)	(.186)	(.199)	(.396)	(.391)
Gov. Exp	.252	.378			
	(.407)	(.399)			
Human Capital	-.394	-.409			
	(.272)	(.262)			
Ln(Pop)*Ln(PIPR)					-1.038**
					(0.434)
Industry FE	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
Industry-Year FE	No	Yes	Yes	Yes	Yes
Country-Year FE	No	No	Yes	Yes	Yes
Country-Indus. FE	No	No	No	Yes	Yes
Observations	1551	1551	1551	1551	1551
R-Square	.9112	.9197	.9252	.9773	.9775

Note: Robust Standard Errors correcting for heteroskedasticity. Sample size consists of 20 countries and 42 industries for the years 1987, 1990, 1995, 2000, and 2005.
* p < .10 , ** p <.05, ***p < .01

Table 5: Products covered in Canadian establishment-level data (aggregated at two-digit HS level)

HS Code	Sector
30-37	Chemicals & Allied Industries
39-40	Plastics/Rubbers
48-49	Paper and Paperboard
54-62	Textiles
64	Footwear/Headgear
73-76	Steel
82-85	Machinery/Electrical
90-96	Miscellaneous

Table 6: Descriptive statistics for key dependent and explanatory variables in Canadian Sample

Variable	Obs.	Mean	SD
Log(R&D Intensity)	910	-9.78	1.33
EIPR	910	3.94	1.24
PIPR	910	4.61	0.28

Table 7: Correlation matrix for explanatory variables in Canadian Sample

	EIPR	FEIPR
EIPR	1.000	
PIPR	0.3412	1.000

Table 8: OLS Estimates of impact of partner IPR on R&D Intensity for Canadian sample

Dependent Variable: Ln of R&D Intensity

Ln(PIPR)	0.0927 (0.0696)
No. Obs.	910
Firm Effects	Yes
Industry Effects	Yes
Year Effects	Yes

Appendix

Table 9: List of countries in our sample

Australia	Austria	Canada	Denmark
Finland	France	Greece	Hungary
Iceland	Israel	Italy	Japan
Korea	Norway	Portugal	Singapore
Spain	Sweden	U.K.	U.S.A

Table 10: List of industries in our sample

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