Intellectual Property Rights Protection and Trade: an Empirical Analysis.*

Emmanuelle Auriol†
Sara Biancini‡, Rodrigo Paillacar§

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Abstract

The paper proposes an empirical analysis of the determinants of intellectual property rights (IPR) adoption and of their impact on innovation. The analysis is conducted with panel data covering 112 countries and 45 years. IPR enforcement is shown to be U-shaped in a country's market size relative to the aggregated market size of its trade partners. Reinforcing IPR protection reduces on-the-frontier and below-the-frontier innovation in developing counties without necessarily being conducive of higher innovation at a global level.

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†Toulouse School of Economics, emmanuelle.auriol@tse-fr.eu
‡Université de Caen Normandie, CREM, sara.biancini@unicaen.fr.
§Université de Cergy-Pontoise, THEMA, rodrigo.paillacar@u-cergy.fr.

1 Introduction

Over the past three decades developed countries have spared no effort to protect their Intellectual Property Rights (IPR) in the face of globalization. They have been met with strong resistance from developing and transition countries. For instance the agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS), which imposes a common framework to all WTO members as regards IPR,[1] has been challenged by many countries, including Korea, Brazil, Thailand, India and the Caribbean states. One source of conflict between developed and developing/emerging countries is that strong IPR limit the possibility of technological learning through imitation. A second source of conflict concerns medical drugs and, more generally, the fact that TRIPS does not stimulate research designed to benefit the poor, because the latter are unable to afford the products once they are developed. The controversy has made the headlines and in 2001 it led to the Doha Declaration, the aim of which is to ensure easier access to medicines by all.[2] This declaration made a significant dent in the TRIPS agreement and has been challenged by the US and other developed countries with the help of organizations such as PhRMA (representing pharmaceutical companies in the US). As a result of these international disputes, the enforcement of IPR legislation varies considerably around the world. There is a substantial theoretical literature which studies the link between North-South trade and IPR protection, but there are surprisingly few empirical studies which focus on how trade impacts countries' willingness to enforce IPR. The present paper is a first attempt to fill this gap.

With the help of panel data covering 112 countries and 45 years of trade, innovation and IPR enforcement, the paper analyses developing countries' incentive to enforce IPR. Using a methodology developed in the new economic geography literature for measuring foreign market potential, the empirical analysis shows that IPR enforcement is U-shaped in a country's market size relative to the aggregated market size of its trade partners. Using detailed trade data we are able to decompose the effect by different type of trade partners. We show that the effect is entirely driven by the trade partners that are strongly enforcing IPRs. This is consistent with the fact that advanced economies monitor their imports to block out goods suspected of infringing intellectual property

[1]The TRIPS agreement, negotiated through the 1986-94 Uruguay Round, is administered by the World Trade Organization and applies to all WTO members.

[2]The declaration states that TRIPS should not prevent a country from addressing public health crises, and, in particular, that developing countries should be able to copy medicines for national usage when tackling such major issues as AIDS, malaria, tuberculosis or any other epidemics. They should also be able to import generic drugs if the domestic pharmaceutical industry cannot produce them.

rights. For instance the European Union has enacted a new regulation concerning customs enforcement of intellectual property rights, which came into force on 1 January 2014 (see IP/11/630 and MEMO/11/327): Suspicious goods can now be destroyed by customs control without the need to initiate a legal proceeding to determine the existence of an infringement of intellectual property rights. In the United States, Customs and Borders Protection similarly targets and seizes imports of counterfeit and pirated goods, and enforces exclusion orders on patent-infringing goods. At the international level if a WTO member is found guilty of violating its IPR obligations, the complaining government obtains the right to impose trade sanctions in the form of punitive tariffs.[3] Consequently a developing country that wants to trade with advanced economies will find it easier if it enforces IPR more strictly as empirically shown by Maskus and Penubarti (1995) and Smith (1999).[4] In other words, violating IPR of the North yields barriers to trade for the South, which is more problematic for small countries, as they benefit more from trade and are generally more open than large ones. When the relative size of its internal market is small compared to the export market, the developing country should therefore choose to respect IPR to enhance its export opportunities, while it might prefer to free-ride on the North's innovations to serve its internal demand when the latter is large compared to the export market. Consistently with these predictions we find an U-shaped relation between IPR enforcement and the relative size of a country internal market versus its export opportunity. As far as we know this result is a new proposal as compared to previous empirical papers on IPR determinants.

Another point within the TRIPS controversy concerns the impact of universal IPR on global innovation and on the ability of the South to develop high-tech industries and autonomous research capacity (see Sachs, 2003). So far, the empirical literature on the effects of TRIPS on innovation has focused on the pharmaceutical industry (see for instance Chaudhuri et al., 2006, Qian, 2007, Kyle and McGahan, 2012, Williams, 2013). Our paper looks empirically at the relation between stronger IPR protection and innovation in other sectors than pharmaceutical and medical research. We find that stricter IPR protection is negatively correlated with patent activity by Southern firms in manufacturing sectors. When IPRs are enforced more strictly, the innovation of the local firms

[3] There have hence been more than 30 TRIPS-relates disputes since the enactment of the agreement. In many cases the simple threat of sanctions was enough for the parties to find a solution (see Fink (2004) for a discussion and https://www.wto.org for the more recent disputes). In other cases sanctions were implemented (see Žigić, 2000 for EU examples and Harris (2008) for US ones).

[4] These authors show that an increase in patent protection has a positive impact, not only on a country's exports, but also on its imports, especially so if it has a high imitation capacity.

decreases in the developing country. Patent data allows us to distinguish between resident and non-resident patents, which are good proxies for indigenous and foreign innovation in developing countries. Restricting our panel to 54 developing countries having enough observations, we confirm the detrimental effect of IPR protection on resident patents. We also find some evidence of a positive effect for non-resident patents, suggesting that stronger local IPR favors foreign firms (mostly from developed countries). These results are robust to instrumentation to deal with potential endogeneity of IPR protection with respect to innovation levels. Increasing the protection of IPR decreases on-the-frontier innovation in the manufacturing sector of resident firms in developing countries, but increases innovation of nonresident firms, usually based in developed countries. Taken together with the empirical results on pharmaceutical and human genome, this gives credibility to the idea that by preventing technological transfers from the North, universal protection of IPR is limiting the development of Southern R&D activities in all manufacturing sectors, and not solely in the pharmaceutical industry.

2 Related literature and motivational evidence

Chin and Grossman (1991), Diwan and Rodrik (1991), Deardorff (1992) and Helpman (1993) were the first to study the effect of patent protection in an international context. These theoretical papers assume that only firms in the North can innovate. The harmonization of IPR amounts to introducing strong protection in the South to the benefit of Northern firms, which is generally conducive of more innovations (i.e., in the North), but it decreases welfare in the South. Lai and Qiu (2003) and Grossman and Lai (2004) extend the literature by looking at two heterogeneous countries which both can innovate: one representing the North (high innovation, high demand) and the other the South (low innovation, low demand). In their models consumers are characterized by Dixit-Stiglitz preferences and innovation is not incremental (i.e., horizontal innovation).[5] There are three main findings that emerge from this theoretical literature. First, a stricter enforcement of IPR has generally a positive impact on global innovation. Second, there is a conflict of interest between the North (which generally gains from stricter enforcement in the South) and the South (which generally loses). Third, the level of IPR protection generally increases monotonically with the level of economic development.[6]

[5]Lai and Qiu (2003) shows that the South has a lower optimal level of protection and that it is also in general worse off if IPR protection is harmonized at the level preferred by the North. Grossman and Lai (2004), who confirm that the South prefers in general a lower level of protection than the North, show that harmonization (i.e., equal patent duration and enforcement rate) is neither necessary nor sufficient to achieve an efficient outcome.

[6]The North protects more because it is the main innovator and has the larger demand for innovative

This monotonicity result is challenged by Diwan and Rodrik (1991) who predict a U-shape relationship between IPR enforcement and development. Assuming that only Northern firms innovate they show that when the market size of the South is small, the country has an incentive to protect IPR in order to give incentives to the Northern firms to produce innovations most suited to their needs. But when the market size of the South increases, firms in the North start putting a higher weight on Southern demand, so that the incentives of the South to protect IPR are relaxed and free-riding becomes more tempting. More recently, Auriol et al. (2017) have proposed a theoretical model where the ability of developing countries to export in rich countries depends on their willingness to respect northern firms' IPR. This assumption is consistent with the evolution of international legislations and the recent tightening of sanctions against IPR infringement in the EU and the US. It is also consistent with the empirical literature, which shows that weak enforcement of IPR creates barrier to South–North trade. Using OECD data, Maskus and Penubarti (1995) find that an increase in patent protection has a positive impact on bilateral manufacturing imports. Similarly, Smith (1999), who studies US exports, shows that stronger IPR have a market expansion effect in countries with a strong capacity for imitation. This creates a trade-off between enforcing IPR to be able to export and infringing IPR to serve domestic demand. Auriol et al. (2017) show that small/poor countries have more incentives to increase IPR protection to access large/rich foreign markets, while relatively larger developing countries can relax IPR protection to foster technological diffusion trough imitation. In other words, they predict that the willingness to protect IPR is U-shaped in the relative size of one country's internal market as compared to its export market.

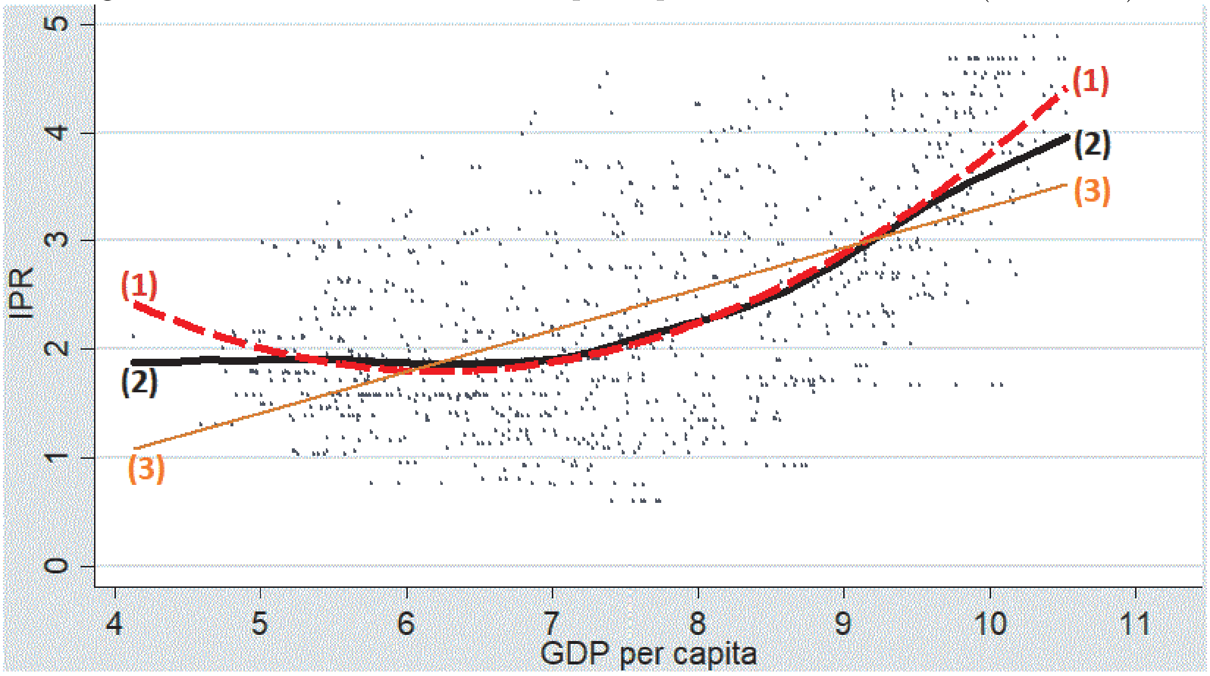
Whether the relationship between economic development and IPR is monotone or U-shape is an empirical question. In pioneer papers, Maskus (2000), Primo Braga, Fink, and Sepulveda (2000) and Chen and Puttitanun (2005) explore the link between patent protection and GDP per capita. They have all identified a *U-shape* relationship.[7] And in fact we also find that, in cross-section, GDP per capita exhibits a non-linear relationship with IPR protection. Figure 1, which presents scatterplots of the GDP per capita and the lagged (i.e., 5 years) value of the IPR indicator, is better represented by a non-linear

goods. The South has an incentive to free-ride which decreases when the South represents a larger share of total demand. Given that the North is either the unique or the main innovator in this literature, when the share of total demand in the South increases, the temptation to free-ride is reduced because of its adverse effect on the North's innovation.

[7]As a first step, Chen and Puttitanun (2005) propose a two-sectors (import and domestic) model where the level of innovation in the rich country is fixed and firms in the poor country do not export. For some values of the parameters the level of protection first decreases and then increases when the per capita GDP of the country increases.

relationship, as suggested by the fits of quadratic and local polynomial regressions.

Figure 1: Correlation between GDP per capita and IPR indicator (1965-2005)

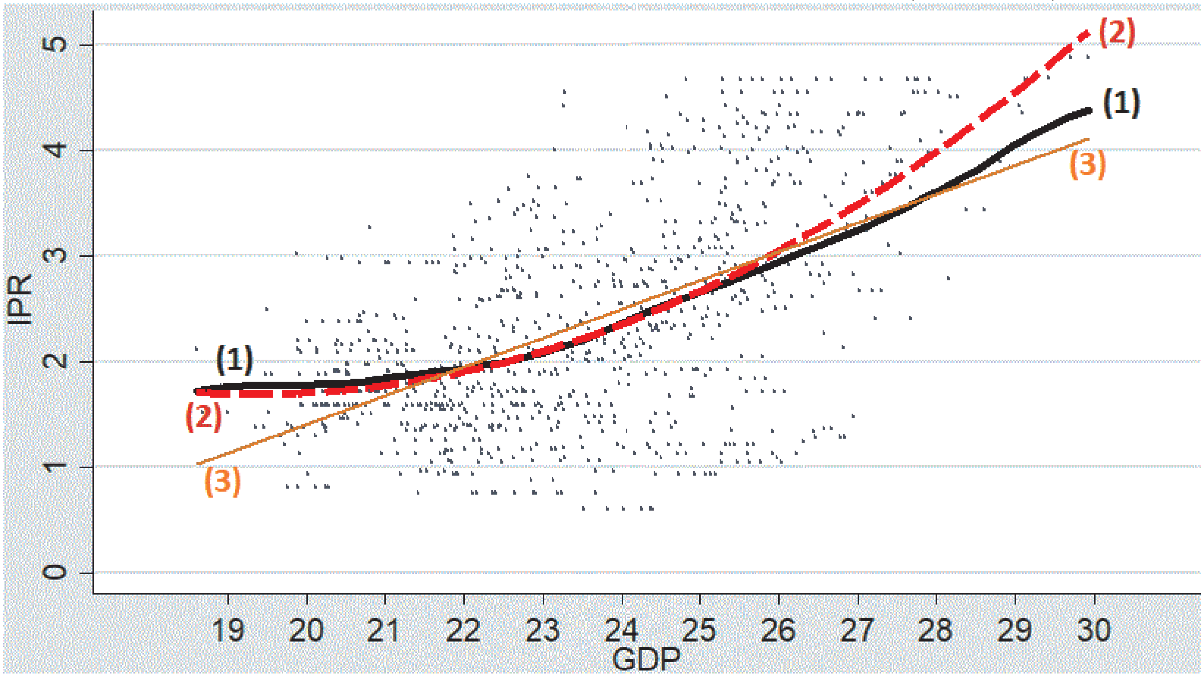


Source: World Bank Development Indicators (in constant values and lagged of one period) and Park (2008).The dashed Line (1) is the fit of a quadratic regression; The solid line (2) is a fit of a kernel-weighted local polynomial regression; the solid line (3) is the fit of a linear regression.

One major limitation of the empirical approach adopted in Maskus (2000), Primo Braga, Fink, and Sepulveda (2000) and Chen and Puttitanun (2005) is that it does not take into account the trade dimension of the IPR enforcement problem. It essentially regresses measure of countries' IPR protection on their per capita GDP and some country-level controls. Yet the theoretical literature, which looks at this problem in the context of an open economy, stresses the importance of trade in countries' incentive to enforce IPR of their commercial partners.

The present paper therefore adds the trade dimension to the empirical analysis. In this end it is necessary to look at the total market size of an economy (i.e., its total GDP) and not solely at its per capita GDP. Because of the size of its population, a developing economy can indeed be larger than a developed one, although poorer in per capita terms and generally endowed with less efficient R&D technology (e.g. China versus UK). Comparing the scatterplots of the total GDP and the lagged value of the IPR indicator in figure 2 with the scatterplots in figure 1, the fit between the quadratic and the local polynomial regressions is much closer in the case of total GDP, although the non-linear relationship is visually more pronounced in the case of GDP per capita. We will see in Section 4 that the regressions are also more robust with total GDP than with GDP per capita.

Figure 2: Correlation between GDP and IPR indicator (1965-2005)



Source: World Bank Development Indicators (in constant values and lagged of one period) and Park (2008). The thick line (1) is the fit of a kernel-weighted local polynomial regression; the dashed line (2) is a fit of a quadratic regression; the solid line (3) is the fit of a linear regression.

Since the size of the Southern market relative to the Northern one matters for IPR protection, one empirical challenge is to find a suitable measure of a country export market. We use gravity models to estimate the export opportunities of a country. We show that the willingness to enforce IPR is U-shaped in the relative size of a country's internal market with respect to its export opportunities: advanced economies and poor countries of small size are protecting IPR more than large emerging countries. Auriol et al. (2017) also show that large developing countries start to protect IPR only when they have developed an efficient R&D system and innovate enough on their own (i.e, when they become rich). This last result suggests that at the country-level IPR enforcement is monotone in economic development as also suggested by Lai and Qiu (2003) and Grossman and Lai (2004). In fact, while we robustly identify a U-shape in our panel data, we are unable to check for individual U-shape patterns at the country level, mainly because of reduced sample size.

Regarding the impact of IPR enforcement on global innovation, the empirical literature has mostly focused on the pharmaceutical industry. Using a product-level data set from India, Chaudhuri, Goldberg, and Jia (2006) estimate the demand and supply characteristics of a segment of the antibiotics market in India (quinolones). They then draw up counterfactual simulations of what prices, profits and consumer welfare would have been if the relevant molecular formulae had been under patent in India, as they were in the US at the time. Their results suggest that concerns about the potential adverse welfare effects of TRIPS are legitimate. Qian (2007) evaluates the effects of patent protection on pharmaceutical innovations for 26 countries that established pharmaceutical patent laws in the period 1978–2002. She shows that national patent protection alone does not stimulate domestic innovation, but that it does in countries with higher levels of economic development, educational attainment, and economic freedom. Kyle and McGahan (2012) test the hypothesis that, as a consequence of TRIPS, increased patent protection results in greater drug development efforts. They find that patent protection in high income countries is associated with increase in R&D effort, but that the introduction of patents in developing countries has not been followed by greater R&D investment in the diseases that are most prevalent there. Williams (2013) focuses on the case of cumulative innovation, when product developments result from incremental inventions. She uses data on the effect of patents on genetic research, following the sequencing of the human genome realized by the public Human Genome Project and by the private firm Celera. While genes sequenced by the public effort were falling in the public domain, Celera's sequenced genes were patented and thus covered by intellectual property. The paper thus identifies the effect of Celera patenting on follow-on research on gene-based diagnostic tests, finding that IPR protection has led to reductions in subsequent scientific research and product development of the order of 20-30 percent.

Our paper complement this literature by looking empirically at the relation between stronger IPR protection and innovation in manufacturing sectors. The impact of IPR on innovation is harder to tackle because of endogeneity concerns. However, using an instrumental variables approach, we propose some empirical evidence that stricter IPR protection is negatively correlated with patent activity by Southern firms in a wide panel of manufacturing sectors. We also find evidence of a positive effect for non-resident patents, suggesting that stronger local IPR favors foreign firms (mostly from developed countries). These last results are consistent with the findings of Hudson and Minea (2013), who shows that the same level of IPR has different impact on richer and poorer countries. Comparing countries with similar level of IPR enforcement, they find that the impact of IPR on innovation is often negative for the poorer and positive for the richer ones. Similarly, we find that strong IPR enforcement decreases the innovation activities of the poorer countries. Taken together with the empirical results on pharmaceutical and human genome, this gives credibility to the idea that by preventing technological transfers from the North, universal protection of IPR is limiting the development of Southern R&D activities in all sectors.

The remainder of the paper is structured as follows. Sections 3 presents the data. Section 4 analyzes Countries' choice of the strength of IPR protection. Section 5 investigates the relationship between the strength of IPR protection and innovation. Finally, Section 6 concludes.

3 The data

We use several data sources. The data on IPR protection are drawn from Park (2008), who updates the index of patent protection published in Ginarte and Park (1997). The original paper presented the index for 1960–1990 for 110 countries. The index has now been updated to 2005 and extended to 122 countries (it is calculated in periods of 5 years).

Trade data is based on COMTRADE, from the United Nations Statistical Department. Although this source contains data from the 1960s to the present, more accurate information is derived from the new release of TradeProd, a cross-country dataset developed at CEPII.[8] This source integrates information from COMTRADE and OECD-STAN and covers the period 1980–2006. A detailed description of the original sources and procedures is available in De Sousa, Mayer, and Zignago (2012).

We measure innovation by the number of patent applications from domestic and foreign firms resident in a country. This information is provided by the World Bank (World Development Indicators). This is a proxy for the discovery of new (enhanced) products.

We also employ information on cross-country human capital levels from Barro and Lee (2010). This widely used dataset reports levels of education attainment in periods of 5 years. All other data are from the OECD and the World Bank.

4 IPR enforcement

We take a first look at the relationship between IPR regimes and measures of economic development and market size in Table 1. These are pooled regressions corresponding

[8] In particular, this dataset takes advantage of mirror flows (reports for both exporting and importing countries) to improve the coverage and quality of trade flows at a very disaggregated product level. TradeProd is available from the CEPII website (http://www.cepii.fr).

to the graphs presented in section 2. We regress the IPR index on per-capita income (*GDPpc*) and total *GDP*. Continuous variables are in logs. To avoid, as far as possible, residual endogeneity problems, the variables describing the economic development or market size are lagged by one period (i.e., 5 years).[9]

Results in Table 1 confirm non-linear relationships in all cases. Of course, many observable and unobservable country characteristics may confound this relationship. For example, institutional aspects may influence the adoption of stricter IPR regulations. Consequently, we exploit the panel dimension of our data to better control for unobservable characteristics. We aim to assess which from economic development and market size is determinant in the choice of IPR regimes. In addition, we want also to consider the market size effect associated with global integration and trade. An empirical challenge is to find a good proxy for a country's export opportunities. We use a methodology developed in the new economic geography literature (see Head and Mayer, 2004, and Redding and Venables, 2004) to compute this proxy, as explained below.

Table 1: Correlation between IPR indicator and economic variables

	(a)	(b)	(c)	(d)
GDPpc	–1.40***	–0.40***		
	(0.13)	(0.04)		
$GDPpc^2$	0.12***	0.05***		
	(0.01)	(0.00)		
GDP			–1.35***	–0.92***
			(0.15)	(0.09)
GDP^2			0 .03***	0.02***
			(0.00)	(0.00)
Period	1965-2005	1985-2005	1965-2005	1985-2005
N. of obs	907	553	906	553
R^2	0.68	0.66	0.60	0.76

Robust Standard Errors in parentheses. ***, ** and * represent respectively statistical significance at the 1%, 5% and 10% levels. All regressions include a constant and time effects. All explanatory variables are lagged one period. In all regressions, GDP is in constant values. In regressions (b) and (d), GDP is PPP-deflated

The results of the regressions are presented in Table 2. We fully exploit the panel dimension of our database, including in all regressions country fixed and time effects. Standard errors are robust and clustered by country. We also include additional controls, namely an economic freedom index, *freedom*, and a dummy indicating the year of entry

[9]Strong IPR protection could possibly stimulate new investment and/or FDI and in turn affect GDP. However, this channel would take some time. We reduce the risk of endogeneity by lagging the variables 5 years. This specification is based on the implications of our theoretical model and on the empirical literature on IPR (e.g., Ginarte and Park, 1997; Maskus, 2000; Chen and Puttitanun, 2005).

into the GATT, or, later, the WTO, $gatt/wto$. Intuitively, these two variables, $freedom$ and $gatt/wto$, should positively influence the level of IPR protection. For instance, entering into the GATT agreements or joining the WTO imposes higher IPR standards upon joining countries. It is thus unsurprising that the coefficients of these controls are positive and significant in all specifications.

The first regression in column (a) focus on the relationship between economic development and IPR regimes using this more demanding specification. With country fixed effects, time effects, and new controls, the relationship is no longer significant. In column (b) we focus on the relationship between market size and IPR regimes. We regress IPR against the size of GDP and its square, with time, country fixed effects and controls. We find that IPR enforcement is a U-shaped function of GDP.

We have also performed the same regression without the controls $freedom$ and $gatt/wto$, to be able to consider a larger time span, covering the period 1965–2005 for which the controls are not available. This allows us to consider a larger unbalanced panel of 118 countries and 906 observations. We have obtained very similar and significant coefficients for both GDP and GDP^2. Finally the same results are obtained if we restrict the analysis to a balanced panel of 79 countries, covering the period 1965–2005.[10]

This first set of results complement the empirical findings by Maskus (2000), Primo Braga, Fink, and Sepulveda (2000) and Chen and Puttitanun (2005), who were the first to illuminate the non-linearity between IPR enforcement and a country wealth. Although the credit of the idea is fully their, we refine it by showing that the result is driven by total national income rather than by per-capita income. IPR enforcement is U-shaped with respect to total GDP (market size).

According to the theoretical literature this is because total GDP is a better measure of a country relative weight in the global economy than per capita wealth. Indeed the prediction of the theory is that a country willingness to enforce IPR is U-shaped in the size of its internal market relative to its export opportunity. The challenge is to find a suitable measure of the foreign market potential. The measure of the foreign market potential we use, denoted $F.MKT$, is a weighted sum of the size of the markets of the foreign trade partners. The weights given to each partner take into account the existence of trade costs. Our empirical methodology thus includes a measure of exportation costs, weighting each potential destination market by their accessibility. To be more specific, we define

[10] In this case, due to data limitations and in order to be able to get the larger possible sample, we use data on GDP at constant 2005 prices, not corrected for PPP.

$$F.MKT_i = \sum_{j \neq i} GDP_j \hat{\Phi}_{ij}, \tag{1}$$

where $\hat{\Phi}_{ij}$ is a weight specific to the relationship between countries i and j. We use a trade gravity equation (see Head and Mayer, 2004, and Redding and Venables, 2004) to obtain these weights for each year of our sample. The gravity equation relates bilateral trade flows to variables that are supposed to deter (e.g., distance among partners) or favor (e.g., common language) economic exchanges between trade partners. In our analysis we include bilateral distance (in log), and dummies equaling one if the partners share a common language or border and if one of the countries was a colonizer of the other.[11] Of course, these bilateral variables are not the only components of trade costs. There are also variables specific to the exporter or the importer, like institutional quality or landlocked status. We include exporter and importer fixed effects in the trade equations to control for these country-specific variables. All these explanatory variables are available from the CEPII Gravity Dataset. We concentrate our analysis on manufacturing data.[12] Using the coefficients of the bilateral variables in the gravity equation, we compute the weights $\hat{\Phi}_{ij}$ for each pair of trade partners. In column (c) we add this measure of the foreign market size and its square (in addition to the fixed effects and controls). Due to data limitations, the regressions including the foreign market potential focus on the period 1985–2005. We expect the coefficient of $F.MKT$ and $F.MKT^2$ to have opposite signs with respect to the own-market variables, GDP and GDP^2, which is confirmed by the estimation. The coefficients of GDP and its square are still significant and of similar size. In other words IPR enforcement is shown to be U-shaped in a country's market size relative to the aggregated market size of its trade partners.

The foreign market potential computed above includes all the trade partners of a country. However, if access to foreign market is indeed a driving force behind IPR enforcement, it seems interesting to distinguish between trade partners who strongly enforce IPR and those who do not. If a country trade only with countries that do not enforce IPR, it will have no incentive to enforce IPR for trade motive. By contrast if a country trade mainly with countries enforcing IPR it will have strong incentive to enforce them to be able to export. In other words, the impact of the size of the foreign market should be conditioned on whether the trade partners protect IPR or not. We decompose a country's

[11] As expected, in the trade equation the coefficient for distance is negative and the coefficients for common language, border and colonial past are positive (regressions available on request).

[12] CEPII developed a dataset based on BACI-COMTRADE called TRADEPROD, specifically for the manufacturing sector. This is the version we use. De Sousa et al. (2012) describe the dataset in detail and make it available through the CEPII website.

Table 2: IPR Equation

	(a)	(b)	(c)	(d)
GDPpc	0.88			
	(0.95)			
GDPpc^2	–0.03			
	(0.06)			
GDP		–2.14*	–2.06*	–2.02*
		(1.10)	(1.18)	(1.11)
GDP^2		0.05**	0.05**	0.05**
		(0.02)	(0.02)	(0.02)
F.MKT			2.72**	
			(1.27)	
F.MKT^2			–0.06**	
			(0.03)	
F.MKT-strong				2.36***
				(0.76)
F.MKT-strong^2				–0.06***
				(0.02)
freedom	0.59*	0.59*	0.56*	0.57*
	(0.32)	(0.31)	(0.31)	(0.31)
gatt/wto	0.43***	0.45***	0.43***	0.44***
	(0.16)	(0.16)	(0.15)	(0.16)
N. of obs	511	511	511	511
N. of countries	112	112	112	112
Within R^2	0.70	0.70	0.71	0.71

Robust Standard Errors in parentheses, clustered by country. ***, ** and * represent respectively statistical significance at the 1%, 5% and 10% levels. All regressions include country fixed effects and time effects. All variables describing the market size are lagged one period.

trade opportunities into different groups based on the strength of IPR protection of the trade partners. In column (d) we replace $F.MKT$ with the weighted sum of the GDPs of trade partners which strongly protect IPR at each period (i.e., which have an IPR index in the highest quartile), namely the variable $F.MKTstrong$. The results shows that the impact of the foreign market size is driven by the countries which strongly protect IPR. We also tried a regression including (in addition to all the other variables in regression (d)) the market size of trade partners with a weak IPR index (i.e., in the lowest quartile). The coefficient for the market potential of trade partners with low IPR index is insignificant and this is true whether we drop $F.MKTstrong$ and its square from the regression or not. We have also performed sensitivity analysis on the definition of countries with "weak" and "strong" protection (considering various alternative thresholds, such as the highest quintile instead of the quartile, and the top 30%). All the results in Table 1 are qualitatively preserved.

Finally to confirm the hypothesis of existence of a U-shape, we perform a last test, using the Sasabuchi-test (Sasabuchi, 1980). The test is performed for the specifications in column (d) of Table 1. It directly tests for the existence of a U-shape with respect to GDP and of an inverse U-shape with respect to $F.MKTstrong$. In both cases the test supports the U-shape hypothesis (i.e. the test does reject the null hypothesis of non-existence of a U-shape).

Put together, these results imply a U-shaped relationship between IPR protection and the relative size of a country interior market, $R.SIZE = GDP/F.MKT$. In particular, the effect of the foreign market potential as measured by $F.MKTstrong$ appears crucial and highly significant in all our specifications and robustness check. Our analysis hence shows that the measure of the foreign market potential is important to explain IPR protection at the domestic level, and the result is largely driven by the export opportunities toward countries which strictly enforce IPR. As far as we know, this result, which empirically illuminates the relationship between IPR strength and trade, is new.

5 IPR and innovation

We now turn to the exploration of the relation between stricter IPR protection and innovation. From an empirical point of view, trying to assess the impact of IPR on innovation presents a problem of endogeneity. The innovation equation should be estimated simultaneously with the equation describing the choice of IPR. However, many of the variables used to explain IPR, as presented in Table 1 columns (b)–(d), are likely to be explanatory variables of innovation as well, and do not represent valid instruments for

IPR in the innovation equation. We address this problem with instrumental variables regressions, based on two original instruments for IPR, which the only sound strategy with the existing data. This is a first significant step to go beyond mere correlations.

The first instrument is a measure of past technological adoption and diffusion. The idea is that the diffusion of modern technologies can change the attitude towards IPR protection. Among similar indices of technology diffusion, we choose the lagged total number of tractors available in the country (in log). This choice is justified by two main reasons. First, it is a relatively old innovation in a traditional sector which is likely to be important in developing countries. Since tractors are generally employed with other inputs such as certified seeds and fertilizers, this may have stimulated the adoption of strong IPR in countries that wanted to take advantage of the potential increase in agricultural productivity implied by mechanization. Second, from a statistical point of view this instrument offers several advantages. It presents important variation not only in the spatial dimension but also in the temporal one. It has, for instance, been shown that in the United States tractor diffusion took several decades (Manuelli and Seshadri, 2003). Nonetheless, the diffusion process is likely to be correlated with the choice of a broader set of public policies (not exclusively IPR protection). As such, it could be correlated with other unobservable variables influencing innovation (thus violating the exclusion restriction from the innovation equation). For this reason, we do not use the number of tractors in the country. Instead we use the diffusion of tractors in neighboring countries. We use the bilateral distances as weights to generate a single indicator for each country and each period: for each country we sum up the number of tractors in neighboring countries, weighted by bilateral distances.[13] The good data availability allows us to introduce the instrument lagged by 3 periods (15 years) to further reduce endogeneity concerns.

The second instrument is the lagged number of students from the neighboring countries studying abroad. We expect migrant students to have an indirect effect on innovation through IPR. This is in line with studies showing that students who spent time abroad can influence the development of institutions in their home country.[14] In addition, student migrations can favor technological transfers by having an impact on the technological gap between the home and foreign countries.[15] Again, to reduce endogene-

[13]The information is provided by Comin and Hobijn (2009) in their Cross-country Historical Adoption of Technology (CHAT) dataset.

[14]For instance, Spilimbergo (2009) shows that individuals educated in foreign democratic countries can promote democracy in their home country.

[15]For instance Naghavi and Strozzi (2011) have shown that the knowledge acquired by emigrants abroad can flow back into the innovation sector at home. This is also in line with findings by Dominguez

ity concerns, we consider the neighboring countries excluding the home country. Several versions of student migration flows are available in the dataset proposed by Spilimbergo (2009) (e.g., students going to democratic versus non-democratic countries). We have tested several versions, as well as different techniques of aggregation (using alternatively weighted distances or contiguity dummies). All specifications give the same type of results. We have thus retained the best instruments in terms of exogeneity and relevance, which correspond to the variable $Students(FH)$, i.e., the number of students in neighboring countries studying in foreign democratic countries (as defined by Freedom House).[16] The instrument is lagged three periods (i.e., 15 years). The coefficients of the excluded instruments in the first-stage equations explaining IPR are reported in the bottom parts of table 3.

As a dependent variable, we use data on patent applications as a proxy for innovation. We focus on the subsample of less developed countries (i.e., excluding the highest income quintile)[17] and we measure domestic innovation as the number of patent applications made by resident firms. Symmetrically, innovations made by firms from developed countries are measured by the number of patent applications made by non-resident firms.[18]

In addition to the variables used as controls in the previous regressions, we add the stock of human capital, *hcap*, and its square, as it should have a direct influence on the innovative capacity of the country. The variable *hcap* is the level of human capital computed with the Hall and Jones method using the new series proposed in Barro and Lee (2010). We first show in columns (a), (b), (c), the result of the regressions when we do not correct for the endogeneity of IPR, and next, in columns (d), (e), (f), IPR is instrumented using the flows of students in neighboring countries going to study in democratic countries ($Students(FH)$), and the number of tractors in neighboring countries ($tractors$).

The first-stage regressions confirm that the instruments are statistically adequate.

Dos Santos and Postel-Vinay (2003) and Dustmann, Fadlon, and Weiss (2011), who put the accent on the positive effects of return migration on technological transfers.

[16] All alternative specifications give very similar results but they are more exposed to weak-instrument problems (tested using the Kleibergen-Paap statistic). To avoid the related biases, we retain the presented specifications. Alternative specifications and related tests are available upon request.

[17] For each year in our sample, we classify a country as developed if it belongs to the highest quintile in term of GDP per capita, and as developing otherwise. We discard oil-exporting countries with very high GDP per capita levels (higher than 40,000 USD with year 2000 value). All these countries, with the exception of Norway, are highly dependent on this commodity (measured as a share of exports) and exhibit low diversification of their economies. Norway is included as a developed country in the regressions, but is not considered in the distribution to set the threshold in year 2005 because its GDP per capita exceeds 40,000 USD.

[18] The vast majority of patents of non-resident firms in the world originate from firms located in high-income economies. For more on this see "World Intellectual Property Indicators" 2011 WIPO Economics & Statistics Series at www.wipo.int.

Table 3: Patent Equation

Patent type	Resident	Non-Resid	All	Resident	Non-Resid	All
	(a)	(b)	(c)	(d)	(e)	(f)
ipr	–0.41***	0.13	0.01	–1.17***	0.35*	0.06
	(0.10)	(0.14)	(0.12)	(0.25)	(0.19)	(0.20)
GDP	–6.58**	2.27	0.88	–11.34***	3.32	1.19
	(2.97)	(3.93)	(4.54)	(4.06)	(4.01)	(4.38)
GDP^2	0.16***	–0.03	0.01	0.26***	–0.05	0.00
	(0.06)	(0.08)	(0.08)	(0.08)	(0.08)	(0.08)
F.MKT-strg	–2.14	4.60*	2.29	–1.54	4.57*	2.25
	(1.55)	(2.57)	(2.18)	(2.06)	(2.48)	(2.03)
F.MKT-$strg^2$	0.06	–0.12*	–0.06	0.04	–0.12*	–0.06
	(0.04)	(0.07)	(0.06)	(0.05)	(0.06)	(0.05)
freedom	0.69**	0.29	0.57	0.46	0.31	0.58**
	(0.28)	(0.36)	(0.34)	(0.43)	(0.31)	(0.30)
gatt/wto	–0.38	0.22	0.10	–0.06	0.12	0.08
	(0.23)	(0.22)	(0.17)	(0.28)	(0.20)	(0.16)
hcap	5.10**	–0.60	1.20	4.74*	–0.40	1.22
	(2.03)	(1.77)	(1.74)	(2.69)	(1.69)	(1.68)
$hcap^2$	–0.16*	0.06	0.01	–0.18	0.06	0.01
	(0.09)	(0.10)	(0.09)	(0.12)	(0.10)	(0.08)
IPR Endogenous	No	No	No	Yes	Yes	Yes
No. of obs	225	244	225	225	244	225
N. countries	54	59	54	54	59	54
Within R^2	0.56	0.31	0.50	–	–	–
Hansen (p-val.)	–	–	–	0.76	0.70	0.87
First-stage regs.:						
Instruments:						
N. of tractors				315.69***	303.43***	315.69***
				(60.00)	(56.10)	(60.00)
Students(FH)				4.82***	4.80***	4.82***
				(1.46)	(1.48)	(1.46)
F (all instr.)	–	–	–	15.26	15.71	15.26
Partial R^2	–	–	–	.17	.18	.17

Robust Standard Errors in parentheses, clustered by country. ***, ** and * represent respectively statistical significance at the 1%, 5% and 10% levels. All regressions include country fixed effects and time effects. All variables describing the market size are lagged one period. First-stage regressions include all controls shown in Table 2. Instruments are lagged several periods (see the text for details). F-stat is the Angrist and Pischke version.

The regressions presented in Table 3 pass the exogeneity and relevance tests. As a last robustness check, we run all IV regressions using alternative estimation methods that are robust to weak instruments. In particular, we use the Limited Information Maximum Likelihood (LIML) and Fuller's modified LIML (see Murray, 2011 for details). We find basically the same coefficients for the IPR variable. All these robustness checks are available upon request.

The results in Table 3 show that increasing IPR strength decreases on-the-frontier innovation of resident firms in developing countries (resident patents) but increases innovation of nonresident firms (which are mostly firms based in developed countries).[19] They also show that failing to correct for endogeneity bias leads to an underestimation of the impact of IPR on innovation activities. The sign of the bias is coherent with our intuitions. First, innovation and IPR could be determined simultaneously, confounding the causal relation. Countries which already produce more indigenous innovation and rely less on imitation, have more incentives to protect IPR. Second, we cannot observe countries' level of technological development, thus we miss the relation between high technological development, high innovation and high propensity to protect IPR (leading to a possible omitted variable bias). Countries with more mature R&D sector innovate more, and tend to strictly protect IPR. This is probably at the origin of the underestimation of the negative effect of stricter IPR on indigenous innovation.

The two effects cancel out when the two sets of patents are merged (see the "All" regression). This result contradicts the idea that stronger protection of IPR in developing countries will lead to more patents at the global level. The total number of patents in the countries which enforce IPR more strictly is not affected: there seems to be a substitution between domestic and foreign patents. This result is consistent with Kyle and McGahan (2012) who find that the introduction of patents in developing countries has not been followed by more R&D investment in the diseases that are most prevalent there. These results illuminate the conflict which sets advanced and developing countries in opposition regarding TRIPS and more generally in matters of strong IPR. According to its critics, a strict enforcement of IPR reduces technological transfer and reverse engineering, which in turn affects the capacity of a country to genuinely innovate. We next focus on this issue.

Our empirical results suggest that increasing IPR in developing countries has an

[19] The coefficient for IPR in the non-resident patent equation is only significant at 10% level. To test the robustness of this result we have also estimate a second specification including also $F.MKTweak$ and its square in addiiton to $F.MKTstrong$ (see footnote 14 for details) and a third one only including $F.MKT$ (as in column (c) of table 1). In all these specifications, the size of the IPR coefficient is almost unaffected and the significativity is always preserved.

adverse effect on the level of innovation produced in the country. One explanation for this negative result is that strict protection of IPR does not allow developing country to close their initial technological gap through imitation and reverse engineering. To assess the empirical relevance of this argument, we explore the effect of stricter IPR on "inside-the-frontier" innovation (i.e. goods that are new to a country production basket, but have already been discovered in other countries). To measure "inside-the-frontier" innovations we follow Klinger and Lederman (2009, 2011), who propose export discoveries, i.e., the discovery of products for exports that have been invented abroad but that are new to the country.[20] This is measured by the number of new products that enter a country's export basket in any given year, calculated using trade data from COMTRADE and BACI-CEPII. Measuring export discoveries requires a strict set of criteria to avoid the inclusion of temporary exports not really reflecting the emergence of a new product in the export capabilities of the country. First, we use the highest possible level of disaggregation of products for the period analyzed. Using BACI-COMTRADE data for the period 1980-2005, the available classification is SITC Rev 2, which allows for 1836 potential product categories. Second, we follow Klinger and Lederman (2009) by considering a threshold of 1 million US dollars (in 2005 constant prices) to assess whether a new product has entered the national export basket. Moreover, we only include products that attain this threshold or higher for two consecutive years. It is possible that some exporters in a country will try new products and, incidentally, will surpass this threshold, while in the next years stoping the exportation. To have a reasonable window of time for the last year in our study, we consider exports until 2007.

We perform the same exercise as for "on-the-frontier" innovation (see the results presented in Table 2), but using "inside-the-frontier" innovation (discoveries) as the endogenous variable. We also use the same instrumentation strategy to deal with the endogeneity of IPR. We concentrate the analysis on less developed countries, excluding, for each year in our sample, the highest quintile in term of GDP per capita. The results are presented in Table 4.

Fixed effects and time dummies are included in all specifications. For the sake of comparison we show in column (a) the result of the OLS regressions when we do not correct for the endogeneity of IPR. In column (b) IPR is instrumented by the flows of students in neighboring countries going to study abroad, and by the spatial distribution of the number of tractors. Finally, as a robustness check, column (c) presents a negative

[20]The use of export discoveries as a measure of "inside-the-frontier" innovation is inspired by the work of Imbs and Wacziarg (2003). These authors show that economic development is associated with increasing diversification of employment and production across industries rather than specialization.

Table 4: Discoveries Equation

SAMPLING:	Panel OLS	Panel IV	Neg. Binomial
	(a)	(b)	(c)
ipr	–0.15	–0.38*	–0.17**
	(0.11)	(0.23)	(0.07)
ALPHA	–2.68	–3.70	1.62**
	(2.91)	(2.93)	(0.73)
ALPHA^2	0.05	0.07	–0.04**
	(0.06)	(0.06)	(0.02)
F-ALPHA-strg	–2.68	–2.90	–1.77
	(2.04)	(1.99)	(1.52)
F-ALPHA-strg^2	0.07	0.08	0.04
	(0.05)	(0.05)	(0.04)
freedom	0.39	0.42	0.63**
	(0.35)	(0.37)	(0.30)
gatt/wto	–0.02	0.10	0.10
	(0.15)	(0.18)	(0.12)
hcap	5.29***	5.06***	0.93
	(1.98)	(1.76)	(0.62)
hcap^2	–0.23**	–0.23**	–0.03
	(0.10)	(0.09)	(0.03)
IPR Endogenous	No	Yes	No
No. of obs	332	332	332
N. countries	74	74	74
Within R^2	0.73	–	–
Hansen (p-val.)	–	0.92	–
First-stage regs.:			
Instruments:			
Students(FH)		2.91**	
		(1.35)	
N. of tractors		273.51***	
		(52.07)	
F (all instr.)	–	13.83	–
Partial R^2	–	.17	–

Robust Standard Errors in parentheses, clustered by country. ***, ** and * represent respectively statistical significance at the 1%, 5% and 10% levels. All regressions include country fixed effects and time effects. All variables describing the market size and the gatt/wto variable are lagged one period. First-stage regressions include all controls shown in Table 2. Instruments are lagged three periods. F-stat is the Angrist and Pischke version.

binomial estimation. This specification does not allow us to use the same instrumentation strategy, but it allows us to treat discoveries as count data.[21] In this regression, as in the instrumented cases, the coefficient of IPR is significantly negative (however, the size of the coefficient of this regression cannot be compared with the ones in the other columns because of the negative binomial functional forms). We interpret the negative coefficient of IPR as evidence that stricter IPR protection, by blocking imitation and reverse engineering, reduces the quality of domestic goods in developing countries that enforce them.

The regressions show that a stricter protection of IPR reduces within-the-frontier innovation. This last set of results gives credit to the idea that more protection slows down innovation in developing countries because it makes it harder to close their initial technological gap.

6 Conclusion

The paper contributes to the understanding of the forces that can encourage/discourage innovation at the global level, focusing on two issues: first, the incentives that developing countries might have to protect IPR; second, the impact of their choices on global innovation. It stresses the role of technical development and internal market size relative to export opportunities. Our empirical analysis shows that the strength of patent protection is a U-shaped function of the relative size of the domestic market with respect to export opportunities. It also shows that the choice of a stricter IPR regime does not necessarily increase innovation. Uniform IPR protection, as opposed to partial protection, seems to be detrimental to innovation (as measured by patent activity) in developing countries, without bringing clear benefits for global R&D activities. One explanation for this result is that stricter IPR protection reduces the ability of countries to close their technological gap. We provide evidence that stricter IPR protection, by blocking imitation and reverse engineering, reduces the quality of domestic goods in developing countries that enforce them.

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Appendix

Table 5 presents the same regression as int Table 2, except that the $GDPpc$, GDP and $F.MKT$ are computed using data in constant prices (year 2000 USD), not PPP. The main results are shown to be robust when using these alternative series of data. The signs of the coefficients of $GDPpc$ are compatible with the U-shape, but they are still insignificant. The importance of the total GDP and of the foreign market potential are confirmed, in particular when considering the size of markets of foreign countries strongly enforcing IPR ($F.MKTstrong$).

Table 5: IPR Equation with GDP not PPP-deflated

	(a)	(b)	(c)	(d)
GDPpc	–0.25			
	(0.49)			
GDPpc^2	0.04			
	(0.03)			
GDP		–3.13***	–1.99	–2.07*
		(0.64)	(1.30)	(1.21)
GDP^2		0.07***	0.05*	0.05**
		(0.01)	(0.03)	(0.02)
F.MKT			2.91**	
			(1.24)	
F.MKT^2			–0.07**	
			(0.03)	
F.MKT-strong				2.56***
				(0.78)
F.MKT-strong^2				–0.06***
				(0.02)
freedom	0.67***	0.70***	0.59*	0.60*
	(0.24)	(0.22)	(0.31)	(0.31)
gatt/wto	0.29**	0.31***	0.43***	0.45***
	(0.13)	(0.12)	(0.15)	(0.16)
No. of obs	709	709	511	511
N. countries	112	112	112	112
W. R^2	0.75	0.76	0.71	0.71

Robust Standard Errors in parentheses, clustered by country. ^{a}, ^{b} and ^{c} represent respectively statistical significance at the 1%, 5% and 10% levels. All regressions include country fixed effects and time effects. All variables describing the market size are lagged one period. GDP is in constant dollars.