The international platform of Ludwig-Maximilians University's Center for Economic Studies and the Ifo Institute

CESifo Working Papers

www.cesifo.org/wp

Universal Intellectual Property Rights: Too Much of a Good Thing?

Emmanuelle Auriol
Sara Biancini
Rodrigo Paillacar

CESIFO WORKING PAPER NO. 4292
CATEGORY 11: INDUSTRIAL ORGANISATION
JUNE 2013

Presented at CESifo Area Conference on Applied Microeconomics, March 2013

CESifo
Center for Economic Studies & Ifo Institute

CESifo *Working Paper No. 4292*

Universal Intellectual Property Rights: Too Much of a Good Thing?

Abstract

This paper studies the incentives that developing countries have to protect intellectual properties rights (IPR). On the one hand, free-riding on rich countries technology reduces their investment cost in R&D. On the other hand, firm that violates IPR cannot legally export in a country that enforces them. Moreover free-riders cannot prevent others to copy their own innovation. The analysis predicts that the willingness to enforce IPR is U-shaped in a country GDP: small/poor countries are willing to respect IPR to access advanced economies markets, while large emerging countries are more reluctant to do so because technological transfers from the West boost their production capacity and their domestic markets. Universal enforcement of IPR yields a higher level of innovation and global welfare only if the developing country does not innovate. A partial enforcement of IPR, strict in the north and lax in the south, is socially better if the developing country invests enough in R&D and if its interior market is large. The theoretical predictions of the model are tested with the help of panel data. The empirical analysis supports the theoretical results.

JEL-Code: F120, F130, F150, L130, O310, O340.

Keywords: intellectual property rights, innovation, imitation, oligopoly, trade policy, developing countries.

Emmanuelle Auriol
Toulouse School of Economics
Toulouse / France
eauriol@cict.fr

Sara Biancini
University of Caen Basse-Normandie
& CREM / Caen / France
sara.biancini@unicaen.fr

Rodrigo Paillacar
University of Cergy-Pontoise &
THEMA / Cergy-Pontoise / France
rodrigo.paillacar@u-cergy.fr

May 2013

1 Introduction

There has always been an international dimension to debates on intellectual property rights (IPR). However with the integration of the world economy IPR debates have become global. The United States, the European Union, Japan and other developed countries, have actively lobbied to impose "Western style" IPR legislations to every other country in the world. Contrary to Paris and Berne Conventions, that allowed considerable flexibility in their application, the agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS) imposes a common framework to all WTO members for IPR.[1] To this date, it is the most important international agreement on the design of intellectual property regimes. It is also the most controversial. It has been challenged by many countries, including Korea, Brazil, Thailand, India or the Caribbean states. The present paper proposes a simple framework in which the desirability of enforcing IPR everywhere, including in developing countries, can be assessed. The empirical relevance of the main theoretical results are tested with the help of panel data covering 122 countries and 45 years of world patents and discoveries.

The first source of conflict between developed and developing/emerging countries regarding the TRIPS agreement is that a strong enforcement of IPR limits the possibility of technological learning through imitation, which has been a key factor of the success of countries such as the US in the 19th century, Japan, Taiwan, or South Korea in the 20th century, and more recently China or India in developing high technological capacity in nuclear energy, computing, biotechnology, pharmaceutical, software or spacial industry (e.g., see Sachs, 2003). Yet after copying the technology invented by others, these countries have become major investors in R&D: today the US, China, and Japan are the top three countries in term of R&D worldwide expenses.[2]

The second source of conflict raised by the TRIPS agreement is about drugs and, more generally, about the fact that TRIPS does not stimulate research to benefit the poor because they are unable to afford the high price products once they are developed. In 2001 this led to a round of talks resulting in the Doha Declaration, whose aim is

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

[2]See WIPO Publication No. 941E/2011 ISBN 978-92-805-2152-8 at www.wipo.int.

to grant an easier access to medicines by all. It states that TRIPS agreement should not prevent a country from dealing with public health crises. In particular developing countries should be able to copy for internal use a medicine in case of national health crisis such 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. This declaration, which made a significant dent in the TRIPS agreement, has been challenged by the US and other developed countries with the help of organisations such as PhRMA (an organization representing pharmaceutical companies in the US). Since the South and the North are continuously fighting over TRIPS, and since the agreement was imposed without the support of much economics studies, more analysis is needed to illuminate the pro and con of universal enforcement of IPR.

The paper studies the impact of different IPR regimes on the investment decisions made by private firms in a two (developing and developed) countries model. We compare three IPR regimes: no protection, partial protection where only the rich country enforces IPR, a full protection where both countries enforce them. Since we want to study the impact of technological transfer we focus on incremental innovation: innovation enhances the quality of a vertically differentiated commodity, which is produced in each country by two national firms competing à la Cournot. This corresponds for instance to a new generation of mobile/smart phone or an improvement of an existing drug.[3] The cost of the R&D investment depends on the efficiency of the R&D process, which by convention is higher in the advanced economy. By contrast we assume that imitation is costless. However it yields a potential indirect cost: a firm that violates IPR cannot export in a country that enforces them. Moreover if one country does not enforce IPRs, imitation occurs in both countries (i.e. both firms imitate). There are thus benefits for a country which enforces IPR to compete with a country that does not enforce them: it can freely copy its competitor innovation, if any, while IPR act as a barrier to entry in its market.

We show that aggregated investment level and welfare are always higher under a partial protection regime than under a regime where there is no protection of IPR. One could argue that the no protection regime is not relevant because rich countries enforce IPR, so that, at worst, partial enforcement holds. However this is true only if illegal

[3] Indeed most new drug products are incremental improvements on existing drugs (see CBO, 2006).

imports are banned. With smuggling the equilibrium converges towards the no protection regime. This bad outcome militates for stricter enforcement of IPR, and helps to explain the lobbying of pharmaceutical companies and of the music and the movie industry as drug, film and disk are commodities which can easily be copied, smuggled or purchased over the internet.[4]

This first result suggests that the more protection of IPR the better it is for investment. However full protection of IPR is not always conducive of a higher level of investment than a partial regime. Market integration with full patent protection guarantees the highest level of innovation in the asymmetric situation where only the rich country does R&D and when the developing country market is sizable. When both countries invest similar level in R&D (e.g. China competing with the US), the global level of investment in the full protection regime converges toward the low level of the no protection regime. The total level of innovation is then higher with partial protection. This result arises because, when technological transfer occurs, the R&D investment of the two competing firms are strategic complement. When it can be copied, innovation by one firm expands the demand of the other firm so that it has more incentive to invest in quality development. Under a partial enforcement regime, an increase of investment by firm in country 1 is matched by an increase in investment by firm in country 2. It leads to higher market and demand growth, and hence welfare, than full enforcement. The optimal regime of IPR hence depends on the capacity of each country to do R&D and on the relative size of their internal market.

We next study the incentive that a developing country has to enforce IPR, as requested by TRIPS. Starting from the premise that rich countries have already adopted a strong level of protection, we show that a developing country will choose to respect IPR when its technological gap is large and its domestic market is small. For small developing countries it is indeed crucial to be able to export. By virtue of TRIPS they need to respect IPR to be granted access to the foreign market. This choice turns out to be globally efficient, also increasing welfare in the developed country. By contrast when the size of its national

[4]For instance "U.S. Customs estimates 10 million U.S. citizens bring in medications at land borders each year. An additional 2 million packages of pharmaceuticals arrive annually by international mail from Thailand, India, South Africa and other points. Still more packages come from online pharmacies in Canada" ("Millions of Americans Look Outside U.S. for Drugs" By Mary Pat Flaherty and Gilbert M. Gaul Washington Post Staff Writers Thursday, October 23, 2003).

market is large compared to the foreign market, the developing country can afford not to protect IPR, even if this precludes its firms to legally export in rich country (e.g., generic drugs produced without licence in India). The paper thus predicts that small developing countries should be willing to enforce IPR, while large emerging ones might be more reluctant to do so. From a static comparative point of view, an increase of foreign market access (which increases the relative importance of the size of foreign demand) increases the incentive to enforce IPR, as IPR protection enhance export opportunities.

These results help to explain why reaching a consensus on IPR at the international level is challenging: rich and poor countries fancy opposite policies in many cases. In particular the advanced economy prefers the full protection regime when it has a significant technological advantage and the market of the developing country is large.[5] Yet this is a case where the developing country prefers partial protection. This is also a case where the free-ridding losses suffered by the advanced economy are higher than the developing country gains so that full protection would be better for global welfare.

Our analysis has two main empirically testable predictions. The first one is that the incentives to protect IPR in a developing country are decreasing in the relative size of its domestic market. Using a methodology developed in the new economic geography literature to construct a measure of the foreign market potential, the empirical analysis confirms the existence of a U-shape relationship between patent protection and the relative size of a country interior market vis à vis its trade partners.

The second set of predictions is about the impact of IPR enforcement on innovation. Empirically we distinguish between within-the-frontier innovations, which are a proxy for the intensity of technological transfer and reverse engineering, and on-the-frontier innovations, which measure genuine innovation. As expected increasing IPR protection decreases within-the-frontier innovation. More interestingly our model also predicts that a stricter enforcement of IPR decreases genuine innovation of the local firm in the developing country, while it increases innovation of the firms in the developed country, without necessarily increasing innovation at the global level. Correcting for the endogeneity of

[5]It prefers a partial protection regime in all other cases, provided illegal imports are banned. Indeed with a partial protection regime the advanced economy enjoys a monopoly on its internal market and incremental innovations made by the firm in the emerging country increase its stock of innovation, increasing in turn the demand for its products and its profit.

IPR policy, the empirical results confirm that increasing IPR enforcement decreases on-the-frontier innovation of resident firms (measured by resident patents) in developing countries, but increases innovation of nonresident firms, which are essentially based in developed countries. The two effects cancel out when the two set of patents are merged, which gives credit to the theoretical result that stronger enforcement of IPR in developing countries is not necessarily conducive of more R&D at the global level.

The rest of the paper is structured as follows. Section 2 reviews the related literature on IPR and trade. Section 3 presents the base model, and robustness is checked in extension in the appendices. Section 4 derives the R&D investment levels equilibrium under different IPR regimes (i.e., none, partial, and full). The welfare analysis at the country level is conducted in section 5, which allows us to study the incentive the South has to enforce IPR and to illuminate the conflicts of interest between advanced and developing countries regarding TRIP. Section 6.1 presents the data. Section 6.2 develops the empirical analysis. Finally section 7 concludes.

2 Related Literature

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.[6] These pioneering papers assume that only firms in the North can innovate and thus concentrate on the incentives that the South could have to protect IPR of Northern firms. Since the harmonization of IPR amounts to introduce strong protection in the South to the benefit of Northern firms, these papers find that the interests of the North and the South often conflict. Moreover, although a uniformly strong system of intellectual property rights is conducive of more innovations (i.e., in the North), it does not always enhance global welfare (e.g. due to the monopoly distortion). In the wake of this theoretical literature, an empirical literature focuses on the impact of IPR protec-

[6] Starting with the seminal work on optimal patent design by Nordhaus (1969), a vast literature focus on the issue of the optimal patent structure, notably length and breadth, in the context of a closed economy. Nice analytical reviews of this literature can be for instance found in Moschini and Langinier (2002), Gallini and Scotchmer (2002) , Scotchmer (2004a), and Hall (2007). The basic argument in favor of IPR is that they are necessary to stimulate invention and new technologies. The main critic against IPR is that they increase the cost of patented commodities and slow down knowledge diffusion which reduce welfare.

tion in the South on exportation by the North. It identifies a basic trade-off between the enhanced market power of the Northern firm created by stronger patent (market power effect), which tends to reduce its exportation due to the monopoly distortion, and the larger market size generated by the reduced abilities of the Southern firms to imitate its product (market expansion effect), which tends to increase its incentive to export. Maskus and Penubarti (1995) find with OECD data that the market expansion effect is prevailing. Similarly, Smith (1999), which assesses how US exports are sensible to national differences in IPR, shows that stronger IPR have a market expansion effect in countries with a strong capacity of imitation.[7]

This first strand of the literature focuses on the impact of IPR enforcement in the South on the incentives of Northern firms to export patented commodities and to innovate. It assumes that the South is not investing in R&D. Yet with the emergence of new players in high tech industry such as India or China,[8] it is important to extend the literature on IPR and trade to the case where all the countries, including poor ones, can innovate. A first important paper in this respect is Grossman and Lai (2004), which looks at two heterogeneous countries: one identifying the North (high innovation, high demand) and the other the South (low innovation, low demand). The authors assume that innovation generates an increase in variety (i.e., horizontal innovation) in an economy in which consumers are characterized by Dixit-Stiglitz preferences. They show that the Southern economy has a lower optimal level of protection at the Nash Equilibrium. Moreover patent policies are strategic substitutes so that the global equilibrium level of patent protection is inefficiently low. Efficiency can hence require to increase the level of protection of both countries, but harmonization (i.e. equal patent duration and enforcement rate) is not necessary nor sufficient to achieve an efficient outcome. Starting from an equilibrium where as in Grossman and Lai (2004) the optimal level of protection is smaller in the South, Lai and Qiu (2003) show that the South is also in general worse off if the policies are harmonized. However, a reduction of tariffs in the North can compensate for this loss and both countries are better off. For the authors, these results prove the merits of

[7] A possible problem of this approach is that the variables used to measure imitation potential (usually the number of R&D scientists, engineers and technicians, the educational attainment and R&D expenditure) could also be capturing technological development and thus autonomous innovation ability.

[8] China is the second largest investor in R&D in the world, just after the US (see the World Intellectual Property Indicators 2011, at www.wipo.int/ipstats).

multi-sectoral negotiations as in the GATT/WTO.

Consistently with these two papers, we look at innovation and IPR choices made by two firms respectively located in a developed and in a developing country. Our paper focuses on vertical innovation: innovation increases the quality of a product (i.e., a new and more effective drug, a new generation of mobile phones, ...). This is a difference with Grossman and Lai (2004) and Lai and Qiu (2003) who focus on horizontal innovation. In their models innovation is not cumulative so that an increase in the strength of protection always increases innovation. By contrast we aim to study the impact of technological transfers on global innovation as it is at the heart of the TRIP controversy (see Sachs, 2003). Our model focuses on incremental innovation to explore this issue and its impact on the South ability to develop an high tech industry, which in turn mights contribute to global R&D, as it has been the case for the US in the XIX century, Japan and Korea in the XX, or China in the XXI. We are hence able to show that an universal enforcement of IPR is not always conducive to more investment in R&D at the global level. Because of the technological transfers it involves, an asymmetric enforcement of IPR, weak in the South strong in the North, means that the investment levels in R&D of Northern and Southern firms are strategic complement. Since they reinforce each other, partial enforcement of IPR leads to higher levels of investment in the South, which implies that total investment often increases. In the empirical application we are hence taking into account the difference between on-the-frontier and inside-the-frontier innovations on the manufacturing sectors of a wide panel of countries. Our analysis shows that full (uniform) IPR protection, as opposed to partial protection, can be detrimental both to imitation-driven innovation and on-the-frontier innovation (as measured by patent activity) in developing countries. As argued by TRIP opponents, by preventing technological transfers from the North, an universal enforcement of IPR is limiting the development of R&D activities in the South.

Compared to the preceding papers we also consider that countries differ not only in per-capita income but also in population size, which are both relevant demand characteristics. This specification allows us to cover different cases, including small, poor countries such as sub-saharan African countries, and large, poor countries such as China or India, competing with small or large, rich countries, such as Norway or the USA. Because of the size of its population, the developing economy can be larger than the developed one, although poorer in per capita term, and generally endowed with a less efficient R&D technology. This is new as most papers focus on a uni-dimensional demand or technology ability: high for rich countries and low for poor countries. For instance in Grossman and Lai (2004) and Lai and Qiu (2003) the same region, the North, is characterized by high innovation, high demand for innovative goods and higher optimal protection of IPR. In this context, the optimal protection increases with the size of the country: the North protects more because it is the main innovator (and gets a higher share of innovation profits) but also because it has a larger demand for innovative goods (and a higher willingness to pay for the new invented varieties). Similarly, protection in the South generally increases when the size of the market increases.[9] This monotonicity result is upset when one takes into account the heterogeneity of developing countries. We hence show that large developing countries have low incentive to protect IPR, while small ones have strong incentives to respect them. This suggests a U-shape relation between IPR enforcement and development (i.e. demand intensity), which is confirmed by our data.

Maskus (2000) and Braga, Fink, and Sepulveda (2000) were the first to empirically identify a U-shape relationship between patent protection and per-capita income. Following these contributions, Chen and Puttitanun (2005) proposed a theoretical model with two sectors, the import and the domestic sectors, to explain this empirical finding. They assume that the level of innovation in the developed country is fixed and firms in the developing country produce only for local consumers (i.e., they do not export). For some values of the parameters they find that, when the level of development of the country (measured by per-capita GDP) increases, the level of protection first decreases and then increases. They again found a U-shape relation between per-capita GDP and IPR enforcement in their data.

Our model generalizes their analysis in several directions. First, we study Northern firms sensitivity to the choice of IPR in the developing country as it has been shown to be a key determinant of their incentives to invest (see Chin and Grossman, 1991, Diwan and Rodrik, 1991, Deardorff, 1992 and Helpman, 1993). Second, we allow the

[9]In Grossman and Lai, 2004 protection in the South, for a given strength of protection in the North, can also decrease with the size of the market for some value of the parameters.

developing country to export because under TRIP the South willingness to respect IPR structures their ability to trade. Their willingness to enforce IPR is directly connected to their incentive to export. Third our analysis distinguishes among the income level, the (population) size of the country and its technological development. As in Scotchmer (2004b) we rely on the relative size of the demand (and not solely the per capita GDP) and on the technological gap between the two countries to conduct our static comparative analysis as they play a crucial role in determining the willingness to enforce IPR.

Scotchmer (2004b) separately analyzes the effect of asymmetries first in the size of the market (for a same innovative capability) and second in innovative capabilities (for a same size of the market). By contrast we are looking at the impact of these two factors simultaneously. In Scotchmer (2004b) each country can produce an innovation, characterized by a given cost and a potential surplus in two separated regions. Studying the simultaneous choice of patent protection in the two regions, she shows that, although enforcement of IPR in only one country is optimal for some types of innovations, it almost never arises in equilibrium. Harmonization then solves some of the inefficiencies of the equilibrium choice of IPR, but might also generate a level of protection that is higher than optimal. Interestingly, under harmonization, stronger protection is more attractive to smaller (and also to more innovative) countries, which is consistent with our results. To be more specific, in our model the South willingness to harmonize IPR to the high level of the North decreases with the relative size of its internal market. The level of enforcement is hence shown to be U-shaped in the relative size of domestic demand.

Since our paper looks at the interaction between IPR enforcement and trade, it is also related to the literature on the impact of parallel imports on innovation. In the presence of parallel imports (or international exhaustion) the possibility to perform price discrimination of Northern firms is reduced, which weakens their incentives to innovate (see Malueg and Schwartz, 1994, Rey, 2003, Valletti, 2006, Li and Maskus, 2006). This result is partially challenged by Grossman and Edwin (2008) and Valletti and Szymanski (2006). Although we do not look at parallel imports, we consider the impact of illegal importation of imitated goods. As in the case of parallel imports, the illegal sales increase product market competition and affect innovation incentives. Our results confirm that innovation is generally harmed by illegal import.

Finally our paper relates to the empirical literature on the effects of TRIPS on innovation in specific industry, namely the pharmaceutical industry. Qian (2007) evaluates the effects of patent protection on pharmaceutical innovations for 26 countries that established pharmaceutical patent laws during 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 (Forthcoming) test the hypothesis that, as a consequence of TRIPS, increased patent protection results in greater drug development effort. They find that patent protection in high income countries is associated with increases in R&D effort but the introduction of patents in developing countries has not been followed by greater R&D investment in the diseases that are most prevalent there, a result which is confirmed by our estimations on a broader set on industries.

3 The model

We consider a two countries economy. There is a firm producing a vertically differentiated commodity in each country. We focus on quality augmented linear demand.[10] Demand for good i in country j writes:

$$p_{ij} = a_j(v_i - b_j(q_{1j} + q_{2j})) \quad i, j \in \{1, 2\} \tag{1}$$

where $a_j > 0$ and $b_j > 0$ are exogenous parameters, v_i represents the quality of good i, and q_{ij} is the quantity of good i sold in country j. It is easy to check that $p_{1j} - p_{2j} = (v_1 - v_2)a_j$ so that, unless goods have the same quality, they are not perfect substitutes. The price of commodity i increases with its quality and with the price of its competitor, it decreases with the quality of its competitor.

Countries differ in population size and per-capita income. In the empirical application, a_j is interpreted as the per-capita income and b_j as the *inverse* of the population size of country j.[11] This specification covers different cases, including small or large poor

[10] For a discussion of quality augmented models, see Singh and Vives (1984).

[11] To see this point assume that the indirect utility of a representative consumer consuming two goods of quality v_1 and v_2 is given by: $V(w, q_1, q_2) = u(w) + v_1 q_1 + v_2 q_2 - \frac{(q_1+q_2)^2}{2}$ where q_i is the quantity of good $i = 1, 2$, u is an increasing and concave function of the consumer net income $w = R - p_1 q_1 - p_2 q_2$. Optimizing V with respect to q_i yields: $\frac{\partial V}{\partial q_i} = -p_i u' + v_i - (q_1 + q_2)$ $(i = 1, 2)$. We deduce that if

countries competing with small or large, rich countries. The parameter $\alpha_i = a_i/b_i$, which is proportional to the GDP, reflects the intensity of the demand in country i, and $\alpha = \alpha_1 + \alpha_2$ is the depth of the global market. A parameter which plays an important role in the analysis below is the ratio

$$\gamma = \frac{\alpha_2}{\alpha_1} > 0. \tag{2}$$

The ratio γ captures the relative intensity of demand in country 2 with respect to demand in country 1. A small γ indicates that the developing country market is small compared to the internal market of the advanced economy. This situation corresponds to traditional north-south trade relation, where the developing country is poor (i.e., it has a small GDP) so that its internal market is small (e.g., sub-saharan African countries). A large γ indicates that the developing country market is important for the advanced economy. It corresponds to the new trade relations between fast emerging countries such as China, India or Brazil, and advanced economies.

Regarding production, we set the common level of quality before investment equal to 1.[12] We assume that innovation increases the quality of the commodity by ϕ_i. As in Sutton (1991, 1997) this corresponds to a quality enhancing innovation, where an increase in the quality shifts the linear demand upwards. This may represent for instance the introduction of a new generation of mobile/smart phone. The cost of the R&D investment is $k_i \frac{\phi_i^2}{2}$, where $k_i > 0$ is an inverse measure of the efficiency of the $R\&D$ process in country $i = 1, 2$. That is, a larger k_i corresponds to a less efficient R&D process. Without any loss of generality we assume that country 1 has the most efficient $R\&D$ process (i.e., it is the rich country). We set $k_1 = k$ and $k_2 = \Delta k$ with

$$\Delta = \frac{k_2}{k_1} \geq 1 \tag{3}$$

The ratio $\Delta \geq 1$ plays an important role in the analysis below. With $\gamma > 0$ defined

$v_i - p_i u' > v_j - p_j u'$ then $q_j = 0$ and $q_i = v_i - p_i u'$. On the other hand, if $\frac{1}{u'} v_i - p_i = \frac{1}{u'} v_j - p_j$ the demand of a representative consumer can be written as $q_1 + q_2 = v_i - \frac{p_i}{u'}$. If N is the size of the population the total demand is $Q_1 + Q_2 = N v_i - N u' p_i$. Let $b \equiv \frac{1}{N}$ be the inverse of the population size, and $a \equiv \frac{1}{u'}$ be the inverse of the marginal utility of income, which corresponds to the per capita income if the utility of income is logarithmic, $u(y) = log(y)$. The aggregated inverse demand is $P_i = a\big(v_i - b(Q_1 + Q_2)\big)$. With 2 countries, the price of good i in country j becomes p_{ij}, and the total quantity in country j, $q_{1j} + q_{2j}$, yielding (1).

[12] In appendix 8.2 we relax this assumption. The main effect of introducing different initial levels of quality is to reduce further the incentive that the developing country has to enforce IPR.

above, these are the two main comparative static parameters of the paper. By investing $k_i \frac{\phi_i^2}{2}$ a firm increases the quality of the good from $v_i = 1$ to $v_i = 1 + \phi_i$. Innovation is thus deterministic.[13] Finally once a quality is developed, the marginal costs of production are normalized to zero for both firms.[14]

This basic model is fairly simple and yet it yields robust results as shown by our extensions in the appendix. In appendix 8.2 we check what happens when the initial level of quality of the commodities is lower in the South. In appendix 9.1 we study the robustness of our result to the presence of linear transportation cost. In appendix 9.2 we check what happens when illegal import occurs in the rich country, and in appendix 9.3 what happens when the developing country has an imperfect imitation technology. Finally in appendix 9.4 we study what happens when the innovation process is non cumulative so that $v_i^P = v_i^N = 1 + max[\phi_1, \phi_2]$. These various extensions are discussed throughout the papers when it is the most useful.

4 Investment in R&D

The firms play a sequential game. In the first stage, they invest in *R&D*. In the second stage, they compete in quantities (Cournot game). In the first stage they might choose to copy their competitor innovation, or not. For the simplicity of the exposition, we assume that if imitation occurs it is perfect. However our results are robust to the assumption of imperfect imitation (see Appendix 9.3). Because of this potential free-rider problem, the level of protection of the innovation influences investment in R&D. We distinguish three intellectual property rights (IPR) regimes, denoted $r = F, N, P$:

1. Full patent protection (F): both countries protect patents and the quality after investment of the good produced by firm i is $v_i^F = 1 + \phi_i$.

2. No protection (N): countries do not protect patents and the quality after investment of the good produced by firm i is $v_i^N = 1 + \phi_i + \phi_j$.

[13] This assumption simplifies the exposition without altering the results of the paper. If innovation was stochastic so that the probability of improving the quality was increasing with the amount invested, the same qualitative results would hold.

[14] Alternatively, we could define p_i as the price net of marginal cost of firm i. In this case, an increase in the intercept parameter $a_i v_i$, for the same level of income a_i could be both interpreted as an increase in quality v_i or a decrease in the marginal production cost. This alternative model gives similar qualitative results (computations available upon request).

3. Partial protection (P): only country 1 (i.e., the rich country) protects innovation. If firm 2 violates the patent rights of firm 1, it will not be able to sell its product in country 1. Moreover, since country 2 does not enforce IPR, firm 1 can reproduce the incremental technological improvement developed by firm 2, if any, so that $v_i^P = v_i^N = 1 + \phi_i + \phi_j$.

If both countries enforce IPR (regime F), imitation is not allowed and each firm privately exploits the benefits of its R&D activity. If one or both countries do not enforce IPRs (regime N or P), imitation occurs in *both* countries/ *both* firms imitate. In the case of imitation, innovations are assumed to be cumulative. Each firm imitates its rival's innovation and improves upon it through its own R&D activity. This assumption is realistic in many industries. Nevertheless, in appendix 9.4 we check the alternative hypothesis that under imitation (regimes P and N), the quality available is the best innovation of the two firms (i.e. $v_i^N = v_i^P = 1 + \max\{\phi_i, \phi_j\}$). It turns out that this assumption is equivalent to the the limit case $\Delta \to \infty$ discussed in the paper.[15]
Differences between N and P arise after the investment phase: in the partial regime (P) country 1, which enforces strictly IPR, forbids importation by the imitator, and is thus a monopoly.[16] To keep the exposition simple we assume that exporting entails no transportation cost. Appendix 9.1 shows that our main results are robust to the introduction of a transportation cost.

The problem is solved backward by first computing the quantities offered by the firms in the different regimes. In regime $r = F, N$ and in regime $r = P$ firms in country 2 are in a duopoly configuration. For a given quality vector (v_1^r, v_2^r), the firm i maximizes its profit, $\Pi_i^r = p_{i1}^r q_{i1} + p_{i2}^r q_{i2} (-k_i \frac{\phi_i^2}{2})$ where p_{ij}^r is defined equation (1) with respect to quality v_i^r. The cost of R&D is in bracket because it has been sunk in the first stage. It is straightforward to check that the profit is concave in q_{ij}. The first order conditions (FOC) are sufficient. At the second stage of the production game, the quantity produced by firm i for country j is the Cournot quantity: $q_{ij}^r = \frac{2v_i^r - v_{-i}^r}{3b_j}$, where the index $-i \neq i$ represents

[15]A shown in Section 9.4 when $v_i^N = v_i^P = 1 + \max\{\phi_i, \phi_j\}$, there always exist an equilibrium in which only firm 1 invests, which is also the equilibrium when $k_2 \to \infty$. Moreover this equilibrium is unique when γ is not too large and Δ is not too small (i.e. larger than 1), which correspond to the case where country 2 is the developing one.

[16]We check the robustness of the results to the possibility of illegal imports in appendix 9.2.

the competitor and the value of v_i^r depends on the IPR regime, i.e. $v_i^r \in \{v_i^F, v_i^N, v_i^P\}$. Under the partial protection regime (P) the quantities produced in country 1 are the monopoly quantity of firm 1. That is, $q_{21}^P = 0$ and $q_{11}^P = q_1^M(v_1^P) = \frac{v_1^P}{2b_1}$. We deduce that the quantities produced at the second stage of the game are:

$$q_{ij}^r = \begin{cases} 0 & \text{if } i = 2,\ j = 1 \text{ and } r = P \\ \frac{v_1^P}{2b_1} & \text{if } i = j = 1 \text{ and } r = P \\ \frac{2v_i^r - v_{-i}^r}{3b_j} & \text{otherwise} \end{cases} \tag{4}$$

The profit of firm $i = 1, 2$ then writes:

$$\Pi_i^r = p_{i1}^r q_{i1}^r + p_{i2}^r q_{i2}^r - k_i \frac{\phi_i^2}{2} \tag{5}$$

where p_{ij}^r is the function defined equation (1) evaluated at the quantities defined in (4) and quality vector (v_1^r, v_2^r) is given by $v_i^P = v_i^N = 1 + \phi_i + \phi_j$ and $v_i^F = 1 + \phi_i$ $i, j = 1, 2$.

4.1 Socially optimal level of investment

As a benchmark case we first compute the optimal level of innovation taking into account the firms market power (i.e., property rights). That is, we compute the optimal investment level from a global social point of view when the production levels are defined by (4). The welfare of country $j = 1, 2$ is $W_j^r = S_j^r + \Pi_j^r$ where Π_j^r is defined equation (5) and

$$S_j^r = a_j(v_1 q_{1j}^r + v_2 q_{2j}^r) - a_j b_j \frac{(q_{1j}^r + q_{2j}^r)^2}{2} - p_{1j}^r q_{1j}^r - p_{2j}^r q_{2j}^r \tag{6}$$

with q_{ij}^r defined equation (4). The optimal investments ϕ_1 and ϕ_2 are the levels chosen by a centralized authority maximizing total welfare:

$$W = W_1^r + W_2^r. \tag{7}$$

A supranational social planner always chooses full disclosure of innovation (i.e. the no protection regime N). Once the costs of $R\&D$ have been sunk, she has no reason to limit innovation diffusion. This result illustrates the social cost imposed by IPR. They give market power to the firms, which limits innovation diffusion, demand expansion, exchange and thus decreases welfare. At the optimum $v_1^* = v_2^* = 1 + \phi_1 + \phi_2$. Substituting these values in (5) and (6) the socially optimal level of innovation in country i is obtained by maximizing W with respect to ϕ_1 and ϕ_2. Recall that $\alpha = \alpha_1 + \alpha_2$. This yields, for

$i = 1, 2$, $\phi_i^* = \frac{\alpha(1+\Delta)}{\frac{9}{8}\Delta k - \alpha(1+\Delta)} \frac{k_j}{(1+\Delta)k}$, which is defined only if $k > \frac{8}{9}\frac{1+\Delta}{\Delta}\alpha$.[17] A necessary condition to obtain interior solutions in all cases (i.e., for all $\Delta \geq 1$) is that k is higher than $\frac{16}{9}\alpha$. To be able to characterize the optimal levels of investment, and to warrant that our different maximization problems are concave, we thus make the following assumption.

Assumption 1 $k = 2\alpha$

Since we are interested in the role of IPR on innovation activities, we concentrate on relatively small k (i.e., $k_1 = k$ is close to the threshold value $\frac{16}{9}\alpha$), for which innovation in country 1 matters and piracy with regime P can be an equilibrium. We fix k equal to 2α simply to ease on notations. This specific value is not crucial for our results as shown in the robustness check we conduct in the appendix. What matters for our results is that k is not too large.[18]

Under the assumption A1 the optimal level of investment, $\phi^* = \phi_1^* + \phi_2^*$, is:

$$\phi^* = \frac{4(\Delta+1)}{5\Delta-4}. \tag{8}$$

It decreases with $\Delta \geq 1$, the efficiency gap between countries 2 and 1, an intuitive result.

The appendix 9.1 extends the analysis to the case with a linear transportation cost and a general value of k. When transportation costs are positive, the symmetry between the two countries is broken so that the size of the two markets in terms of population matters: the higher is $1/b_1$ or $1/b_2$, the higher is the investment. Moreover, a decrease in transportation costs always increases investment, and this effect is larger when the populations of the two countries increase.[19]

4.2 Full IPR protection (F regime)

In the case of full IPR protection, the quality of good i after investment is determined by $\phi_i^F = \phi_i$. Indeed under the F regime firms cannot free-ride on each other innovation.

[17] If $k \leq \frac{8}{9}\frac{1+\Delta}{\Delta}\alpha$ the optimal level of investments are unbounded.

[18] By contrast when k (and thus $k_2 = \Delta k \geq k = k_1$) is very large compared to α, country 2 is always better off under (F) (see section 5.1). Indeed, when R&D is very costly only marginal innovations can take place. Innovation does not matter and the regimes (F) and (P) mainly differ in the possibility of selling output in one or two markets. This is a case where country 2 always chooses the full IPR regime to be able to export its production in country 1.

[19] For the sake of comparison with linear transportation cost, t, and $k = 2\alpha$, the formula hence becomes $\phi_t^* = \frac{4(\Delta+1)}{5\Delta-4}(1 - \frac{t}{\alpha}\frac{b_1+b_2}{2b_1b_2})$ (see appendix 9.1).

Investment costs need to be duplicated to obtain similar level of quality in both firms. At the second stage quantities are given by the levels in (4). At the first stage (investment stage), firm i maximizes the profit (5) with respect to ϕ_i, for a given level of ϕ_j, $i \neq j$. Profit maximization gives the following reaction function:

$$\phi_i(\phi_j) = \frac{\alpha}{2.25k_i - 2\alpha}(1 - \phi_j) \tag{9}$$

The slope of the reaction function is negative: $\frac{\partial \phi_i(\phi_j)}{\partial \phi_j} = \frac{-\alpha}{2.25k_i - 2\alpha} < 0$ under assumption 1. Quality levels (and thus investment levels) are *strategic substitutes.* When i innovates, commodity i becomes more valuable to the consumer. Other things being equal, this decreases the demand for good j and so firm j's incentive to innovate. This is a pure competition effect that passes through substitution. When the quality of a good is increased, this not only increases the demand for this good, but decreases the demand for the competitor's good which becomes of lower relative quality.[20] Solving the system of first order conditions, we obtain that $\phi_i^F = \frac{3\frac{k_j}{\alpha} - 4}{15\Delta - 8}$.

The level of quality chosen by firm i depends positively on k_j, the parameter describing the competitor's cost of innovation. Since by convention $k_2 = \Delta k \geq k_1 = k$, the highest quality available to consumers in this setting is $\phi^F = \phi_1^F$, which after some rewritings is under A1:

$$\phi^F = \frac{6\Delta - 4}{15\Delta - 8} \tag{10}$$

Term ϕ^F is an increasing function of $\Delta \geq 1$. Not surprisingly, when the relative efficiency of firm 1 increases, its incentives to invest also increase. Indeed the investment levels of the two firms are strategic substitutes.

As shown in the appendix 9.1, when transportation costs are positive, the relative size of the internal market also matters. Firms in larger markets invest more than competitors operating in smaller ones. Moreover, a decrease of the transportation cost increases the level of investment of country i if and only if country j is relatively large in terms of population.[21] The perspective of competing in a large foreign market increases the

[20]In the alternative version of the model in which innovation decreases costs, the same effect arises. Without imitation, innovation by firm i makes this firms more efficient than j. This increases its demand and decreases the one of the competitor (and its incentive to innovate).

[21]Interestingly, the same effect does not occur when per-capita revenue increases. Starting from a symmetric situation ($a_i = a_j$), if the revenue of a country increases, both firms invest more, but the investment levels remains symmetrical. This can explain why larger countries tend to invest more in

incentive to invest. On the contrary, when the foreign market is relatively small, a decrease in transportation costs tends to increase the negative impact of competition on domestic profits, and thus to reduce the level of investment.

4.3 No IPR protection (N regime)

When IPR are not protected, firms can imitate the innovations of competitors at no cost. The quality of good i after investment is given by $1 + \phi^N = 1 + \phi_1^N + \phi_2^N$. At the second stage quantities are given by the Cournot levels in (4). At the first stage, profit maximization gives firm $i = 1, 2$ reaction function:

$$\phi_i(\phi_j) = \frac{\alpha}{\frac{9}{2}k_i - \alpha}(1 + \phi_j) \tag{11}$$

In this case the slope of the reaction function is positive: $\frac{\partial \phi_i(\phi_j)}{\partial \phi_j} = \frac{\alpha}{\frac{9}{2}k_i - \alpha} > 0$ under A1. Quality levels (and thus investment) are *strategic complements*. This result is counter-intuitive because free-riding behaviors are associated to under investment problems. Nevertheless, focusing on the reaction function, the more the competitor invests the more the national firm wants to invest in its own R&D activity. The level of investments in innovation become strategic complements when technological transfers occur. Because of imitation, when firm i innovates this has a positive impact on the demand for good j. The size of the market for the two goods increases. Then, the incentive of j to innovate is also enhanced. If the firm can exploit the innovation developed by its competitor without loosing the benefit of its own innovation, to win market shares it tends to invest more when its competitor invests more. Solving for the equilibrium we have: $\phi_i^N = \frac{1}{8\Delta - 1}\frac{k_j}{2\alpha}$. Since $\phi^N = \phi_1^N + \phi_2^N$ we deduce that under A1:

$$\phi^N = \frac{\Delta + 1}{8\Delta - 1}. \tag{12}$$

As in the optimal case (8) the total level of investment ϕ^N decreases with $\Delta \geq 1$ because investment levels are strategic complements.

In section 9.1 we derive the total investment level ϕ^N when transportation costs are positive. Contrarily to case F, a decrease of transportation cost is not always conducive

R&D, independently of income levels. For instance, countries like China and India invest more than smaller countries with similar per capita income characteristics.

to more investment in R&D. The net effect depends on the relative size of the two markets and on the technological gap between the two countries.[22] The larger is Δ, the competitive advantage of firm 1 in term of R&D technology, the less likely it is that a reduction in transportation costs increases the global investment in R&D. Indeed a reduction of transportation cost implies an increase in the intensity of competition on domestic markets. This business stealing effect discourages firm 1 to invest when free-ridding (i.e. Δ) is large. This effect is also relevant when the advanced economy enforces IPR, but enforcement is imperfect (the case of imperfect enforcement is illustrated in Appendix 9.2).

4.4 Asymmetric IPR protection (P regime)

When only one country protects IPR, firms can imitate their competitors' innovation. The quality of good $i = 1, 2$ after investment is given by $\phi^P = \phi_1^P + \phi_2^P$. Moreover both firms can sell in the market in which IPR are not protected. IPR are usually well established in developed countries, while less developed ones have lower incentive/capacity to protect them. If country 1 protects IPR, imitated goods cannot be exported in 1. Then if firm 2 chooses imitation, firm 1 has a monopoly in country 1, and it competes with firm 2 in country 2. At the second stage quantities in country 2 are given by the Cournot levels in (4). At the first stage, profit maximization gives the following reaction functions:

$$\phi_1(\phi_2) = \frac{9 + 4\gamma}{27 + 32\gamma}(1 + \phi_2) \tag{13}$$

$$\phi_2(\phi_1) = \frac{\gamma}{9\Delta(1 + \gamma) - \gamma}(1 + \phi_1) \tag{14}$$

In the case of partial enforcement of IPR, investments are *strategic complements*. That is, the slope of reaction function is positive for both firms: $\frac{\partial \phi_i(\phi_j)}{\partial \phi_j} > 0 \quad i, j = 1, 2 \ i \neq j$. The slope is larger for firm 1 because it sells its production in both countries. By contrast firm 2 sells only in country 2. Nevertheless, the slope of its reaction function is positive because technological transfers from firm 1 expands its domestic demand. Confronted with a larger demand, the firm 2 optimally increases its investment level. Since it has no access to the foreign market, its incentives to invest are lower than that of firm 1. In

[22] The total investment level with linear transportation cost $t \geq 0$ is $\phi_t^N = \frac{\Delta + 1 - \frac{t}{\alpha}\frac{b_1(2\Delta - 1) + b_2(2 - \Delta)}{b_1 b_2}}{8\Delta - 1}$. We deduce that a reduction in t increases ϕ_t^N if and only if $\frac{b_1}{b_2} \geq \frac{\Delta - 2}{2\Delta - 1}$.

equilibrium investment levels are:

$$\phi_1^P = \frac{(9+4\gamma)\Delta}{27\Delta+4\gamma(8\Delta-1)} \qquad (15)$$

$$\phi_2^P = \frac{4\gamma}{27\Delta+4\gamma(8\Delta-1)} \qquad (16)$$

We deduce that the total level of investment $\phi^P = \phi_1^P + \phi_2^P$ is :

$$\phi^P = \frac{9\Delta+4\gamma(1+\Delta)}{27\Delta+4\gamma(8\Delta-1)} \qquad (17)$$

It is intuitive in light of the previous results that the total level of investment ϕ^P decreases with $\Delta \geq 1$. More interestingly, and contrary to the cases F and N, the total level of investment depends on $\gamma = \alpha_2/\alpha_1$. This is because when firm 2 imitates the innovation of firm 1 it cannot export in country 1, which breaks the symmetry between the two markets.

As shown in section 9.1, the introduction of transportation costs has here a similar effect as under regime F.

4.5 Comparison of investment levels

Comparing the level of investment in the absence of IPR protection, (12), with the optimal level of investment (8), the level in N is suboptimal: $\phi^N < \phi^*$. Despite the fact that the free flow of innovations stimulates demand growth and thus encourages firms to invest more in innovation, firms under-invest in R&D compared to the optimum. This result is hardly surprising. The incentives of the firms are wrong (i.e., they focus on profit) and the free-rider problem takes its toll on R&D investment when their property rights are not protected. A more interesting issue is whether a stronger enforcement of the IPR regime will help to move the equilibrium level of investment in the right direction, or on the contrary will degrade it. Comparing (8), (12), and (17) it is easy to check that $\phi^* > \phi^P > \phi^N$. Independently of the level of efficiency of the national R&D process, aggregated investment level is always higher under a partial protection regime than under a regime where there is no protection at all. This result gives credit to the idea that a better protection of property rights is conducive to more innovation at the global level. In what follows we assess whether the imposition of the full IPR regime will increase further the global investment in R&D compared to the partial regime, or not.

Proposition 1 *There is a threshold* $\Delta(\gamma) \in (1, \frac{4}{3})$ *decreasing in* $\gamma \geq 0$ *such that:*

- *If* $\Delta \leq \Delta(\gamma)$ *then* $\phi^N \leq \phi^F \leq \phi^P \leq \phi^*$
- *If* $\Delta > \Delta(\gamma)$ *then* $\phi^N \leq \phi^P < \phi^F \leq \phi^*$.

Proof. The proof is in the appendix. ■

Contrary to what the proponent of strong enforcement of IPR argue, it is not always true that stronger enforcement of IPR increases global investment. In particular the result very much depends on the capacity of each country to do R&D. Two cases are particularly relevant from an empirical perspective.

First of all, there are cases where developing countries are not doing any R&D (i.e., $\Delta \to +\infty$). Indeed innovative activities are concentrated in a handful of countries with the top seven countries accounting for 71 % of the total R&D worldwide expenses.[23] In many sectors, the innovation activity of less developed countries is still negligible. When only the advanced economy, by convention country 1, invests in R&D, which corresponds in our model to $\Delta \to \infty$, the second condition of Proposition 1 holds and market integration without strong IPR yields a low level of investment compared to stronger IPR regimes. By continuity market integration with full patent protection F guarantees the highest level of innovation whenever the two countries have very unequal technological capacity.

Second the imposition of the full IPR regime does not increase the global investment in R&D compared to the partial regime when Δ is small enough. This case is also relevant empirically as emerging countries, such as China or India, have developed world-class level R&D systems. When country 2 is able to decrease its technological gap, global innovation is higher if country 2 does not protect IPR. The investment level of the two competing firms are strategic complement, and an increase of investment by firm in country 1 is matched by an increase in investment by firm in country 2. This result arises because, in the Nash equilibrium played by the two competing firms, the level invested by the competitor is perceived as exogenous. It is a demand booster which stimulates market growth when it can be copied. Thanks to the apparition of new generation of products

[23]These countries are the US, China, Japan, Germany, France, the UK and South Korea. See WIPO Publication No. 941E/2011 ISBN 978-92-805-2152-8 at www.wipo.int

and/or new applications, in equilibrium the demand is larger so that the firms have more incentive to invest in quality development. In the limit, when the R&D technologies become identical, the global level of investment in the full protection regime F converges towards the low level of the no protection regime N. That is, $\lim_{\Delta \to 1} \phi^F = \phi^N$. Imitation is then preferable because it does not reduce the quality of the product available in the two markets but reduces the total investment costs (they are not duplicated). Therefore the total level of innovation is higher (i.e., it is closer to the first best level) under a partial protection system P than under a full protection system F. This equilibrium does not militate for universal IPR enforcement.

The fierce battle between Apple and Samsung somehow illustrates this point.[24] James Allworth argues that the alleged piracies by Samsung, and before that by Microsoft, have never stopped Apple from aggressively investing in R&D and innovating (e.g., the iMac, the OS X, the iPod, the iPhone, the iPad), on the contrary. Moreover he shows that copying is a two ways street. He hence quotes an email from Apple executive Eddy Cue, advocating a change to Apple's lineup of tablet products as a result of him trying out a product that Samsung had released on to the market.[25]

Third the threshold value so that the innovation level under F becomes larger than the innovation level under P, $\Delta(\gamma)$, increases when the size of the interior market of country 1 rises compared to the interior market of country 2 (i.e., it decreases with the ratio γ). Intuitively, for a given size of the total market (i.e., total GDP α), when the relative size of market 2 is small, the free-riding problem becomes less important. Firm 2 can only sell in country 2, a small market, and the investment in R&D is less harmed by partial protection of IPR. On the contrary, if market 2 is large, free-riding by firms 2 has a stronger effect on the total incentives to innovate. In other words when small poor countries free-ride on investment by rich countries, they have a smaller impact on the total incentives to innovate than when large poor countries free-ride.

[24] In the spring of 2011, Apple began litigating against Samsung in patent infringement suits regarding the design of smartphones and tablet computers. By July 2012, the two companies were embroiled in more than 50 lawsuits around the globe, with billions of dollars in damages claimed between them. While Apple won a ruling in its favor in the U.S., Samsung won rulings in South Korea and Japan (see $http://en.wikipedia.org/wiki/Apple_Inc.\_v.\_Samsung\_Electronics\_Co.,\_Ltd.$).

[25] "Who Cares If Samsung Copied Apple?" by James Allworth published on the Harvard Business Review Blog (August 20, 2012).

Finally comparing equations (10) with (8), one can check that under assumption 1 the levels of investment in R&D are suboptimal in the case of full protection of IPR: $\phi_2^F < \phi_1^F = \phi^F < \phi^*$. This is worse for the less efficient country. We deduce that, no matter what the IPR regime is, the innovation level is never optimal: ϕ^* is larger than all the equilibrium values, ϕ^F, ϕ^N, ϕ^P. Moreover under all regimes, the investment level of country 2 decreases with the ratio Δ (while the investment of country 1 increases).

The result of Proposition 1 is at the aggregate level and is based on a comparison of all hypothetical regimes. In practice advanced economies are already enforcing IPR, while developing/emerging countries are not necessarily protecting them, so that the relevant comparison is between the regimes F and P. In the empirical part, where we rely on country level data, we thus focus on these two regimes. Moreover in the base model we have assumed that before investment the two firms have the same quality, normalized to $v_1 = v_2 = 1$. However, in many real word situations, the quality of the two firms will differ ex-ante (i.e. before investment). The Appendix 8.2 proposes an extension of the model where before investment the quality of firm 1 is $v_1 = 1$ and the quality of firm 2 is $v_2 = 1 - d$, with $d \in [0, 1]$ representing the quality gap between the two goods. If imitation occurs, this gap can be closed and everything is as in the base case. The only difference between the two variations of the model is thus under regime F, where the quality of firm 2 after innovation will be $v_2^F = 1 - d + \phi_2^F$, while the quality of firm 2 is $v_1^F = 1 + \phi_1^F$. The next result, which is derived from the previous analysis, provides predictions at the country level. We rely on these predictions to assess the relevance of the theory in the empirical analysis.

Corollary 1 *Let ϕ_{id}^F denotes the level of investment by firm $i = 1, 2$ when $d \in [0, 1]$. We have that $\phi_{2d}^F \leq \phi^P$ $\forall d \in [0, 1]$. Moreover it exists two thresholds $0 < \tilde{d} < \hat{d} \leq \frac{1}{4}$ such that*

- $\phi_{1d}^F \geq \phi_1^P \Leftrightarrow d \geq \tilde{d}$
- $\phi_{2d}^F \leq \phi_2^P \Leftrightarrow d \geq \hat{d}$

Proof. The proof is in the Appendix 8.2. ■

On the one hand, the level of quality obtained by the firm in the developing country is always higher under regime P (i.e., as ϕ_{2d}^F is decreasing in $d \in [0, 1]$ $\phi^P \geq \phi_2^F \geq \phi_{2d}^F$), while by virtue of Proposition 1 it is not always the case for the advanced economy (i.e., if $\Delta > \Delta(\gamma)$ then $\phi^P < \phi^F = \phi_1^F$, which is the value of ϕ_{1d}^F when $d = 0$). On the other hand, the level of investment (i.e. the quality developed autonomously by the firm in the developing country) can be higher or lower depending on the existence of the initial gap in the quality levels. Since the threshold gap $\hat{d}$ is quite low (i.e., $\hat{d} \leq 0.25$), in most cases we should observe that, when IPR are better enforced in a developing country, innovation of the local firm decreases. By contrast for the firm in the advanced economy, when IPR are better enforced in the developing country, we should observe an increase of innovation.

5 Endogenous IPR regimes

In this section we study the choice of IPR regime by utilitarian governments. They make their decision based on domestic criteria. Since advanced economies have already adopted strong IPR regimes, we focus on the case where country 1 (the advanced economy) has a strong IPR regime. The first question we address is whether developing countries will choose to adopt strong IPR regime too or not. In this end we assume that country 2, which is a follower, takes the IPR regime of country 1 as given. It chooses the protection regime F or P which yields the highest national welfare. This in turn influences the level of welfare in country 1 and the optimal IPR regime, F or P, from a global (utilitarian) welfare point of view.

5.1 Optimal IPR choice of country 2

The next result establishes that when either γ or Δ is large, regime P might yield a higher welfare for country 2 than regime F and thus become an equilibrium.

Proposition 2 *There are two thresholds* $0 < \underline{\gamma} < \overline{\gamma}$ *so that:*

- *If* $0 < \gamma < \underline{\gamma}$ *then* $W_2^F > W_2^P$*;*
- *If* $\underline{\gamma} \leq \gamma \leq \overline{\gamma}$ *then there exists a threshold value* $\Delta_2(\gamma) \geq 1$ *such that* $W_2^F \geq W_2^P$ *if and only if* $\Delta \leq \Delta_2(\gamma)$*;*
- *If* $\gamma > \overline{\gamma}$ *then* $W_2^F < W_2^P$*.*

Proof. The proof is in the Appendix 8.3. ■

Country 2 chooses to enforce IPR when its domestic market is relatively small (i.e., when γ is small). In this case it is very important for country 2 to have access to the market of country 1. This can happen only if country 2 respects IPR. It thus adopts F to be able to trade freely with country 1. By contrast when the size of its national market is relatively large, country 2 can afford not to protect IPR, even if this precludes firm 2 to legally export in country 1. This helps to explain why fast emerging countries, such as China and India, have been reluctant to enforce IPR as their huge domestic market developed. This result is reinforced if illegal imports occur (for instance because as in the case of medicines sell through the internet it is too costly for country 1 to enforce IPR). Then country 2 would choose to protect IPR even less often. Indeed, it can be shown that country 2 always prefers the N regime to the F regime. As argued by proponents of universal IPR regime, this might discourage innovation in country 1. When IPR is not protected in 1 because of illegal imports, the situation is equivalent to regime N, and total innovation is reduced (investments decrease both in 1 and 2). Imperfect enforcement would correspond to an intermediate case between N and P.

From an empirical point of view, everything else being equal, we expect the degree of enforcement of IPR to be U-shaped in a country market intensity α_i. Poor countries with a small interior market will tend to strictly enforce IPR. Symmetrically rich advanced economies are, for historical reasons, also strictly enforcing IPR. In the middle, emerging countries with large population will tend to free-ride on rich countries innovations by adopting a weak enforcement of IPR.

Finally a robustness check shows that if k (and thus Δk) is very large, then country 2 is always better off under regime F. To see this point consider the limit case $k \to \infty$, then $\phi_1^P = \phi_2^P = \phi_1^F = \phi_2^F \to 0$. Substituting these limit values in the welfare functions (see equations (27) and (29) in the appendix) we obtain that $W_2^F - W_2^P \to \frac{1}{9}(3\alpha_2 + \alpha_1) - \frac{1}{3}\alpha_2 = \frac{1}{9}\alpha_1 > 0$. By continuity this dominance result of F over P still holds for large enough values of k. When k is very large, free-riding on country 1 innovation is not worthwhile, because there is not much to copy. Country 2 always chooses the F regime to be able to export and to sell its production in country 1. However this result is upset when k is small enough, as under Assumption 1.

5.2 Policy adoption and Global welfare

In order to compute the total welfare and thus to be able to determine what is the optimal IPR policy from a global point of view we need to compute the welfare of country 1. For country 1, it is not clear that the choice of not protecting IPR in country 2 is necessarily a bad thing. If IPR are effectively respected in country 1 by banning illegal imports from country 2, when firm 2 chooses to steal the technology developed in country 1, this reduces competition in country 1. At the same time, if firm 2 also innovates and IPR are not protected in 2, firm 1 can include the innovations developed by its competitor in its own products. Incremental innovations made by 2 increase the stock of innovation offered by 1, increasing in turn the demand for its products and thus its profit. The next result establishes that indeed the position of the advanced economy vis à vis IPR adoption is sometimes ambiguous.

Proposition 3 *There is a threshold* $\gamma_1 > 0$ *so that:*

- *If* $\gamma < \gamma_1$ *then* $W_1^P > W_1^F$*;*
- *If* $\gamma \geq \gamma_1$ *then there exists a threshold value* $\Delta_1(\gamma)$ *increasing in* γ *such that* $W_1^F \geq W_1^P$ *if and only if* $\Delta \geq \Delta_1(\gamma)$*.*

Proof. The proof is in the Appendix 8.4. ■

Contrary to the developing country, country 1 prefers regime P whenever γ or Δ are small enough. It prefers full enforcement F otherwise. Comparing the results of Propositions 2 and 3, it is clear that there are potential conflicts of interest between the two countries. These conflicts of interest are illustrated Figure 1. It represents the welfare gains obtained by country i when the protection regimes shifts from P to F (i.e., the difference $W_i^F - W_i^P$). In the shaded regions, country i prefers (F) to (P). In the white region, there is no conflict of interest.

Starting from a situation of strong enforcement of IPR in advanced economies, country 2 is not always willing to enforce them. In many cases it will prefer not to protect innovation. For small levels of γ (i.e. when the intensity of demand in country 2 is relatively small), Country 2 always chooses strong enforcement of IPR F while Country 1 would prefer P. For intermediate values of γ, a conflict arises for both very small and

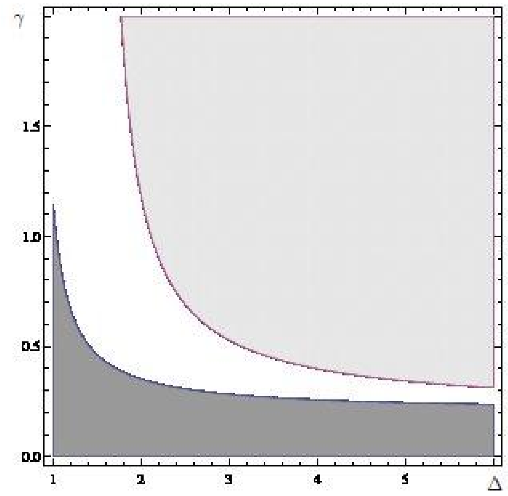

Figure 1: Welfare difference $W_i^F - W_i^P$. In the dark shaded region $W_2^F - W_2^P > 0$ and in the light shaded region $W_1^F - W_1^P > 0$.

very high levels of Δ: when country 2 has an efficient R&D technology (small Δ), it chooses regime F while country 1 would prefer P; on the contrary, when country 2 is very inefficient (large Δ), it chooses not to protect IPR (regime P), while country 1 would prefer F. Finally, when γ is large, the conflict arises for Δ large: in this case, country 2 chooses the partial regime P to free ride on country 1 technology, while country 1 would prefer full protection of IPR F. This result helps to explain why it is so hard to find a consensus on agreements such as TRIPS. The interests of developing countries and of advanced economies are generally antagonist.

We conclude the theoretical analysis by a brief presentation of the optimal policy from a collective utilitarian point of view. A normative approach mights help to look for a better compromise between the South and the North. It turns out that $W_1^F + W_2^F$, the total welfare under regime F, hasn't a smooth behavior. For this reason, the comparison with the regime P is not straightforward. Figure 2 illustrates the non-monotonicity of total welfare with respect to γ for high values of Δ (i.e. for high levels of Δ, F is socially preferable than P if γ is either very small or very large). When γ is small, country 2 prefers F and country 1 prefers P but the losses of country 1 are smaller than the gains of 2 and F is preferred from a global point of view. In this case the choice of IPR enforcement by 2 is efficient. On the contrary, when γ is very large (i.e. country 2 is very large or becomes richer), country 1 prefers F and country 2 prefers P, while the losses of country 1 are larger than the gains of country 2. Then F should be preferred at the global level, but country 2 has no incentive to enforce IPR. These results hold true especially when country 2 does not do R&D at all ($\Delta \to \infty$).

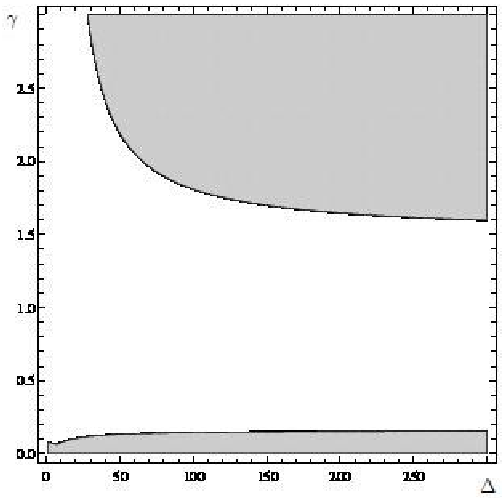

Figure 2: Total welfare difference: $(W_1^F + W_2^F) - (W_1^P + W_2^P)$. In the colored region $(W_1^F + W_2^F) - (W_1^P + W_2^P) > 0$.

By contrast when country 2 has developed an efficient R&D system, (i.e., when Δ is small) welfare is higher under a partial system P than under a full system F, unless γ is very small. Since developing countries that managed to set up competitive R&D systems are fast emerging countries with large interior markets, such as India or China, the most relevant case is one of a relatively large γ. This result suggests that as an emerging country moves from zero to substantial investment levels in R&D, partial IPR become more attractive from a global point of view, as it is conducive of a higher level of investment at the global level and of total market and demand growth. Yet this is also the case where generally the developing country will start to enforce IPR (see Proposition 2 and figure 1). This dynamics is illustrated by the Indian pharmaceutical industry. For decades India has produced drugs without respecting IPR, which has led western pharmaceutical companies to lobby for a strict enforcement of IPR at the world level and, eventually, to the TRIPS agreement. However, now that India has developed a full fledged R&D capacity, it has changed its legislation. As a result of the 2005 new patent legislation, Indian drug firms can no longer copy medicines with foreign patents.[26]

6 Empirical Analysis

6.1 The data

To empirically test the two main predictions of the model, we use several data sources. Data on IPR protection are from Park (2008), who update 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. Altough this source contains data from the 1960s to date, more accurate information is derived from the new release of TradeProd, a cross-country dataset developed at CEPII.[27] 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 Mayer (2008).

For measuring innovation, following Klinger and Lederman (2009, 2011) we distinguish between "inside-the-frontier" innovation and "on-the-frontier" innovation. This distinction is important because in the case of partial enforcement (P), both imitation and incremental innovation take places and not all innovations are patented (because imitating firms cannot patent their innovation). Klinger and Lederman (2009, 2011) propose export discoveries, i.e. the discovery of products for exports that have been invented abroad but that are new to the country, as a measure of "inside-the-frontier" innovations. It 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 (for more details on the construction of the variable, see Appendix 10.2). The use of ex-

[26] In India, prior to 2005, drug producers could copy patented medicines of foreign firms to create generic by means of alternating production procedures and reverse engineering. This measure was introduced in the seventies by the Government of India to promote the growth of the domestic market and to offer affordable medicine to the population who was unable to afford highly priced foreign drugs. This policy of piracy has boosted the Indian pharmaceutical sector, making it able to address the local market needs with surpluses that facilitated exports.

[27] In particular, this dataset take 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 in the CEPII website (http://www.cepii.fr)

port discoveries as a measure of "inside-the-frontier" innovation is inspired by the work of Imbs and Wacziarg (2003). In this paper, the authors show that economic development is associated with increasing diversification of employment and production across industries rather than specialization. Klinger and Lederman (2009, 2011) then study one aspect of economic diversification, namely the introduction of new export products. One problem recognized by the authors when concentrating on export data is that, contrarily to production discoveries, a product emerging as a new export may have been produced domestically for some time, and therefore would not represent a genuine discovery. In our case, this element makes export discoveries an even more appealing proxy for "within-the-frontier" innovation in the sense of our paper (i.e. driven by imitations). In fact, countries are known to export those goods in which they become the most productive, as argued by Hausmann, Hwang, and Rodrik (2007). Then, innovation in the production of goods that are not on the technological frontier, but are obtained mainly imitating foreign technology, can be captured by this measure of export innovations. This was the best proxy we could find, because comparable data on production are not available.

"On-the-frontier" innovation is defined as the invention of products that are new not only to the country but also internationally. We measure it with the number of patents applications of domestic and foreign firms resident in a country and it is provided by the World Bank (World Development Indicators).

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 OECD and the World Bank.

6.2 Empirical results

Our model predicts that developing countries with a relatively small internal market compared to their trade partners prefer to enforce patent rights, while those with a larger internal market become less willing to enforce strictly IPR.[28] By contrast, developed countries always protect IPR. The first empirical implication of the model is that patent

[28] As explained earlier when testing the empirical predictions of the model, we focus on regimes P and F, while bearing in mind that the existence of illegal imports can affect the actual choice of the protection regime and thus influence the magnitude of the results in the empirical analysis. The analysis of the N regime is a limit case useful to understand the impact of imperfect enforcement and illegal imports, when the actual regime is P (see Appendix 9.2).

enforcement is a U-shape function of the size of the internal market. Symmetrically the access to the foreign market has the opposite effect, increasing the relative importance of exports with respect to domestic sales. Patent enforcement is an inversed U-shape function of the size of the foreign market.

To test this prediction we use the information about per-capita GDP (variable $GDPPC$) and population (POP). In our model, α_i, the intensity of demand in the domestic market, is represented by the ratio a_i/b_i where a_i is interpreted as the inverse of the marginal utility of income and b_i as the inverse of the population size. Assuming the utility of income is logarithmic, α_i then corresponds to the total GDP.[29] We thus define the empirical equivalent of α_i as $ALPHA = GDPPC * POP$.

The results of the performed regressions are presented in Table 1. Exploiting the panel dimension of our database all the regressions include country fixed effect and time effect. Standard errors are robust and clustered by country. Continuous variables are in logs. To avoid possible endogeneity problems, the variables describing the market size are lagged 5 years.[30] In column (a) we regress IPR against the size of the internal market $ALPHA = GDPPC * POP$ and its square. We expect the coefficient of $ALPHA$ to be negative and the coefficient of $ALPHA^2$ to be positive, which is confirmed by the estimation. This estimation considers an unbalanced panel of 118 countries. We obtain very similar and significant coefficients if we restrict the analysis to a balanced panel of 79 countries, covering the period 1965-2005 (computation available upon request).

In column (b) we add a measure of the foreign market size, denoted F-ALPHA, which is a proxy for α_j. Following Head and Mayer (2004) and Redding and Venables

[29]Recent empirical studies have assessed the pertinence of the widespread use of the logarithmic form for the utility of income, providing new estimates. They start with the more general specification:

$$u(R) = \begin{cases} \frac{(R^(1-\rho)-1}{1-\rho}, & \text{if } \rho \neq 1; \\ log(R), & \text{if } \rho = 1. \end{cases} \tag{18}$$

For instance, Layard et al. (2008) estimate $\rho \simeq 1.2$. In this case, the empirical equivalent of our α_2 can be recalculated as ALPHA=GDPPC$^{1.2}$*POP. We tried this specification in our estimations: it does not qualitatively change the empirical results nor significantly affects the magnitude of the effects (estimations available on request). For simplicity, we thus stick to $u(y) = log(y)$.

[30]Theoretically, strong IPR protection could stimulate new investment and/or FDI and in turn affect GDP. This channel is likely to take some time, and we reduce the risk of endogeneity lagging the variables. We recognize that this not fully ensure exogeneity. However, our specification is based on the implications of our theoretical model and on the existing literature on IPRs (e.g., Ginarte and Park, 1997; Maskus, 2000; Chen and Puttitanun, 2005).

(2004), we construct a measure of the foreign market potential, denoted $F - ALPHA$, using a methodology developed in the new economic geography literature, based on the estimation of bilateral trade equations. In our case, we define

$$F - ALPHA_i = \sum_{j \neq i} GDP_j \hat{\phi}_{ij}, \tag{19}$$

where $\hat{\phi}_{ij}$ includes bilateral distances, contiguity, common language, regional trade agreements, WTO affiliation and a national border dummy (for more details on the construction of $F - ALPHA$ see appendix 10.1). Due to data limitations, in the regression and the following, we focus on the period 1985-2005. In our specification, we expect the coefficient of $F - ALPHA$ and $F - ALPHA^2$ to have opposite sign with respect to the own market variables, $ALPHA$ and $ALPHA^2$, which is confirmed by the estimation. However the coefficients of $ALPHA$ and its square are no longer significant. We will see that adding relevant controls allow to recover their statistical significance. These results are robust if we restrict the empirical analysis to a subsample of 101 countries whose observations are available for the entire period 1980-2005 (not shown to save space but available upon request).

In column (c) we add an economic freedom index ($lnfreedom$) and a dummy indicating the year of entry in the GATT or later in the WTO ($gatt/wto$) as additional controls (The $gatt/wto$ dummy is lagged two periods, i.e., 10 years). It is intuitive that these two variables should influence positively the level of enforcement of IPR. It is thus unsurprising that the coefficients of these controls are positive and significant. More importantly for our analysis the signs of $ALPHA$, $F - ALPHA$ and squared, do not change. In column (d) we control for the stock of human capital, *hcap* and its square. The variable *hcap* is the level of human capital computed with Hall & Jones method using the new series proposed in Barro and Lee, 2010. This variable does not appear to be significant and is clearly collinear with $ALPHA$, the GDP measuring the size of the internal market. However, as we will see later, the variable has an autonomous role in explaining "on-the-frontier" innovation of firms from developing countries.

These empirical results confirms the existence of a U-shape relationship between patent protection and the relative size of domestic market, as measured by GDP. They are

Table 1: IPR Equation

	(a)	(b)	(c)	(d)
L5.ALPHA	–2.24***	–1.20	–1.98	–1.53
	(0.40)	(0.88)	(1.36)	(1.87)
L5.ALPHA^2	0.05***	0.03	0.05*	0.04
	(0.01)	(0.02)	(0.03)	(0.04)
L5.F-ALPHA		3.32***	3.16***	3.49***
		(1.21)	(1.18)	(1.14)
L5.F-ALPHA^2		–0.07**	–0.07**	–0.08***
		(0.03)	(0.03)	(0.03)
freedom			0.59*	0.65*
			(0.32)	(0.33)
L10. gatt/wto			0.38***	0.40***
			(0.14)	(0.14)
hcap				–0.36
				(1.33)
hcap^2				0.00
				(0.06)
N. of obs	906	553	511	493
N. of countries	118	118	112	106
Within R^2	0.75	0.68	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. L(t) refers to the lagged period. For example, $L5.ALPHA$ means that the variable is lagged 5 years, which corresponds to one period in this 5-years panel.

consistent with previous studies by Maskus (2000), Braga, Fink, and Sepulveda (2000) and Chen and Puttitanun (2005). The novelty of our paper with respect to this literature is to consider an economy where both the advanced economy and the developing country can import, export and innovate.[31] So in addition to the per-capita income, which has been used in these previous studies, we also consider the size of the population, as well as the country's export opportunities. Our analysis hence shows that the measure of the foreign market potential $F-ALPHA$ is key to explain IPR enforcement at the domestic level. In fact the coefficients of $ALPHA$ and its square loose significance when we control for foreign market access. As predicted by the theory, the empirical analysis confirms the existence of an inverse U-shape relationship between patent protection and $F-ALPHA$. Put together these results imply a U-shape relation between IPR enforcement and the relative size of a country interior market, $GAMMA = (ALPHA)/(F - ALPHA)$. One important contribution of the paper is thus to empirically illuminate the complex relationship existing between trade and IPR policies (and not solely between development as measured by per capita GDP and IPR).

The second set of testable implications comes from Proposition 1 and, more specifically, Corollary 1. The theoretical analysis shows that a stricter enforcement of IPR is not necessarily conducive of more innovation at the country level, and in fact, by virtue of Proposition 1, not even at the global level. From an empirical point of view trying to assess the impact of IPR on innovation poses a clear problem of endogeneity. According to the theory, the innovation equation should be estimated simultaneously with the equation describing the choice of IPR. However, many of the variables used to explain IPR and presented in Table 1 columns (a)-(d), are likely to be explanatory variable of innovation as well, and do not represent valid instruments for IPR in the innovation equation. We thus instrument IPR using an additional set of instruments which satisfies the exclusion restriction from the innovation equations (tested as a group using the Hansen J-statistics and individually using the differences-in-Sargan statistic).

[31] In the two sectors (import and domestic) model of Chen and Puttitanun (2005), the level of innovation in the developed countries is fixed and firms in the developing country produce only for local consumers (i.e. they do not export). In their empirical analysis Maskus (2000) and Braga, Fink, and Sepulveda (2000) focus on the relationship, at a country level, between IPRs enforcement and domestic per-capita income.

The first instrument is the dummy variable *GATT/WTO* (lagged 10 years as indicated): entering into the GATT agreements or in the WTO imposes higher IPR standards to joining countries. The variable is lagged as it takes time to enforce the new norms.

The second instrument is a measure of technological adoption and diffusion, i.e. the lagged number of tractors in neighbor countries (in log). We focus onneighbor countries instead of data on the home country because the diffusion process might be endogeneous to the choice of a broader set of public policies, including enforcement of IPR. Among similar indices, we choose the tractor variable for several reasons. First of all it is a relatively old innovation in a traditional sector which is the focus of policy makers in developing countries. Since tractors are generally used with other inputs such as certified seeds and fertilizers, this may have stimulated the enforcement of IPR in countries that wanted to take advantage of the potential increase in agricultural productivity implied by mechanization. Second it provides 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). Finally the good data availability allows us to introduce the instrument lagged 3 periods (15 years) to reduce endogeneity concerns. This is also to limit endogeneity problem that we only use the information on the neighbors and do not include the country itself. We use the bilateral distance as weight to generate a single indicator for each country and each period (i.e., for each country we add the number of its neighbors' tractors weighted by the bilateral distance). The information is provided by Comin and Hobijn (2009) in their Cross-country Historical Adoption of Technology (CHAT) dataset.

The third instrument is the number of students from the neighbor countries studying abroad. As before, we focus on students from neighbor countries instead of students from the home country to reduce the risk of endogeneity. There are several studies showing that students who spent time abroad can influence the development of institutions in their home country (see Spilimbergo, 2009).[32] More specifically, Naghavi and Strozzi (2011) have shown that the knowledge acquired by emigrants abroad can flow back home into

[32]Spilimbergo (2009) shows that individuals educated in foreign democratic countries can promote democracy in their home country. Similarly, the same individuals, exposed to a full set of institutions, often including well-protected property rights, can also have an impact on the diffusion of attitudes towards IPR.

the innovation sector if IPR protection in the sending country is sufficiently strong. This is also in line with findings by 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. We consider several variants of this instrument (available in the dataset by Spilimbergo (2009) and deflated by the population size of the origin country). In the case of inside-the-frontier innovations, the instrument is the (log of) students that goes to non-democratic countries, as defined by Adam Przeworksi. To aggregate the countries into a single indicator, we considered several alternatives. The best instrument both in terms of exogeneity and relevance is based on a dummy of contiguity with the country and a lag of 5 years ($Students{*}Contig.$). In the case of on-the-frontier innovations we use the (log of) students going to democratic countries, as defined by the Freedom House ($Students(FH)$). Again, we explore several alternatives of spatial aggregation, and we finally retain a version with bilateral distance as weights and a lag of 20 years.[33]

We expect both instruments - tractors and students - to have an indirect effect on innovation through IPR. For example, if these students help the neighbor country to import technology, this will have an impact on the technological gap between the home country and its neighbor (either positive, if there are imitation and spillover, or negative through competition effect). Similarly, if these returning students induce the adoption of institutions such as IPR in the neighbor countries, this will also affect the enforcement of IPR in the home country

The results of the first stage equation explaining IPR including the excluded instruments are reported in the bottom parts of Tables 2 and 3.

Corollary 1 has two sets of implications. The first one is on the level of innovation incorporated in the production of the firm in the developing country. The corollary states that this level is higher when the developing country does not enforce IPR: $\phi_2^F \leq \phi^P$.[34] In order to assess the relevance of this result we rely on inside-the-frontier innovation, as measured by discoveries (i.e. the goods that are new in the export basket of a country, although already produced abroad) in developing countries. For these countries,

[33]Alternative specifications give very similar result when estimating the second stage equation, but they are more exposed to weak instrument problems. To avoid the related biases, we retain the presented specifications, but alternative specifications and related tests are available on request.

[34]The condition of Corollary 1 is $\phi_{2d}^F \leq \phi^P \ \forall d \geq 0$. Since ϕ_{2d}^F decreases in d we deduce the result.

Table 2: Discoveries Equation

SAMPLING:	All	Developing	All	Developing
	(a)	(b)	(c)	(d)
ipr	–0.13	–0.16	–0.39*	–0.40*
	(0.10)	(0.12)	(0.21)	(0.23)
L5.ALPHA	4.06	7.38*	3.18	6.01
	(3.71)	(4.25)	(3.64)	(4.25)
L5.ALPHA^2	–0.09	–0.15*	–0.07	–0.12
	(0.07)	(0.09)	(0.07)	(0.09)
L5.F-ALPHA	4.51**	–1.35	5.59**	–1.18
	(1.90)	(3.93)	(2.24)	(3.86)
L5.F-ALPHA^2	–0.13***	0.02	–0.15***	0.02
	(0.05)	(0.10)	(0.05)	(0.10)
freedom	0.56	0.74*	0.66	0.82**
	(0.39)	(0.38)	(0.40)	(0.39)
hcap	2.78	0.95	2.78	1.00
	(2.32)	(2.38)	(2.21)	(2.27)
hcap^2	–0.10	–0.06	–0.11	–0.08
	(0.12)	(0.13)	(0.11)	(0.12)
IPR Endogenous	No	No	Yes	Yes
No. of obs	366	265	366	265
N. countries	85	56	85	56
Within R^2	0.69	0.74	–	–
Hansen (p-val.)	–	–	0.49	0.28
First-stage regs.:				
Instruments:				
L10. gatt/wto			0.25**	0.20
			(0.13)	(0.14)
L5.Students * Contig.			–0.07**	–0.06**
			(0.03)	(0.03)
L15.N. of tractors			212.66***	248.32***
			(41.75)	(54.91)
F (all instr.)	–	–	20.61	21.73
Partial R^2	–	–	.17	.21

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. L(t) refers to the lagged period. For example, $L5.ALPHA$ means that the variable is lagged in 5 years (corresponding to one period in this 5-years panel). First-stage regressions include all controls shown in column (d) of Table 1.

discoveries can be considered a proxy for inside-the-frontier innovation (see Klinger and Lederman, 2009). The results are presented in Table 2. Fixed effects and time dummies are included in all specifications. For the sake of comparison we show in columns (a) and (b) the result of the regressions when we do not correct for the endogeneity of IPR. In column (c) and (d) IPR is instrumented using the GATT/WTO dummy, the flows of students in neighboring countries going to study to non-democratic countries (as defined by Przeworski), and the spatial distribution of the number of tractors. As expected from the theory, increasing IPR protection decreases within-the-frontier innovation. The regression is run both for the full sample and for a subsample of excluding developed countries (colums (b) and (d))[35]. When using the entire sample, the higher number of observations allows that the GATT/WTO instrument reaches statistical significance at conventional levels. According to the results of the "difference-in-Sargan" statistic the instruments can be considered as individually exogenous in both regressions. Moreover an IV regression without the GATT/WTO instrument gives virtually the same results (regressions available on request). We interpret the negative coefficient for IPR as evidence that stricter IPR protection, by blocking imitation and reverse engineering, reduces the quality of domestic goods in countries that enforce them, especially developing ones.

The second set of implications focuses on the level of investment in R&D and the quality developed autonomously by the firms in the developing country (i.e. on-the-frontier innovation). Starting from a situation where there is an initial gap in the quality levels produced by developed and developing countries, we predict that, when IPR are enforced more strictly innovation of the local firm decreases in the developing country, while the one of the firms of the developed increases. More protection can slow down on-the frontier-innovation because it makes harder for the developing country to close the initial gap in quality levels (see Appendix 8.2). To test this second set of predictions, we use data on patents as a proxy for on-the-frontier innovation. We focus on the subsample

[35]For each year in our sample, we consider that a country is developed if it belongs to the highest quintile in term of GDP per capita. We discard oil-exporting countries exhibiting very high GDP per capita levels (higher than 40000 USD of 2000). All these countries, at the exception of Norway, which is included as a developed country in the regressions, are highly dependent on this commodity (measured as a share of exports) and exhibit a low diversification of their economies. Norway is included as developed country in the regressions, but it is not considered in the distribution to set the threshold in year 2005 because its GDP per capita exceeds 40000 USD.

Table 3: Patent Equation

Patent type	Resident	Non-Resid	All	Resident	Non-Resid	All
	(a)	(b)	(c)	(d)	(e)	(f)
ipr	–0.48***	0.18	0.04	–1.26***	0.41**	0.15
	(0.10)	(0.12)	(0.11)	(0.24)	(0.18)	(0.18)
L5.ALPHA	–6.69	3.47	3.09	–16.35***	5.50	4.50
	(4.55)	(5.03)	(6.22)	(5.78)	(5.25)	(6.06)
L5.ALPHA^2	0.17*	–0.05	–0.04	0.37***	–0.09	–0.06
	(0.09)	(0.10)	(0.12)	(0.11)	(0.11)	(0.12)
L5.F-ALPHA	–0.91	5.54	2.90	0.36	5.66*	2.72
	(2.96)	(3.43)	(3.50)	(3.45)	(3.39)	(3.23)
L5.F-ALPHA^2	0.03	–0.14	–0.07	–0.00	–0.14	–0.06
	(0.07)	(0.09)	(0.09)	(0.09)	(0.08)	(0.08)
freedom	0.67**	0.30	0.60	0.28	0.34	0.66**
	(0.28)	(0.37)	(0.38)	(0.49)	(0.32)	(0.30)
hcap	3.98*	–0.43	0.68	6.11**	–0.70	0.37
	(2.34)	(1.47)	(1.79)	(2.79)	(1.46)	(1.67)
hcap^2	–0.11	0.05	0.03	–0.25**	0.08	0.05
	(0.11)	(0.09)	(0.08)	(0.13)	(0.09)	(0.09)
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	0.54	0.30	0.50	–	–	–
Hansen (p-val.)	–	–	–	0.52	0.82	0.73
First-stage regs.:						
Instruments:						
L10. gatt/wto				0.17	0.16	0.17
				(0.17)	(0.16)	(0.17)
L15.N. of tractors				254.58***	240.86***	254.58***
				(53.73)	(48.90)	(53.60)
L20.Students(FH)				–3.08*	–3.74**	–3.08*
				(1.62)	(1.57)	(1.62)
F (all instr.)	–	–	–	15.48	18.44	15.48
Partial R^2	–	–	–	.19	.21	.19

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. L(t) refers to the lagged period. For example, $L5.ALPHA$ means that the variable is lagged in 5 years (corresponding to one period in this 5-years panel). First-stage regressions include all controls shown in column (d) of Table 1. First stage regression for All Patents (column f) not shown but available on request.

of less developed countries (i.e. excluding the highest income quintile) and we measure on-the-frontier innovation as the number of patents application made by resident firms. Symmetrically, innovations made by firms from the developed countries are proxied by the number of patents applications made by non-resident firms. In fact, in developing (and developed) countries, the vast majority of patents of non-resident firms are registered by firms coming from high-income economies.[36] We first show (i.e., in columns (a), (b) (c)) the result of the regressions when we do not correct for the endogeneity of IPR, and next in column (d), (e), (f), IPR is instrumented using the GATT/WTO dummy, the flows of students in neighboring countries going to study to democratic countries (as defined by the Freedom House), and the spatial distribution of the number of tractors. The first-stage regressions confirm that the instruments are adequate. The GATT/WTO variable is no longer significant. While results are robust to the exclusion of this instrument, we have preferred to keep it for the sake of completeness. The regressions presented in Table 3 passe the exogeneity and relevance tests. Moreover each instrument can be considered exogenous individually. As a last robustness check, we run all IV regressions using alternative estimation methods robust to weak instruments. In particular the limited Information maximum likelihood (LIML) and the Fuller's modified LIML (See Murray, 2011 for details). We find virtually the same coefficients for the IPR variable. All these robustness checks are available upon request.

The results, shown in Table 3, confirm that failing to correct for endogeneity bias leads to an underestimation of the impact of IPR on innovation activities. More importantly they show that increasing IPR enforcement decreases on-the-frontier innovation of resident firms in developing countries (resident patents) but increases innovation of non-resident firms (which are mostly firms based in developed countries). In the non-resident equation the sign of $ALPHA$ and squared is hence inverted because the incentive to invest in patent of foreign firms depends positively on the size of the internal market of the developing countries. The two effects cancel out when the two set of patents are merged (see the "All" regression). This result contradicts the idea that stronger enforcement of IPR in developing countries will lead to more patents at the global level. Our results show

[36] For more on this see "World Intellectual Property Indicators" 2011 WIPO Economics & Statistics Series at www.wipo.int.

that the total number of patents is not affected: there is simply a substitution between domestic and foreign patents when IPR is more strongly enforced. This regression illuminates the conflict opposing advanced and developing countries over TRIPs agreement and more generally strong IPR enforcement.

7 Conclusion

This paper has studied in a two countries model the incentives developing countries might have to enforce IPR. It also studied the impact of their adoption choice on global innovation and welfare. The analysis illuminates that one size does not fit all. The results depend both on the maturity of the R&D system and on the size of the developing country internal market. When developing countries do not have a R&D system, the global level of investment in R&D and of welfare are higher under strict and uniform IPR regimes. However with the emergence of new players in the R&D world system, such as China and India, the results are reversed: investment levels in R&D and welfare are higher under a partial IPR.

The main predictions of the model have been tested empirically on trade data offering support to the main insight of the theoretical analysis.

References

R.J. Barro and J.W. Lee. A new data set of educational attainment in the world, 1950–2010, 2010.

C.A.P. Braga, C. Fink, and C.P. Sepulveda. *Intellectual property rights and economic development*. World Bank Publications, 2000.

CBO. *Research and Development in the Pharmaceutical Industry*. Congress of the Unites States, Congressional Budget Office, 2006.

Y. Chen and T. Puttitanun. Intellectual property rights and innovation in developing countries. *Journal of Development Economics*, 78(2):474–493, 2005.

J.C. Chin and G.M. Grossman. Intellectual property rights and north-south trade. *NBER Working paper No. 2769*, 1991.

D.A. Comin and B. Hobijn. The chat dataset. *NBER Working paper No. 15319*, 2009.

A.V. Deardorff. Welfare effects of global patent protection. *Economica*, pages 35–51, 1992.

I. Diwan and D. Rodrik. Patents, appropriate technology, and north-south trade. *Journal of International Economics*, 30(1):27–47, 1991.

C. Dustmann, I. Fadlon, and Y. Weiss. Return migration, human capital accumulation and the brain drain. *Journal of Development Economics*, 95(1):58–67, 2011.

N. Gallini and S. Scotchmer. *Intellectual property: when is it the best incentive system?* MIT Press, 2002.

J.C. Ginarte and W.G. Park. Determinants of patent rights: A cross-national study. *Research policy*, 26(3):283–301, 1997.

G.M. Grossman and L.C.L. Edwin. Parallel imports and price controls. *RAND Journal of Economics*, 39(2):378–402, 2008.

G.M. Grossman and E.L.C. Lai. International protection of intellectual property. *American Economic Review*, 94(5):1635–1653, 2004.

B. H. Hall. *Patents and Patent Policy*. OxREP article, December, 2007.

R. Hausmann, J. Hwang, and D. Rodrik. What you export matters. *Journal of Economic Growth*, 12(1):1–25, 2007.

K. Head and T. Mayer. Market potential and the location of Japanese investment in the European Union. *Review of Economics and Statistics*, 86(4):959–972, 2004.

E. Helpman. Innovation, imitation, and intellectual property rights. *Econometrica*, 61 (6):1247–80, 1993.

J. Imbs and R. Wacziarg. Stages of diversification. *American Economic Review*, pages 63–86, 2003.

B. Klinger and D. Lederman. Diversification, innovation, and imitation of the global technological frontier. *Breaking Into New Markets: Emerging Lessons for Export Diversification*, pages 101–10, 2009.

B. Klinger and D. Lederman. Export discoveries; diversification and barriers to entry. *Economic Systems*, 2011.

M. Kyle and A. McGahan. Investments in pharmaceuticals before and after trips. *The Review of Economics and Statistics*, Forthcoming.

E.L.C. Lai and L.D. Qiu. The North's intellectual property rights standard for the South? *Journal of International Economics*, 59(1):183–209, 2003.

R. Layard, G. Mayraz, and S. Nickell. The marginal utility of income. *Journal of Public Economics*, 92(8-9):1846–1857, 2008.

C. Li and K.E. Maskus. The impact of parallel imports on investments in cost-reducing research and development. *Journal of International Economics*, 68(2):443–455, 2006.

D.A. Malueg and M. Schwartz. Parallel imports, demand dispersion, and international price discrimination. *Journal of International Economics*, 37(3):167–196, 1994.

R. Manuelli and A. Seshadri. Frictionless technology diffusion: The case of tractors. *NBER Working paper No. 9604*, 2003.

K.E. Maskus. *Intellectual property rights in the global economy.* Peterson Institute, 2000.

K.E. Maskus and M. Penubarti. How trade-related are intellectual property rights? *Journal of International Economics*, 39(3-4):227–248, 1995.

T. Mayer. *Market potential and development.* Centre for Economic Policy Research, 2008.

G. Moschini and C. Langinier. *The Economics of Patents: An Overview.* In "Intellectual Property Rights and Patenting in Animal Breeding and Genetics", Edited by Scott Newman and Max Rothschild, CABI Publishing, 2002.

M.P. Murray. Avoiding the Pitfalls of Instrumental Variables Estimation with Few or Many Instruments. *Bates College. Mimeo*, 2011.

A. Naghavi and C. Strozzi. Intellectual property rights, migration, and diaspora. *IZA Discussion Papers*, 2011.

W. Nordhaus. *Invention, Growth and Welfare: A Theoretical Treatment of Technological Change.* Cambridge, MA: MIT Press., 1969.

W.G. Park. International patent protection: 1960-2005. *Research Policy*, 37(4):761–766, 2008.

Y. Qian. Do national patent laws stimulate domestic innovation in a global patenting environment? a cross-country analysis of pharmaceutical patent protection, 1978-2002. *The Review of Economics and Statistics*, 89(3):436–453, 2007.

S. Redding and A.J. Venables. Economic geography and international inequality. *Journal of international Economics*, 62(1):53–82, 2004.

P. Rey. The impact of parallel imports on prescription medicines. *University of Toulouse, manuscript*, 2003.

J. Sachs. *The Global Innovation Divide.* Chapter in NBER Book Series Innovation Policy and the Economy, MIT Press, Adam B. Jaffe, Josh Lerner and Scott Stern, editors (p. 131 - 141), 2003.

M.D.D. Santos and F. Postel-Vinay. Migration as a source of growth: the perspective of a developing country. *Journal of Population Economics*, 16(1):161–175, 2003.

S. Scotchmer. The political economy of intellectual property treaties. *The Journal of Law, Economics, & Organization*, 20(2):N2, 2004a.

S. Scotchmer. *Innovation and incentives.* MIT press, 2004b.

N. Singh and X. Vives. Price and quantity competition in a differentiated duopoly. *The RAND Journal of Economics*, pages 546–554, 1984.

P.J. Smith. Are weak patent rights a barrier to US exports? *Journal of International Economics*, 48(1):151–177, 1999.

A. Spilimbergo. Democracy and Foreign Education. *American Economic Review*, 99(1): 528–543, 2009.

J. Sutton. *Sunk costs and market structure: Price competition, advertising, and the evolution of concentration.* The MIT press, 1991.

J. Sutton. One smart agent. *The Rand Journal of Economics*, 28(4):605–628, 1997.

T.M. Valletti. Differential pricing, parallel trade, and the incentive to invest. *Journal of International Economics*, 70(1):314–324, 2006.

T.M. Valletti and S. Szymanski. Parallel Trade, International Exhaustion and Intellectual Property Rights: A Welfare Analysis. *The Journal of Industrial Economics*, 54(4):499–526, 2006.

8 Appendix

8.1 Proof of Proposition 1

Comparing equation (12) with (17) it is straightforward to check that $\phi^P > \phi^N$ is equivalent to $\alpha_1 \frac{2.25k_2}{k_1+k_2} + \alpha_2 > \alpha_1 + \alpha_2$, which is always trues since $k_2 > k_1$. Comparing next equation (8) with (17), $\phi^P < \phi^*$ is equivalent to $1.125(\alpha_1 \frac{2.25k_2}{k_1+k_2} + \alpha_2) < 4.5(\alpha_1 + \alpha_2)$. This inequality is always true because $\frac{2.25k_2}{k_1+k_2} \leq 2.25$ under the assumption $k_2 > k_1 \geq 1$ (see (3)). QED

We already established that $\phi^N \leq \phi^P \leq \phi^*$. We need to check when $\phi^P \leq \phi^F$. We now let $\gamma = \frac{\alpha_2}{\alpha_1}$ (see (2)). Under Assumption 1 we can rewrite the relevant innovation levels. Under regime (F) we have

$$\phi_1^F = \frac{6\Delta - 4}{15\Delta - 8} \tag{20}$$

$$\phi_2^F = \frac{2}{15\Delta - 8} \tag{21}$$

Similarly, under regime (N) we have, $\phi_1^N = \frac{\Delta}{8\Delta-1}$ and $\phi_2^N = \frac{1}{8\Delta-1}$ so that

$$\phi^N = \frac{\Delta + 1}{8\Delta - 1} \tag{22}$$

Under regime (P) we have, $\phi_1^P = \frac{(9+4\gamma)\Delta}{27\Delta+4\gamma(8\Delta-1)}$ and $\phi_2^P = \frac{4\gamma}{27\Delta+4\gamma(8\Delta-1)}$ so that

$$\phi^P = \frac{9\Delta + 4\gamma(1 + \Delta)}{27\Delta + 4\gamma(8\Delta - 1)} \tag{23}$$

It is easy to check that investment of firm 2 increases more when γ increases (i.e. $\frac{\partial \phi_1^P}{\partial \gamma} \geq \frac{\partial \phi_2^P}{\partial \gamma} \geq 0$)and that $\phi_2^P \leq \phi_2^F \leq \phi^P$. Moreover, comparing equation (20) with (23) one can easily check that:

$$(\phi^F - \phi^P)\big|_{\Delta \to 1} = -\frac{9}{7(28\gamma + 27)} \leq 0$$

$$(\phi^F - \phi^P)\big|_{\Delta \to \infty} = \frac{44\gamma + 9}{160\gamma + 135} \geq 0$$

$$\frac{\partial(\phi^F - \phi^P)}{\partial \Delta} = 12\left(\frac{12\gamma(\gamma + 1)}{(27\Delta + 4\gamma(8\Delta - 1))^2} + \frac{1}{(15\Delta - 8)^2}\right) \geq 0$$

We deduce that the difference $\phi^F - \phi^P$ is always increasing in Δ. Moreover, at the lowest admissible value $\Delta \to 1$, the difference is negative. At the other extreme $\Delta \to \infty$

is positive. Then, there exists a positive threshold $\hat{\Delta}(\gamma)$ such that $\phi^F - \phi^P) \geq 0$ if and only if $\Delta \geq \hat{\Delta}(\gamma)$. This threshold corresponds to:

$$\hat{\Delta}(\gamma) = \frac{2\left(15\gamma + \sqrt{\gamma(49\gamma+54)+9}+3\right)}{44\gamma+9}$$

which is decreasing in γ for all positive values of γ. We deduce that $\hat{\Delta}(\gamma) \in [1, 4/3]$. QED

8.2 Proof of Corollary 1

We assume that before investment the quality of firm 1 is $v_1 = 1$ and the quality of firm 2 is $v_2 = 1 - d$. Under regime P, this gap is closed by imitation and everything is as in the base case. Under regime F, the quality of firm 1 after innovation will be $v_1^F = 1 + \phi_1^F$ and the quality of firm 2 $v_1^F = 1 - d + \phi_2^F$. Solving for the optimal level of investment we obtain that the level of investment of firm 2 is:

$$\phi_{2d}^F = \max\left\{\frac{2-8d}{15\Delta-8}, 0\right\} \tag{24}$$

and Firm 1 investment is:

$$\phi_{1d}^F = \tfrac{6(1+d)\Delta-4}{15\Delta-8} \quad if \;\; \phi_{2d}^F > 0; \tag{25}$$

$$\phi_{1d}^F = \tfrac{2}{5}(1+d) \quad otherwise. \tag{26}$$

As the intuition suggests, ϕ_{1d}^F increases and ϕ_{2d}^F decreases in d. Comparing Equation (24) with (16) it is straightforward to verify that, for $d \geq \hat{d} = \frac{27\Delta+2(6+\Delta)\gamma}{27\Delta+4(32\Delta-4)\gamma}$, ϕ_{d2}^F is smaller than ϕ_2^P. Similarly, comparing Equation (25) with (15) it can be verified that, for $d \geq \tilde{d} = \frac{3\Delta(12+40\gamma-\Delta(44\gamma+9))-16\gamma}{6\Delta(\Delta(32\gamma+27)-4\gamma)}$), ϕ_{d1}^F is larger than ϕ_1^P. QED
Moreover, one can also show that W_1^F is increasing in d while W_2^F is decreasing: when the developing country has an initial disadvantage, it is more likely to prefer not to enforce IPR.

8.3 Proof of Proposition 2

Let $\gamma = \frac{\alpha_2}{\alpha_1}$ (see (2)). Under full protection of IPR (F), welfare in country $i = 1, 2$ can be written:

$$W_i^F = \frac{1}{18}\Big[3\alpha_i\Big(2(1+\phi_i^F)^2 + (\phi_i^F - \phi_j^F)^2\Big) + 2\alpha_j(1 + 2\phi_i^F - \phi_j^F)^2\Big] - k_i\frac{(\phi_i^F)^2}{2} \quad (27)$$

While under no protection (N) :

$$W_i^N = \frac{1}{9}(3\alpha_i + \alpha_j)(1 + \phi_1^N + \phi_2^N)^2 - k_i\frac{(\phi_i^N)^2}{2} \quad (28)$$

Finally, under partial protection (P) welfare of country 2 is:

$$W_2^P = \frac{1}{3}\alpha_2(1 + \phi_1^P + \phi_2^P)^2 - \Delta k\frac{(\phi_2^P)^2}{2} \quad (29)$$

Substituting the investment equilibrium value, under Assumption 1, welfare under full protection of IPR (F) can be rewritten as:

$$W_2^F = \frac{\alpha(\gamma(\Delta(81\Delta - 76) + 18) + \Delta(9\Delta - 4))}{(\gamma+1)(8 - 15\Delta)^2} \quad (30)$$

Under partial protection (P):

$$W_2^P = \frac{16\alpha\gamma\Delta(27(\gamma+1)\Delta - \gamma)}{(4\gamma(8\Delta - 1) + 27\Delta)^2} \quad (31)$$

Finally, under no protection (N):

$$W_2^N = \frac{\alpha\Delta(\gamma(27\Delta - 1) + 9\Delta - 1)}{(\gamma+1)(1 - 8\Delta)^2} \quad (32)$$

Comparing equation (30) with (31) it is straightforward to verify that:

$$(W_2^F - W_2^P)|_{\Delta\to 1} = \frac{\alpha(3645 - 3\gamma(56\gamma(14\gamma + 17) - 1053))}{49(\gamma+1)(28\gamma + 27)^2}$$

$$(W_2^F - W_2^P)|_{\Delta\to\infty} = \frac{\alpha(729 - \gamma(16\gamma(99\gamma + 314) + 2511))}{25(\gamma+1)(32\gamma + 27)^2}$$

$$\frac{\partial(W_2^F - W_2^P)}{\partial\Delta} = \frac{4\alpha\left(\gamma\left(\frac{20\gamma(\gamma+1)(4\gamma(46\Delta-1)+189\Delta)}{(4\gamma(8\Delta-1)+27\Delta)^3} + \frac{85-195\Delta}{(15\Delta-8)^3}\right) - \frac{5(21\Delta-8)}{(15\Delta-8)^3}\right)}{5(\gamma+1)}$$

Then, the difference $W_2^F - W_2^P$ is decreasing in Δ at least for γ sufficiently small (and $\gamma \leq 1.14$ is a sufficient condition). At the lowest admissible value $\Delta \to 1$, the difference is positive if and only if $\gamma \geq 1.14$. At the other extreme $\Delta \to \infty$ is positive if and only if $\gamma \geq 0.2$. Then, for $\gamma < 0.2$ $W_2^F - W_2^P$) is always positive. In fact, this holds both at $\Delta \to 1$ and $\Delta \to \infty$ and the difference $W_2^F - W_2^P$ is decreasing. For $0.2 \leq \gamma \leq 1.14$, $W_2^F - W_2^P$ is positive in $\Delta \to 1$ and negative in $\Delta \to \infty$. Since $W_2^F - W_2^P$ is always increasing, there must exist a threshold value $\Delta_2(\gamma)$ such that $W_2^F \geq W_2^P$ if and only if $\Delta \leq \Delta_2(\gamma)$. Finally, if $\gamma > 1.14$, $W_2^F - W_2^P$ is always negative. QED

8.4 Proof of Proposition 3

Let $\gamma = \frac{\alpha_2}{\alpha_1}$ (see (2)). Under full protection of IPR (F), welfare in country $i = 1$ is defined in (27), and under no protection (N) it is defined in (28), while under partial protection (P) it is:

$$W_1^P = \frac{1}{72}(27\alpha_1 + 8\alpha_2)(1 + \phi_1^P + \phi_2^P)^2 - k_1 \frac{(\phi_1^P)^2}{2} \tag{33}$$

Substituting the investment equilibrium value, under Assumption 1, welfare under full protection of IPR (F) can be rewritten as:

$$W_1^F = \frac{\alpha\left(5\gamma(2 - 3\Delta)^2 + 3\Delta(39\Delta - 44) + 38\right)}{(\gamma + 1)(8 - 15\Delta)^2} \tag{34}$$

Under partial protection (P):

$$W_1^P = \frac{\alpha(2\gamma(64\gamma + 279) + 405)\Delta^2}{(4\gamma(8\Delta - 1) + 27\Delta)^2} \tag{35}$$

Finally, under no protection (N):

$$W_1^N = \frac{2\alpha(4\gamma + 13)\Delta^2}{(\gamma + 1)(1 - 8\Delta)^2} \tag{36}$$

Comparing equation (34) with (35) it is straightforward to verify that:

$$\begin{aligned}
(W_1^F - W_1^P)|_{\Delta\to 1} &= -\frac{6\alpha(\gamma(7\gamma(56\gamma + 191) + 1461) + 513)}{49(\gamma + 1)(28\gamma + 27)^2} \\
(W_1^F - W_1^P)|_{\Delta\to\infty} &= \frac{\alpha(2\gamma(\gamma(960\gamma + 2401) + 1017) - 648)}{25(\gamma + 1)(32\gamma + 27)^2} \\
\frac{\partial(W_1^F - W_1^P)}{\partial\Delta} &= \frac{4\alpha}{5(\gamma + 1)}\Big(5\gamma\Big(\frac{2(\gamma + 1)(2\gamma(64\gamma + 279) + 405)\Delta}{(4\gamma(8\Delta - 1) + 27\Delta)^3} \\
&\quad + \frac{15(3\Delta - 2)}{(15\Delta - 8)^3}\Big) + \frac{15(9\Delta - 7)}{(15\Delta - 8)^3}\Big)
\end{aligned}$$

We deduce that the difference $W_1^F \geq W_1^P$ is increasing in Δ. Moreover, at the lowest admissible value $\Delta \to 1$, the difference is negative. At the other extreme $\Delta \to \infty$, $W_1^F \geq W_1^P$ is positive if and only if $\gamma \geq 0.21$. Then, for $\gamma < 0.21$ $W_1^F - W_1^P$ must be always negative. For $\gamma > 0.2$, $W_1^F - W_1^P$ is negative in $\Delta \to 1$ and positive in $\Delta \to \infty$. Since $W_1^F - W_1^P$ is always increasing, this means that there must exist a threshold value $\Delta_1(\gamma)$ such that $W_1^F \geq W_1^P$ if and only if $\Delta \geq \Delta_1(\gamma)$. QED

9 Robustness Checks

9.1 Variable Transportation Cost

In this section we aim to test the robustness of our results to the introduction of transportation costs. We assume that exporting in a foreign country implies a unit transportation cost equal to $t \geq 0$. In the open economy the total profit of firm i writes:

$$\Pi_i^D = p_{i1}q_{i1} + p_{i2}q_{i2} - tq_{ij} - k_i\frac{\phi_i^2}{2} \tag{37}$$

At the second stage, the Cournot quantity produced by firm i in country j becomes:

$$q_{ijt}^D = \frac{2v_i^I - v_{-i}^I}{3b_j} + \frac{2t}{3a_ib_j}, \qquad i, -i, j \in \{1,2\}, i \neq -i \tag{38}$$

where the index $-i$ represents the competitor and the value of v_i^I depends on the IPR regime, i.e. $v_i^I \in \{v_i^F, v_i^N, v_i^P\}$.

9.1.1 The socially optimal level of investment:

Optimizing (7) with the profit function being replaced by (37) and the quantity formula by (38) the socially optimal level of innovation in country i becomes:

$$\phi_i^* = \frac{\alpha - t\frac{b_1+b_2}{2b_1b_2}}{\frac{9}{8}\frac{k_1k_2}{k_1+k_2} - (\alpha)}\,\frac{k_j}{k_1+k_2} \tag{39}$$

and the optimal level of innovation in the common market is

$$\phi_t^* = \phi_1^* + \phi_2^* = \frac{\alpha - t\frac{b_1+b_2}{2b_1b_2}}{\frac{9}{8}\frac{k_1k_2}{k_1+k_2} - (\alpha)}. \tag{40}$$

9.1.2 Full IPR protection (F regime)

Substituting the quantities (38) in the profit function firm i maximizes (37) with respect to ϕ_i, for a given level of ϕ_j, $i \neq j$. Profit maximization gives the reaction function:

$$\phi_i(\phi_j) = \frac{\alpha(1-\phi_j) - \frac{2b_i - b_j}{b_i b_j} t}{2.25k_i - 2\alpha} \tag{41}$$

We first notice that the slope of the reaction function remains negative: $\frac{\partial \phi_i(\phi_j)}{\partial \phi_j} < 0$. Quality levels, and thus investment levels, are strategic substitutes. Moreover the slope of the reaction function does not depend on the transportation cost t, which only affects the intercept of the function. When $t = 0$, investment does not depend on local market characteristics but only on total demand and on the cost of $R\&D$ investment k_i. Then, if $k_1 = k_2$ firms invest the same amount in R&D and produce the same quality. When $t > 0$, an increase in the relative size of demand i (i.e. $b_j - b_i$) shifts the reaction function of firm i upwards. As a consequence, at the equilibrium firm i invests more than firm j if and only if $b_i < b_j$ (i.e. the country i has a larger demand size).

Solving the system of first order conditions, we obtain:

$$\phi_i^F = \frac{1}{2} \frac{\alpha(1-\frac{\alpha}{3k_j})\frac{k_j}{k_1+k_2} - \frac{t}{k_1+k_2}(k_j(\frac{2}{b_j} - \frac{1}{b_i}) - \frac{4\alpha}{3b_j})}{\frac{9}{8}\frac{k_1 k_2}{k_1+k_2} - \alpha(1 - \frac{\alpha}{3\frac{k_1+k_2}{2}})} \tag{42}$$

As in the benchmark case the level of quality chosen by firm i depends negatively on k_i and positively on k_j. More interestingly ϕ_i^F decreases with t if and only if:

$$\frac{b_j}{b_i} \leq 2 - \frac{4}{3}\frac{\alpha}{k_j} \tag{43}$$

Inequality (43) is easier to satisfy when k_j increases.

9.1.3 No IPR protection (N regime)

When IPR are not protected, the quality of good i after investment is given by $\phi^N = \phi_1^N + \phi_2^N$. At the second stage quantities are given by the Cournot levels in (4). At the first stage, profit maximization gives the reaction functions:

$$\phi_i(\phi_j) = \frac{\alpha(1+\phi_j) - \frac{2b_i - b_j}{b_i b_j} t}{4.5k_i - \alpha} \tag{44}$$

In this case the slope of the reaction function is positive (quality levels and thus investment are strategic complements).

$$\frac{\partial \phi_i(\phi_j)}{\partial \phi_j} > 0$$

The role played by the transportation cost is equivalent than in the F case. When the transportation cost is positive, countries with larger population tend to invest more than smaller ones (everything else being equal). We have:

$$\phi_i^N = \frac{\alpha \frac{k_j}{k_1+k_2} - \frac{t}{k_1+k_2}(k_j(\frac{2}{b_j} - \frac{1}{b_i}) - \frac{2}{3}\alpha(\frac{1}{b_j} - \frac{1}{b_i}))}{4.5\frac{k_1 k_2}{k_1+k_2} - \alpha} \tag{45}$$

As before investment in country i increases with k_j and decreases with k_i. Moreover, ϕ_i^N decreases with t if and only if:

$$\frac{b_j}{b_i} \leq \frac{2(3k_j - \alpha)}{3k_j - 2\alpha} \tag{46}$$

Then, a decrease of the transportation cost increases the level of investment of country i if and only if country j is relatively large. Inequality (46) is easier to satisfy when k_j decreases.

We deduce that:

$$\phi^N = \phi_1^N + \phi_2^N = \frac{\alpha + \frac{t}{k_1+k_2}(k_1(\frac{1}{b_2} - \frac{2}{b_1}) + k_2(\frac{1}{b_1} - \frac{2}{b_2}))}{4.5\frac{k_1 k_2}{k_1+k_2} - \alpha}. \tag{47}$$

Then, a decrease of the transportation cost increases the total level of investment if and only the two countries have sufficiently different sizes.

9.1.4 IPR protection only in one country (P regime)

When only one country protects IPR, the quality of good i after investment is given by $\phi^P = \phi_1^P + \phi_2^P$. If firm 2 chooses imitation, it will sell only in country 2. Then, firm 1 is a monopoly in country 1 and compete with 2 à la Cournot in country 2. At the second stage quantities are given by the Cournot levels in (38). At the first stage, profit maximization gives the reaction functions:

$$\phi_1(\phi_2) = \frac{(1+\phi_j)(2.25\alpha_1 + \alpha_2) - \frac{2t}{b_2}}{4.5k_1 - (2.25\alpha_1 + \alpha_2)} \tag{48}$$

$$\phi_2(\phi_1) = \frac{(1+\phi_1)\alpha_2 + \frac{t}{b_2}}{4.5k_2 - \alpha_2} \tag{49}$$

Once again, investments are strategic complements. That is, the slope of reaction function is positive for both firms: $\frac{\partial \phi_i(\phi_j)}{\partial \phi_j} > 0 \;\; i,j = 1,2 \; i \neq j$. Solving for the equilibrium we have:

$$\phi_1^P = \frac{(2.25\alpha_1 + \alpha_2)k_2 - \frac{t}{b_2}(2k_2 - \frac{1}{2}\alpha_1 - \frac{2}{3}\alpha_2)}{4.5k_1k_2 - (2.25\alpha_1 + \alpha_2)k_2 - \alpha_2 k_1} \tag{50}$$

$$\phi_2^P = \frac{\alpha_2 k_1 + \frac{t}{b_2}(2k_1 - \frac{1}{2}\alpha_1 - \frac{2}{3}\alpha_2)}{4.5k_1k_2 - (2.25\alpha_1 + \alpha_2)k_2 - \alpha_2 k_1} \tag{51}$$

We deduce that the total level of investment under the partial protection IPR regime is :

$$\phi^P = \phi_1^P + \phi_2^P = \frac{(\alpha_1 \frac{2.25k_2}{k_1+k_2} + \alpha_2) - \frac{4t}{b_2(k_1+k_2)}(2k_2 - k_1)}{4.5\frac{k_1k_2}{k_1+k_2} - (\alpha_1 \frac{2.25k_2}{k_1+k_2} + \alpha_2)} \tag{52}$$

This section shows that the results and the main intuitions are robust to the introduction of a variable exportation cost. In order to keep the analysis and the presentation simple we thus set $t = 0$ in the main text.

9.2 Imperfect enforcement in country 1

Until now, when considering the possibility for firm 2 to imitate, we have restricted the attention to the limit cases of perfect enforcement in country 1 (regime P) and no enforcement (regime N). However, country 1 could have some difficulties in fully enforcing patent protection and excluding firm 2 from the market. For instance, firm 2 could manage to sell illegally in country 1. We explore this possibility assuming that if firm 2 imitates, it manages to (illegally) sell only a limited quantity of the good. To make things interesting, we assume this quantity is higher than zero but lower than the unconstrained optimal quantity that firm 2 would choose to sell in country 1 (i.e. $q_{21}^o = \frac{2v_2 - v_1}{3b_2} = \frac{1+\phi_1+\phi_2}{3b_2}$). The higher is the capacity of enforcement of IPR of country 1, the smaller will be the quantity sold illegally. To fix ideas, we can assume that, for given qualities v_1 and v_2, firm 2 manage to sell at maximum $(1-f)q_{21}^o$, where $f \in [0,1]$ represents the quality of enforcement. If $f = 1$, we are in the former regime P and firm 2 cannot export in 1 ($q_{21}^P = 0$). If $f = 0$ there are no constraint to imports of imitated goods in country 1, as in regime N. Naturally, the optimal investment levels will be affected by perspective sales. The reaction functions under (P) become:

$$\phi_1(\phi_2) = \frac{\alpha_1 \frac{(2+f)^2}{4} + \alpha_2}{4.5k_i - \left(\alpha_1 \frac{(2+f)^2}{4} + \alpha_2\right)}(1 + \phi_2)$$

$$\phi_2(\phi_1) \quad = \quad \frac{\frac{(2-f(1+f))}{2}\alpha_1 + \alpha_2}{4.5k\Delta - \left(\frac{(2-f(1+f))}{2}\alpha_1 + \alpha_2\right)}(1+\phi_1) \tag{53}$$

Solving the system we find:

$$\phi_{1f}^P = \frac{\Delta\left(\frac{(2+f)^2}{4}\alpha_1 + \alpha_2\right)}{4.5k\Delta - \frac{2+f}{4}\alpha_1(f(\Delta-2)+2(\Delta+1)) - \alpha_2(1+\Delta)}$$

$$\phi_{2f}^P = \frac{\left(\frac{f^2+f-2}{2}\alpha_1 + \alpha_2\right)}{4.5k\Delta - \frac{f+2}{4}\alpha_1(f(\Delta-2)+2(\Delta+1)) - \alpha_2(1+\Delta)}$$

$$\phi_f^P = \frac{\frac{f+2}{4}\alpha_1(f(\Delta-2)+2(\Delta+1)) + 4\alpha_2(\Delta+1)}{4.5k\Delta - \frac{f+2}{4}\alpha_1(f(\Delta-2)+2(\Delta+1)) - \alpha_2(1+\Delta)}$$

It is easy to verify that when $f=1$, $\phi_f^P = \phi^P$ and when $f=0$, $\phi_f^P = \phi^N$. Moreover:

$$\frac{\partial \phi_f^P}{\partial f} = \frac{2.25k\alpha_1\Delta(2\Delta - 1 + f(\Delta-2))}{4.5k\Delta - \frac{f+2}{4}\alpha_1(f(\Delta-2)+2(\Delta+1)) - \alpha_2(1+\Delta)} \geq 0$$

Then, the ϕ_f^P curve lies between ϕ^P and ϕ^N and it is the closest to ϕ^N the lowest is f. The same property holds for all curves (investment levels, profits, welfare, consumer surplus). Then, imperfect enforcement would correspond to an intermediate case between (N) and (P).

9.3 Imperfect imitation

Until now, we have assumed that innovation is cumulative and both firms can fully incorporate the innovation developed by the rival when imitating, i.e. $v_i^N = v_i^P = 1 + \phi_1 + \phi_2$. However, it can be reasonable to think that in some cases imitation is only partial and the imitating firm can only partially reproduce the innovation developed by the competitor. We explored this case assuming $v_i^N = v_i^P = 1 + \phi_i + g\phi_j$, with $0 \leq g \leq 1$. In this case, the reaction functions under (P) become:

$$\phi_1(\phi_2) \quad = \quad \frac{2.25\alpha_1(1+g\phi_2) + (2-g)\alpha_2(1+(2g-1)\phi_2)}{4.5k_i - (2.25\alpha_1 + (2-g)^2\alpha_2}$$

$$\phi_2(\phi_1) \quad = \quad \frac{(2-g)\alpha_2(1+\phi_1(2g-1))}{4.5k_2 - (2-g)^2\alpha_2}$$

And under (N):

$$\phi_i(\phi_j) = \frac{\alpha(2-g)(1+(2g-1)\phi_2)}{4.5k_i - (2-g)^2\alpha} \tag{54}$$

As the reaction function shows, for $g > 1/2$, the investment levels are strategic complements and the reaction functions are qualitatively similar to the ones in the base case. On the other hand, when g is very small, the public good effect of investment under imitation becomes negligible. Solving the system we obtain:

$$\begin{aligned}
\phi_{1g}^P &= \frac{3k\Delta(9\alpha_1 + 4(2-g)\alpha_2) - 4(2-g)(1-g)\alpha_2(3\alpha_1 + 2(2-g)\alpha_2)}{54k^2\Delta - 3k\left(4(2-g)^2\alpha_2(\Delta+1) + 9\alpha_1\Delta\right) - 4(2-g)(1-g)(g+1)\alpha_2(3\alpha_1 - 2(2-g)\alpha_2)} \\
\phi_{2g}^P &= \frac{4(2-g)\alpha_2((1-g)(3\alpha_1 + 2(2-g)\alpha_2) + 3k)}{54k^2\Delta - 3k\left(4(2-g)^2\alpha_2(\Delta+1) + 9\alpha_1\Delta\right) - 4(2-g)(1-g)(g+1)\alpha_2(3\alpha_1 - 2(2-g)\alpha_2)} \\
\phi_{g}^P &= \frac{3k\Delta(9\alpha_1 + 4(2-g)\alpha_2) - 4(2-g)\alpha_2\left(3g(g\alpha_1 + k) - 2(2-g)\left(1-g^2\right)\alpha_2 - 3\alpha_1\right) -}{54k^2\Delta - 3k\left(4(2-g)^2\alpha_2(\Delta+1) + 9\alpha_1\Delta\right) - 4(2-g)(1-g)(g+1)\alpha_2(3\alpha_1 - 2(2-g)\alpha_2)}
\end{aligned}$$

$$\begin{aligned}
\phi_{ig}^N &= \frac{2(2-g)\alpha(3k\Delta - 2(2-g)(1-g)\alpha)}{4\left(g^2-1\right)(g-2)^2\alpha^2 + 6(g-2)^2k(\Delta+1)\alpha - 27k^2\Delta} \\
\phi_{g}^N &= \frac{2(2-g)\alpha\left(3k\Delta - 2g^3\alpha + 4g^2\alpha + g(3k+2\alpha) - 4\alpha\right)}{4\left(1-g^2\right)(2-g)^2\alpha^2 + 6(2-g)^2k(\Delta+1)\alpha - 27k^2\Delta}
\end{aligned}$$

These expressions are significantly more complicated than in the base case. Then, the comparison, of investment levels, profit an welfare has been just studied by simulations. Naturally, when g is sufficiently close to 1, all the results are preserved. In the general case $0 < g < 1$, the main impact of imperfect imitation is to reduce the free-riding effect of imitation. Than, innovation of firm 1 increases as well as the total level of innovation. As a result, the profit of firm 2 tends to decrease while the profit of firm 1 and consumer welfare to increase. This does not affect the main qualitative results of our model, except that regimes (P) and (N) are preferred more often from the total welfare point of view. On the contrary, imitating becomes less attractive for firm 2, then imitation occurs less often.

Moreover, the relative quality of firm 1, which invests more, increases. Then its exports to country 2 are increased with respect to the base case. This is in line with the predictions of several empirical works that find that, when the imitation capacity is lower, the negative impact of weak IPR on imports is less pronounced (or disappears).

9.4 Non cumulative innovation: $v_i^P = v_i^N = 1 + max[\phi_1, \phi_2]$

Suppose now that in case of imitation, the quality of the good corresponds to the highest of the two, i.e. $v_i^P = v_i^N = 1 + max[\phi_1, \phi_2]$. Then, either the equilibrium level of investment of firm 1 is higher and $v_i^P = v_i^N = 1 + \phi_1$, or the level of investment of firm 2 is higher and $v_i^P = v_i^N = 1 + \phi_2$ or finally $\phi_1 = \phi_2$. In the last case, we can assume that the "winning" invention is ϕ_1 with probability 1/2 and ϕ_2 with probability 1/2.

Under these assumptions, there always exists an equilibrium where only firm 1 invests and the quality under (N) is:

$$\phi_1 = \frac{2\alpha}{9k_1 - 2\alpha}$$

While under (P):

$$\phi_1 = \frac{9\alpha_1 + 4\alpha_2}{18k_1 - 9\alpha_1 - 4\alpha_2}$$

These investment levels correspond exactly to the base case when $k_2 \to \infty$ (and then $\phi_2 \to 0$). Then, when the quality of the good depends on the maximal developed quality, at this equilibrium everything is as in our previous analysis for the case $\Delta \to \infty$.

This equilibrium might not be unique if Δ is small and γ large. In the latter case, another equilibrium may exists in which only firm 2 invests. However, this second Nash equilibrium seems less realistic, because it arises only for very small Δ and high γ. For these values of the parameter, it would be not clear that country 2 can be intended as a less developed one.

Proof:

Regime N:

Assume the IPR regime is (N) and consider a candidate equilibrium in which $\phi_1 > \phi_2$ (first candidate equilibrium). Then, replacing $v_1 = v_2 = 1 + \phi_1$ in equation (11) and maximizing the two profits we obtain:

$$\phi_1^{I_1} = \frac{2\alpha}{9k_1 - 2\alpha}$$

$$\phi_2^{I_1} = 0$$

Replacing the values of ϕ_1 and ϕ_2 in the profit function 11:

$$\Pi_1^{I_1} = \frac{k_1\alpha}{9k_1 - 2\alpha}$$

$$\Pi_2^{I_1} = \frac{9k_1^2\alpha}{(9k_1 - 2(\alpha_1 + \alpha_2))^2}$$

Under Assumption 2 we have:

$$\Pi_1^{I_1} = \frac{\alpha}{8}$$
$$\Pi_2^{I_1} = \frac{9\alpha}{64}$$

Now consider a candidate equilibrium in which $\phi_2 > \phi_1$. With the same steps one obtains:

$$\phi_1^{I_2} = 0$$
$$\phi_2^{I_2} = \frac{2\alpha}{9k_2 - 2\alpha}$$

Replacing the values of ϕ_1 and ϕ_2 in the profit function (11) we get:

$$\Pi_1^{I_2} = \frac{9\alpha k_2^2}{(9k_2 - 2\alpha)^2}$$
$$\Pi_2^{I_2} = \frac{\alpha k_2}{9k_2 - 2\alpha}$$

Which under Assumption 2 becomes:

$$\Pi_1^{I_2} = \frac{9\Delta^2\alpha}{(9\Delta - 1)^2}$$
$$\Pi_2^{I_2} = \frac{\Delta\alpha}{9\Delta - 1}$$

Moreover, if no firm invests, both firms get the Cournot profits:

$$\Pi_1^0 = \Pi_2^0 = \frac{1}{9}\alpha = \frac{1}{9}\alpha$$

One can first notice that it is never an equilibrium for the two firms to invest. In addition, under Assumption 2, $\Pi_2^{I_1} > \Pi_2^{I_2}$ and $\Pi_1^{I_1} > \Pi_1^{I_2}$ if and only if $\Delta \geq \frac{3+2\sqrt{2}}{3} \simeq 1.94$. Then, for $\Delta \geq \frac{3+2\sqrt{2}}{3}$, the first candidate equilibrium (firm 1 invests, firm 2 does not) is the only equilibrium of the game. The quality of the goods is $v_1 = v_2 = 1 + \phi_1 = 1 + \frac{2\alpha}{9k_1 - 2\alpha}$, which corresponds to the base case for $\Delta \to \infty$.

For $1 \leq \Delta < 1 + \frac{2\sqrt{2}}{3} \simeq 1.94$, the second Nash equilibrium (firm 2 invests, firm 1 does not) can also arise.

Finally, if we consider a candidate equilibrium in which $\phi_1 = \phi_2$, firms maximize the expected profit:

$$E\,\Pi_i = \frac{1}{2}\Pi_i(v_i^N = 1 + \phi_1) + \frac{1}{2}\Pi_i(v_i^N = 1 + \phi_2)$$

It can be easily verified that there is no equilibrium with $\phi_1 = \phi_2$ (when maximizing the expected profit, firm 1 always invests more than firm 2).

Regime P:

Now assume the IPR regime is P and consider a candidate equilibrium in which $\phi_1 > \phi_2$. Then, replacing $v_1 = v_2 = 1 + \phi_1$ in equation (11) and maximizing the two profits we obtain:

$$\begin{aligned} \phi_1 &= \frac{9\alpha_1 + 4\alpha_2}{18k_1 - 9\alpha_1 - 4\alpha_2} \\ \phi_2 &= 0 \end{aligned}$$

The profits are:

$$\begin{aligned} \Pi_1^{I_1} &= \frac{k_1(9\alpha_1 + 4\alpha_2)}{36k_1 - 8\alpha_2 - 18\alpha_1} \\ \Pi_2^{I_1} &= \frac{36k_1^2\alpha_2}{(18k_1 - 9\alpha_1 - 4\alpha_2)^2} \end{aligned}$$

Under Assumption 2 we have:

$$\begin{aligned} \Pi_1^{I_1} &= \frac{\alpha(9 + 4\gamma)}{27 + 32\gamma} \\ \Pi_2^{I_1} &= \frac{144\alpha(1 + \gamma)}{(27 + 32\gamma)^2} \end{aligned}$$

Now consider a candidate equilibrium in which $\phi_2 > \phi_1$. We have:

$$\begin{aligned} \phi_1 &= 0 \\ \phi_2 &= \frac{2\alpha_2}{9k_2 - 2\alpha_2} \end{aligned}$$

The profits are:

$$\begin{aligned} \Pi_1^{I_2} &= \frac{9k_2^2(4\alpha_2 + 9\alpha_1)}{4(9k_2 - 2\alpha_2)^2} \\ \Pi_2^{I_2} &= \frac{k_2\left(9k_2\alpha_2 - 2\alpha_2^2\right)}{(9k_2 - 2\alpha_2)^2} \end{aligned}$$

Under Assumption 2 and letting $\gamma = \frac{\alpha_2}{\alpha_1}$ (see (2)), we have:

$$\begin{aligned} \Pi_1^{I_1} &= \frac{9\Delta^2\alpha(1 + \gamma)(9 + 4\gamma)}{4(9\Delta(1 + \gamma) - \gamma)^2} \\ \Pi_2^{I_1} &= \frac{\Delta\alpha\gamma}{9\Delta(1 + \gamma) - \gamma} \end{aligned}$$

Proceeding as above, we can verify that, under Assumption 2, for $\gamma \leq \frac{9(5+3\sqrt{17})}{64}$ the only equilibrium is the one in which only firm 1 invests. For $\gamma > \frac{9(5+3\sqrt{17})}{64}$ and $\Delta < \frac{9+4\gamma}{9(9+4\gamma)-3\sqrt{(9+4\gamma)(27+32\gamma)})}$ a second equilibrium in which only firm 2 invests exists. One may notice that $\frac{9(5+3\sqrt{17})}{64} \simeq 2.44$ and $\frac{9+4\gamma}{9(9+4\gamma)-3\sqrt{(9+4\gamma)(27+32\gamma)}} \leq 1 + \frac{2\sqrt{2}}{3} \simeq 1.94$. Then, the second Nash equilibrium can arise only if γ is lager than 2.4 and Δ smaller than 1.94. Finally, as under regime (N) there is no equilibrium with $\phi_1 = \phi_2$.

Notice that we have computed the equilibria assuming that firm 2 is not allowed to export in country 1 when the regime is (P). If we assume that, when $\phi_2 = \max\{\phi_1, \phi_2\}$ et $\phi_1 = 0$, firm 2 is than allowed to export in country 1 even under (P), then the conditions for having the second equilibrium to exist is ever more demanding. A necessary condition is $\gamma > 333/32 \simeq 10.4$ and $\Delta \leq \frac{\sqrt{128\gamma^2+396\gamma+243}+12\gamma+27}{12\gamma+162} \leq 1 + \frac{2\sqrt{2}}{3} \simeq 1.94$.

10 Empirical specification

10.1 Foreign market access construction

In the text we argue that market size can be proxied by GDP and we want to assess the impact of internal and external market sizes. As discussed in Section 4 and appendix 9.1, the existence of transportation costs is not altering the main insights of the model, but it interacts with the (relative) size of the foreign market in determining the quantitative impact of the IPR regime choice. We thus incorporate the role of transportation costs in our measure of the size of foreign demand. In order to take into account the foreign component, we need a measure to weight each potential destination market by their accessibility. In particular, F-ALPHA $= \sum_{j \neq i} GDP_j \hat{\phi}_{ij}$, 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. Of course, these 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. To focus on the bilateral component, we include exporter and importer fixed effects to control for these country-specific variables. The bilateral variables that we consider are bilateral distance (in log), and dummies equaling one if the partners shares a common language or border and if one of the countries was a colonizer of the other. All these explanatory variables are available from the CEPII Gravity Dataset. Bilateral trade is from BACI-COMTRADE which provides detailed information on trade flows for manufacturing, agricultural products and raw materials. We concentrate our analysis on the manufacturing trade, as most of empirical studies on market access and innovation. As expected, the coefficient for distance is negative and the coefficients for common language, border and colonial past are positive (regressions available on request). Using the coefficients of the bilateral variables we predict the trade costs for each pair of partners.

10.2 Inside the frontier innovation

Detecting export discoveries requires a strict set of criteria to avoid the inclusion of temporary exports not really reflecting a new product. First, we will 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 if a product is new in the national export basket. Moreover, to be sure that it is a truly new export, we only include products that keep these export level or higher for two consecutive years. It is possible that some exporters in a country try new products and incidentally, they surpass this threshold. Nevertheless, the next year, exports fall to tiny levels. Consequently, to have a reasonable window of time for the last year in our study, we consider check exports until 2007.