Meet me after the TRIPs. Do IPRs Reinforcement Facilitate International Technological Cooperation?

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ABSTRACT

This paper tests the impact of the reinforcement of IPRs, and in particular of the TRIPS agreement, on technological collaborations between emerging and advanced countries using international patent databases (EPO and USPTO). Technological collaborations generate knowledge flows between inventors through interpersonal and face to face contacts. This paper covers eleven emerging economies: Argentina, Brazil, India, Israel, China, South Korea, South Africa, Mexico, Malaysia, Singapore, Turkey and the G7 countries: USA, UK, Japan, Italy, Germany, France and Canada. We use a modified version of a gravity model. Our preliminary evidence suggests that there may be some positive effects on international collaborations generated by the reinforcement of IPRs in emerging countries and in particular by the TRIPs agreements. Other results indicate that IPR strengthening has a greater impact on the international patent collaboration greater is the value of the bilateral imports.

Jel Codes: O30, O10, O11

Keywords: Intellectual Property Rights, TRIPs, Knowledge flows, Patents, Inventors

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Introduction

This paper studies the impact of IPRs reinforcement in the emerging countries on their international technological collaborations with advanced economies. The IPRs legislation is changing rapidly in recent year after the approval of TRIPs agreement signed in 1994 and adopted and implemented by different countries at different points in time. The economic impact of IPRs reinforcement in emerging countries still remains a controversial issue[1]. One of the main economic justifications of the TRIPs agreement is that IPRs reinforcement in emerging countries facilitates knowledge transfer and dissemination from advanced countries[2]. Accordingly the TRIPs agreements and the inclusion of IP chapters in bilateral trade and investment agreements, accelerating the international harmonization of intellectual property rights, are aimed at favoring North-South knowledge flows and the acquisition of technological capabilities in emerging countries. As a matter of fact asymmetries in intellectual property institutions and laws challenge a smooth circulation of knowledge.

This papers focus on international technological collaborations for two reasons. First international research collaborations have been rising globally[3]. The diffusion of information and communication technologies increases the opportunities for collaborating, cooperating and sourcing knowledge from physically distant agents. In addition, the technological convergence and the emergence of complex and multi-disciplinary technological paradigms (such as biotechnology and nanotechnology) increase the need for carrying out joint research projects, which usually involve partners located in different countries.

The second reason is that technological collaborations provide a substantial source of knowledge transfer. International knowledge spillovers are driven not only by the effective transfer of codified knowledge, but also by interpersonal links and face-to-face contacts across countries. As a result research on knowledge diffusion through inter-personal links across countries has recently come to the fore. This is because technology includes not only materials and knowledge codified in patents, blueprints and manuals but also know-how, routines and organizational capabilities, much of which is tacit in nature (Dosi, 1988; Arora, 2008; Cimoli et al. 2009). Tacit knowledge is costly to transfer, and its transferability is limited by its embeddedness in individuals, teams and organizations. Preliminary evidence indicates that not only

[1] Recent papers have analyzed the economic impact of stronger IPRs and of the TRIPs agreements and find mixed evidence. There is no clear cut evidence that stronger IPRs have a positive impact on domestic innovation, trade activities and FDIs in emerging countries (McCalman, 2001; Basheer, 2005; UNCTAD-ICTSD, 2005; Qian, 2007; Kyle and McGahan, 2008; Delgado et al. 2008; Cimoli et al. 2009).

[2] Article 7 of the TRIPS Agreement claims that "The protection and enforcement of intellectual property rights should contribute to the promotion of technological innovation and *to the transfer and dissemination of technology*". Moreover Article 66.2 asks developed WTO Members to "provide incentives to enterprises and institutions in their territories for the purpose of promoting and encouraging technology transfer".

[3] see Table A5 in Appendix for collaborations in patenting activities between selected emerging countries and G7 countries.

international collaboration between inventors is growing but also that international co-operation has a positive a significant effect on domestic innovative activity[4]. In addition, developing countries seem to benefit significantly when domestic inventors collaborate with foreign inventors in developed countries (Montobbio and Sterzi, 2008).

While it is increasingly recognized that international knowledge spillovers affect importantly countries' ability to learn and innovate (Grossman and Helpmann, 1991; Cimoli et al. 2009), few studies address the impact of the IPRs on international technological collaborations (Picci, 2008; Park and Lippoldt, 2009). This paper provides – to our knowledge - the first attempt to estimate the impact of IPRs reinforcement on international technological collaborations in the emerging countries using a gravity model. It examines whether the homogenization of IP regimes across countries has supported international collaboration in research. Different legal legislations, differences in patent exceptions, patent subject matters and enforcement conditions, just to name a few, are considered to affect the propensity of companies to disclose their knowledge. Multinational firms' decisions to locate subsidiaries in given countries and their willingness to undertake collaborative research projects and to search for joint patent protection are importantly affected by the characteristics of the IP regime.

We measure international technological collaborations using the information contained in international patents about the inventors' address. We observe an international technological collaboration when a patent is co-signed by inventors resident in different countries. We use two international patent databases from the US Patent and Trademark Office (USPTO) and from the European Patent Office (EPO) and collect economic and institutional data from different sources. The sample covers 18 countries: the G7 (USA, UK, Japan, Italy, Germany, France and Canada) and a group of emerging economies (Argentina, Brazil, , India, Israel, China, South Korea, South Africa, Mexico, Malaysia, Singapore, Turkey). We use a modified version of a gravity equation to model the impact of IPRs reinforcement and adopt different empirical specifications in order to tackle different econometric problems. To identify the time varying impact of IPRs strength we build a longitudinal database and we use panel data techniques. We use also Heckman and Poisson models to address zero inflated distributions.

The paper is organized as follows. In Section 1 we discuss the main empirical evidence on the evolution of international IPRs introduced by TRIPS and the impact of patenting on emerging and developing economies. In the subsequent session we show that co-inventor relationships are an indicator

[4] Governments, for example in Brazil, in Mexico as well as in India, set up different types of incentives for their researchers to build close interpersonal collaboration with foreign researchers, and encourage local firms to collaborate with foreign subsidiaries to access foreign knowledge, or support delocalization of firms to learn from foreign practices in foreign markets. However, while those policies are managed under the innovation policy umbrella, there are other policies affecting international knowledge flows and learning by collaborating: mainly IP regulations.

of knowledge flows. Section 3 theoretically motivates the hypothesis to be tested. In Section 4 presents the data and the empirical model and Section 5 discusses the results of the econometric analysis. Section 6 concludes.

1. Harmonizing IP standards in a heterogeneous setting: an overview of the economic impact of TRIPs

In recent years developing countries expanded significantly the strength of their IPR legislations to comply with TRIPS requirement (Basheer, 2005). TRIPS requires that WTO member nations enact and enforce laws on copyrights, trademarks and patents to protect intellectual property. Rights expanded in many fields such as computer software, publications of various types, and pharmaceuticals. Besides the special and differential treatment (SDT) provisions which confer specific rights to LDC (Least Developed Countries) and a series of flexibilities, the Agreement put the reform and strengthening of IP in the innovation policy agenda of developing and emerging economies.

The basic rationale for the international harmonization and reinforcement of IPRs is based on three arguments. (1) Stronger IPRs would support technology transfer by reducing the risks to establish multinational corporations operations in developing countries (2) would create more incentives to sell goods in these markets, (3) would enhance international knowledge transfer through the development of markets for technologies. Arguments against the TRIPS policy emphasize the possibility of important welfare losses due to market power pricing, the costs of closing down infringing activities, higher imitation costs and other risks related to patenting indigenous knowledge, enforcement problems and the adverse impact on the trajectory of technological learning and catching up, as well as the mismatch between IP policies, innovation policy and industrial policy (Cimoli and Primi, 2008; Cimoli et al. 2009).

After the introduction of TRIPS, many scholars and policy analysts studied and assessed the impact of the agreement on emerging countries. Various papers offered different measures of the effect of the TRIPS on trade, FDIs and innovation, as well as access to drugs. Generally, this literature suggests that the extension of patent protections under TRIPS has nuanced effects that varied by product category, country, and development level.

For example, McCalman (2001) estimated that the benefits from the harmonization of patent are concentrated mainly in the US. Kanwar and Evenson (2003) found evidence that IP rights spurred innovation (or at least investment in research and development) in a sample of 29 countries from 1981-1995. Allred and Park (2007) studied innovative activity in a panel of countries and find that there is no evident relationship between IPRs, R&D investment and patenting activity in developing countries. Qian

(2007 and 2008) show no statistically significant relationship between national pharmaceutical-patent protection and innovation or FDI establishments. The author shows, however, that the interactions of national patent-law implementation with development level, educational attainment, and economic freedom, respectively, are shown to have a positive relationship with domestic R&D expenditures and domestic pharmaceutical-patent awards in the United States after national patent implementation. Coriat et al. (2006) show the adverse impact of TRIPS on access to drugs and health-care strategies in developing countries. Recent evidence about the impact of the TRIPs in the pharmaceutical sectors on investments and trade can be also found in Kyle and McGahan (2008) and Delgado et al. (2008). Overall this evidence suggests that the link between reinforced IPRs and increased international knowledge flows is not very strong.

Countries' participation in USPTO and EPO patenting depends upon their R&D efforts and their economic links with US and Europe. Developing countries spend few financial resources on R&D, as they are in general specialized in low-knowledge intensive activities, especially natural resources and labor-intensive industries, and their domestic innovation efforts are basically adaptive in nature and rarely encompass inventions and scientific discoveries. Consequently their patenting activity is scarce. In contrast, industrialized countries are more specialized in knowledge- and technology-intensive sectors and they invest more resources in R&D; it therefore comes as no surprise that they are also leaders in the number of patents applied for and granted (Cimoli et al. 2005; Montobbio, 2008).

If patenting activity is in general scant, we are aware that international patenting is a tiny portion of the innovative activity of emerging economies, not to mention developing countries. However we are not interested in the "magnitude" per se of the phenomenon, but on its implications on learning and knowledge transfer to domestic agents, in a cumulative process of catching up. Besides the "number of agents involved" the phenomena matters for its dynamic cumulative evolution. If knowledge flows from advanced to emerging countries represent one of the ways for learning and acquiring practice through direct collaboration, it is relevant to assess the impact of TRIPS not only on FDI or domestic innovation efforts, but on knowledge flows and joint collaborations in order to assess the impact on ongoing collaborations and contacts. In the data session, therefore, we give a precise quantitative assessment of the size of the phenomenon we are studying (see also Montobbio, 2008 for a broader discussion on international patenting in developing countries).

2 *Co-inventorship as source of knowledge flows.*

Collaboration via co-inventorship, i.e number of patents co-signed by inventors living in different countries, is a proxy of knowledge flows generated by interpersonal and social links deriving from joint collaboration. Co-inventorship can be used to track the transfer of non-codified knowledge (e.g. technical know-how, non-standardized production procedures etc.), which requires, at least periodically, face-to-face interactions. Collaboration via co-inventorship is particularly relevant since it is likely to have a great impact on technological learning and on making technology transfer effective.

Knowledge flows via direct collaboration in research and face to face contacts are also important for innovation activities. The recognition of the relevance of personal interaction for knowledge transfer led the literature to measure knowledge flows through co-inventorship. Actually, knowledge and know-how embodied in individuals and firms circulates mainly through informal and non-codified face-to-face interactions and it involves different spheres, such as mobility of workers and researchers, participation to executive boards, effective participation in joint research programs etc. Co-inventorship can be used as a proxy of direct interaction, and hence transfer of experience, routines and knowledge between co-inventors.

Recently the literature has been using co-inventorship to capture knowledge transfer between regions and countries (Breschi and Lissoni, 2001; Hoekman et al. 2008). Singh (2006) analyzes if and how interpersonal networks determine knowledge diffusion patterns in terms of geographic localization and intra-firm transfers using USPTO data since 1975. Singh (2005) finds that flows are stronger within firm and within regions than across them. Singh explores direct and indirect network ties between inventors, using past co-signed patents. He finds that the social link between inventors is associated with a greater probability of knowledge flow (measured by patent citations), with the probability decreasing as the social 'distance' between inventors increases. Breschi and Lissoni (2009) show that inventors' mobility and the co-invention network are crucial determinants of knowledge diffusion.

The characteristics and the density of the community of inventors and the networks arising among them play a relevant role in the innovative process. Research collaborations create social networks which can foster mutual learning. Actually, joint research efforts and collaborations create opportunities for learning which go beyond the exchange of formalized and codified information and knowledge. Participation or exclusion from given research networks not only affect the innovative performance of the country, the region, the firm or the individual in question, it also affect the set of possibilities for learning routines and practices.

3 Does Patent Strength Facilitate International Knowledge Flows?

This paper asks whether strengthening IPRs increases technological cooperation between *advanced* and emerging economies. We consider bilateral relations of co-inventorship and - using a gravity model - we assume that they depend upon some joint characteristics of the two countries. We assume that variables such as the economic size and innovative activities of the two countries, their geographical and technological distance, the presence of common cultural roots, the level of foreign direct investment and bilateral trade, have an impact on technological cooperation. In particular we test how the adoption of TRIPs and the consequent increase in IP protection affects co-inventorship and as a results bilateral knowledge flows.

In order to derive precisely a set of testable hypothesis let's assume that there are two countries (North and South). The North has stronger IPRs than the South. Assume also that there are two companies (A) and (B) with different level of technological capabilities. Company A is technologically more sophisticated and operates in the North and company B operates in the South. Company A discovers a new plant variety with new characteristics (e.g. in terms of therapeutic properties, resistance to specific pathogens or taste). Company B has a lab making research in the same field that could be a competitor and, at the same time, could adapt the plant variety to the local environment to set up, for example, production facilities. Company A may have an incentive to collaborate with company B not only for local production but also for international markets, if the product can be exported and the main destination markets are in the North. This leads to joint research, knowledge transfer and, eventually, company A could decide to file together with company B a patent in the destination markets.

How is this situation affected by modifications in the patent legislation in the South? How does international patent harmonization - and the resulting strengthening of IP for less developed countries – affect the incentive for company A to cooperate with company B? In principle, with stronger IPRs, technology markets guarantee that company B does not misappropriate the technology of company A. This could generate a greater level of technological cooperation and technology transfer. The strength of IPRs in a developing country should reassure companies willing to invest and develop technologies in these countries. We suggest therefore the following first hypothesis.

H1. Stronger IPRs in developing countries increase the incentives of foreign companies to cooperate with local companies and laboratories.

In fact IPRs should reduce the costs of contracting (transactions, monitoring and litigation costs) because they generate a clearer definition of the technologies and higher certainty about the enforceability of contracts (Yang and Maskus, 2001). As a result of a reinforcement of IPRs, we should also observe more trade, FDIs and more R&D collaborations between developed and developing countries. Likewise, as long as stronger IPRs stimulate trade, FDI and international joint ventures (e.g. reducing transaction costs and costs related to contract enforcement (Yang and Maskus, 2001; Bascavusoglu and Zuniga, 2005)) this may improve the probability of direct international collaborations between inventors (Park and Lippoldt, 2008). We can therefore extend H1 as follows:

H1a. Stronger IPRs in developing countries induce more export in these countries and more investment in knowledge related activities. In turn this creates more technological collaboration.

Stronger IPRs in developing countries should increase their economic openness, via FDIs, imports and joint ventures. New harmonized legislation and stricter enforcement generate greater incentives to disclose technological knowledge, especially when technological spillovers are linked to the imports of goods because the strengthening of IP reduces the imitation risk and favors the export mode (Helpman 1993; SGlass and Saggi 2002). Moreover we can expect that the positive effect of IPRs reinforcement on international technological collaboration is stronger when companies have already the opportunity to know each others' activities and have economic relations. This occurs for those emerging countries that are closer in term of GDP and GDP per capita to the G7 countries. We can also expect a higher elasticity of collaborations to IPRs strength between emerging countries and G7 countries when there is substantial trade relationships and the countries are active in similar industries and technological fields. In this case it can also be argued that trade favors international technological collaborations, in particular for those countries with stronger IPRs. As a result a further extension of H1 can be articulated in two sub-hypotheses:

H1c. The effect of stronger IPRs in developing countries on international technological collaborations is more pronounced for those pairs of countries that are more similar in terms of GDP, have similar industries and technologies.

H1d. International technological collaborations are positively affected by the intensity of trade relationships. This positive effect is particularly strong for those emerging countries that reinforce their IPRs.

H1e. The effect of stronger IPRs in developing countries on international technological collaborations is more pronounced for those pairs of countries that have stricter trade relationships.

In addition an exogenous change in IP legislation in developing countries could raise the innovativeness of domestic companies and increase the R&D effort of domestic companies. As a consequence the *mass* in terms of innovative activity in a developing country increases the probability to observe international technological cooperation in that country. We can therefore add a second hypothesis.

H2. Stronger IPRs in developing countries create more incentives to innovate for domestic companies and, in turn, be conducive to increased level of international technological collaborations.

However it has also been suggested that increased patent protection could harm innovative activities in developing countries. Part of the explanation comes from possible different strategies that multinational companies may adopt. As long as MNCs use patents to prevent the use or import of a specific technology this could harm domestic production and innovation. Moreover with stronger IPRs and stricter enforcement we can expect less international knowledge flows through imitation and adoption and the closing down infringing activities. Helpman (1993) underlines the risk that a tighter IPR in developing countries could provoke a reduction of FDI and an increase of imports which in turn would have deterred innovation because of monopoly pricing and a higher dependence of imports.

Worries have also been expressed that stronger IPRs generate higher cost of access to imported technologies and difficulties in accessing basic scientific knowledge (McCalman, 2001; Grossman and Lai, 2004; Lai, 2008; Lerner 2000, Thompson and Rushing 1996; Mazzoleni and Nelson 1998). Moreover strong domestic IPRs makes the local market more attractive for foreigners and this may have an adverse effect on the domestic market structure, through mergers or acquisitions, and hence lead to a greater market concentration (Lesser, 1998), ultimately leading to the erosion of the local technical base. As a result we can put forward the following alternative hypothesis:

H3. If stronger IPRs end up hindering the research and technological activity of developing countries (in particular - maybe high tech – sectors) and changing the structure and composition of their innovative activities we can expect a decline in the use of foreign technology in some fields and less international technological collaborations.

We note also that companies could use different channels of technology transfer. Companies and research laboratories in order to make profits out of their discoveries may pursuit different innovative and collaborative strategies. These different innovative strategies keep into account not only the strength of IP but also a lot of other variables like market size, the degree of appropriability, the intensity of the competition, the type of knowledge base, power relationships and the degree of asymmetry in the technological capabilities. Some evidence shows that substantial technological collaboration takes place also when strong IPRs are *not* enforced (e.g. Lanjouw, 1998 and Cockburn and Lanjouw, 2001). In this context it is not obvious how stronger patents and greater enforceability in developing countries could affect international technological collaboration. Going back to the initial example we can put forward the following conjectures:

(1) Company A could not want to share its tacit knowledge with a potential competitor: strengthening of IP makes the local market appealing and potentially profitable. Interpersonal links and face-to-face cooperation involve a substantial transfer of knowledge. Not only knowledge that can be codified but also tacit knowledge.

(2) Strong IPRs and the creation of technology market may increase the incentive to license and decrease the incentives to undertake technological cooperation. With a weak patent legislation Company A could find more profitable the cooperative solution (possibly with a fee or an access price), conversely with a strong patent legislation company A can always force Company B to buy a license on its technology. This is because through face-to-face cooperation Company A would incur costs in terms of uncompensated knowledge spillovers to a potential competitor. Other technological transfer agreements, like licensing, could be more effective in controlling the technology, avoiding at the same time, uncompensated knowledge spillovers to Company B. Moreover licenses can also regulate subsequent discoveries via the so called *reach-through* agreements. While in this case a license would be preferable for Company A, it possibly generates higher costs and less knowledge absorption in Company B. Cooperation with open access is preferable for most of developing countries.

(3) Strong patent protection could also give Company A the option of *not* licensing its technology. In a harmonized patent system Company B could become a more dangerous competitor (in particular on subsequent innovations) not only in the South but also in the North.

(4) Patents may involve substantial litigation and transaction costs. Company A could not want to cooperate with Company B simply because it does not want to spend time and resources to negotiate complex licensing agreement.

(5) Company A may wish to access directly the market in the South that thanks to IP reform is now more profitable. Appropriability conditions vary substantially across sectors and technologies and accordingly companies use many different appropriability strategies that often do not involve the use IPRs. In many cases to cooperate technologically with a local company can provide increased appropriability because the local company can have important complementary assets, in particular the ability to adapt products to local needs and distribute them. Patent reform may change the appropriability strategy of foreign companies that can use stronger IP and stricter enforceability (instead of technological cooperation) to make profits out of their new products and processes.

(6) The choice to cooperate depends upon the skill endowments and research capabilities of the two companies. For example strengthening IPRs may decrease the incentive to cooperate in particular when there is a high asymmetry in the technological sophistication and research capabilities of the companies.

We can incorporate the previous discussion in the following alternative hypothesis.

H4. Stronger IPRs in developing countries may induce changes in appropriability strategies by foreign companies that can reduce the level of international technological collaborations

4. Data and Methodology

Our patent data come from the EP and USPTO KITES data set[5], which contains complete information on all patent applications at United States Patent and Trademark Office (USPTO) and to the European Patent Office (EPO). In particular we use all patent applications from 18 countries from 1990 to 2004. We consider eleven emerging countries: Argentina, Brazil, , India, Israel, China, South Korea, South Africa, Mexico, Malaysia, Singapore, Turkey and 7 advanced countries: Canada, France, Germany, Italy, Japan, UK and US. Patents are assigned to countries using the addresses of the inventors and, in particular, are assigned to a specific country *i* if there is at least one inventor resident in country *i*.

[5] KITeS provide the cleaning and preparation of the database. The original source is the standard EPO Worldwide Patent Statistical Database (also known as PATSTAT): http://www.epo.org/patents/patent-information/raw-data/test/product-14-24.html

We observe an international technological collaboration between country A and country B when a patent is co-signed by at least one inventor resident in country A and at least one inventor resident in country B[6]. A possible noise in the data can be generated by individual inventors that work abroad but keep on declaring the address of the home country. We control for this looking at those teams where the number of domestic inventors is less than 20% of the total number of inventors in the team. For example if we observe a patent with 6 US inventors and one Brazilian inventor we could argue that this is not an international collaboration between Brazil and the US but rather it is a Brazilian inventor working in a US institution. The inventors' address is a more precise information than the applicant address. In dealing with emerging countries, the applicant address may not contain the relevant information regarding the place where the innovative effort takes place. In many cases applicants are multinational corporations and in patent applications use the legal address of the headquarters even if the patent is the result of a collaborative effort with a foreign laboratory. Moreover in order to study technological collaborations it is much more appropriate to look at the inventor level. The first reason is that we assume that knowledge spillovers pass through interpersonal links and therefore it is at the individual level that the real knowledge exchange takes place; secondly if we look at international teams of inventors (rather than at patents that are co-applied by institutions in different countries) there is much more collaborative activity going on.

4.1 International knowledge flows and collaborations in the emerging countries. A descriptive analysis

Table 1 shows for the emerging countries the total number of patents per country per year and the number patents with at least a foreign inventor resident in the G7 countries (i.e. the share of collaborative patents). It shows that emerging countries have a substantial share of international patents which are co-invented with the G7 countries, at the same time the same percentage is very small for the G7 countries[7]. On average for the emerging countries the share of international collaborations range between 3% and 66% (higher for Turkey and smaller for South Korea). It is also important that this share is increasing in all the 7 advanced countries while no clear patterns emerge from the emerging countries. The share of international collaborative patents seems to decline in China and India indicating a growing importance of domestic technological activity in these two countries. At the same time the same share display a positive trend in Brazil and Mexico with a peak in the mid nineties and then either the trend remains flat or declines.

[6] If a patent is signed by three inventors from three different countries in our sample, we consider all three bilateral relations.
[7] The table is available on request

4.2 The Econometric model

We estimate the impact of the IPRs strength on the international technological collaborations using a gravity model (Picci, 2008; Peri, 2005). Classic gravity models use cross section data to estimate trade relationship for a particular time period. Nevertheless we are interested in evaluating the impact of changes in IP laws over time, hence the panel data structure is more useful. Moreover the advantages of this method are twofold: (1) panel data can capture the occasional shocks which may affect the relationship among variables over time, (2) panel data can also control for unobservable partner's individual effects.

Gravity models have been widely used in explaining trade flows. Disdier and Head (2008) show that the negative impact of distance on trade flows began to rise after the 1950s and remains high. Taking into account in their meta-analysis of approx 1400 distance effects estimated in 103 different econometric papers, they show that the mean bilateral trade flow elasticity to distance is equal to 0.9 and challenge significantly the idea that distance is becoming less relevant as globalization and international integration get deeper.

Peri (2005) analyses knowledge flows across regions in a gravity framework using patent citations. He finds that knowledge flows go much farther than trade flows even if knowledge flows remain highly localized. Guellec and van Pottelsberghe de la Potterie (2001) studies technological internationalization of the OECD countries and show that small and low tech countries are more open. They also find that technological collaboration depends upon technological proximity and the presence of both a common language and a common border. Picci (2009) studies international collaboration using co-inventors and co-applicants of a set of patent applications at the European national patent offices and at the EPO and studies the increased level of technological collaborations of the European countries. He finds that distance, common language and common borders explain a substantial part of the variation in bilateral collaborations.

In this vein this paper provides the first attempt to estimate the impact of IPRs reinforcement on international technological collaborations in the emerging countries using a gravity model. We follow a standard empirical implementation (e.g. Disdier and Head, 2008) for the expected value of x_{ijt}, that is, in our case, (1) the number of collaborations between emerging country *i* and developed country *j* at time *t*: . The gravity equation can be represented in the following equation:

$$E[x_{ijt}] = A^{\alpha}_{it} A^{\beta}_{jt} D^{\theta}_{ij} IPR^{\gamma 1}_{it} Trade^{\gamma 2}\, FDI^{\gamma 3} \exp(\lambda L_{ij}) e^{\tau t} \qquad (1)$$

In equation (1) A^{α}_{it} and A^{β}_{jt} measure specific characteristics of country *i* and *j*, D_{ij} is the geographical distance between them, and L_{ij} is a vector of bilateral indicators linking the two countries. θ is the "distance effect", that is the negative of the elasticity of technological collaborations with respect to geographical distance: the ideas is that the amount of collaboration is decreasing in the costs of transport between two countries.

The main variable under scrutiny is the general strength of the domestic intellectual system (IPR_{it}). This variable is the Ginarte and Park index (Ginarte and Park, 1997; Park and Wagh, 2002; Park, 2008). This index ranges from zero to five and its value is the un-weighted sum of five sub-indexes that range from 0 to 1: (1) extent of coverage (subject matter and types of invention), (2) membership in international treaties, (3) duration of protection, (4) absence of restrictions on rights (e.g. degree of exclusivity), and, finally, (5) statutory enforcement provisions (e.g. preliminary injunctions)[8].

For what concern the other variables[9], in our empirical application A_{it} and A_{jt} are the constant price GDP and the total number of patent applications respectively of country *i* and country *j*, at time *t* Moreover we control for some further specific characteristics of emerging countries *i*. In particular we also expect technological collaborations to be related to the inflow of foreign direct investments (FDI_{it})[10]. Trade is the value of imports of country *i* from country *j*

The vector λ represents the coefficients of the variables that describe the links between emerging country *i* and developed country *j* at time *t*. The vector L is composed by the following 'linkage' variables that may affect both technological collaborations and knowledge flows:

- technological proximity (TP_{ijt}). The proximity of countries *i* and *j* is measured by the uncentered correlation of the two countries' distribution vectors of patents across 30 technological classes (OST, 2004) at time *t* (P_i and P_j), as follows: $TP_{ij} = P_i P'_j / [(P_i P'_i)(P_j P_j)]^{1/2}$. This indicator typically ranges between 0 and 1 for all other pairs of countries. It is equal to one for the pairs of countries with identical distribution of technological activities, it is equal to zero if the distributions are orthogonal (Jaffe, 1988).
- a dummy indicating a common legal origin (LEG_{ij}): is a dummy variable which is equal to one if *i* and *j* have a common legal origin (La Porta et al. ,1999)

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[8] The data are available for an avarage of 1960-1990, fro 1995, 2000 and 2005. Following Picci (2009), For the years 1990, 1991 and 1992, the 1960-1990 average has been used. The years 1993, 1994, 1996 and 1997 are set equal to the observation for 1995. The observation for year 2000 is also used for the years 1998, 1999, 2001 and 2002. Last, the observation for year 2005 is also used for the years 2003 and 2004.

[9] In the Appendix we provide a description of the datasets used (Table A3)

[10] We consider the total inward of FDI in country *i* at time *t*. It is not a bilateral measure.

Taking the logs we obtain the following specification that, being linear in the parameters, we estimate using ordinary least squares or with a least square dummy variable model:

$$\ln x_{ij} = \alpha_i + \alpha_j + \alpha_t + \alpha_1 \ln PAT_{it} + \alpha_2 \ln GDP_{it} + \alpha_3 \ln PAT_{jt} + \alpha_4 \ln GDP_{jt} + \alpha_5 \ln FDI_{it} + \theta \ln D_{ij} + + \omega \ln TP_{ijt} + \sigma LEG_{ij} + \gamma_1 \ln IPR_{it} + \gamma_2 \ln Trade_{ijt} + \eta_{ijt}. \quad (2a)$$

All the regressions contain a full set of time dummies (α_t) to control for time varying un-observables that are common across countries. Moreover we include unobserved individual time constant effects specific to country *i* and country *j* (in the Tables reported as OLS estimates) – specification 2a - [11]. The dependent variable is the log of the number of patents with at least one inventor who resides in country *i* (one of the emerging countries) and one inventor in country *j* (G7). We control for the inventive mass (PAT) and the GDP of the two countries, the inward FDI, the distance (D), the legal origin, the bilateral imports (IMP) and the technological proximity (TP)[12]. The main variable is the log of IPR index; moreover in order to estimate the impact of a stronger IP for different level of trade we interact the log of IPR with the bilateral imports (IMP).

Standard estimates of the gravity model may yield biased estimates of the volume of collaborative patents because there is no heterogeneity allowed for in the regression (Cheng and Wall, 2003). According to the possibility of heterogeneity a country *i* would exchange different levels of knowledge with two different countries even though the two countries have the same GDPs, intensity of patents and are equidistant from the country *i*, for example because they can share similar historical, cultural or political factors that often are difficult to observe. This is why we also control for these factors using a simple FE model (in this case α_{ij} is the specific "country-pair" effect between country *i* and country *j*) – specification 2b - .

$$\ln x_{ij} = \alpha_{ij} + \alpha_t + \alpha_1 \ln PAT_{it} + \alpha_2 \ln GDP_{it} + \alpha_3 \ln PAT_{jt} + \alpha_4 \ln GDP_{jt} + \alpha_5 \ln FDI_{it\ j} + \omega \ln TP_{ijt} + \gamma_1 \ln IPR_{it} + \gamma_2 \ln Trade_{ijt} + \varepsilon_{ijt}. \quad (2b)$$

[11] We also control for Random Effect model which provides consistent estimates of the coefficients under the hypothesis of non correlation between the error and the explanatory variables. The Hausman test (1978), based on differences between FE and RE estimators, confirms that the random effect estimator is biased.

[12] FDI and bilateral imports are both expressed millions of US dollars at current prices; however the inclusion of a full set of time dummies makes it unnecessary to use constant prices.

The disturbance term η_{ijt} and ε_{ijt} are assumed to be log-normally distributed with zero mean and constant variance for all the observations; moreover it is also assumed that the disturbances are pairwise not correlated.

One problem in estimating the gravity models resides in the presence of cases when pairs of countries are not involved in any relation of inventive activity. This occurs in more than 30% of cases both at the USPTO and at the EPO (see Figure A1 and A2). Given that the initial model is expressed in logs, all these cases generate missing values and at the same time the truncation of the dependent variable may be a source of biased estimates.

For this reason we followed three procedures. First, we set zeroes equal to one and allow the corresponding observations to have a separate intercept (zero dummy) as in Pakes and Griliches (1984) and then simply estimate the model by OLS; second, we adopt the two-step procedure introduced by Heckman (1979). Following Helpman et al. (2006) we use two stage estimation: we use a probit model on the likelihood that 2 countries collaborate in patenting activity, and then we estimate the gravity equation introducing the estimated (for each panel year) Mills Ratio to control for sample selection bias. Third, we implement the Poisson estimator which provides a natural way to deal with zero values of dependent variable and at the same time is takes into account the integer nature of the dependent variable. Moreover the nature of the estimation issues in a gravity model may induce a form of heteroskedasticity of the error term which leads to the inconsistency of the OLS estimator, while the Poisson estimator is not prone to this problem (Santos Silva and Tenreyro, 2006). Following the Fixed Effect Poisson (FEP) Estimation three assumptions have to be valid:

- $E(x_{ijt} | X_{j1},..., X_{jT}, c_j) = c_j m(X_{j1},, \beta_0)$[13] $t=1,2,...15$
- $x_{ijt} | X_{j1}, c_i \sim$ Poisson $[c_j m(X_{j1},, \beta_0)]$
- x_{ijt}, x_{ijr} are independent conditional on x_i, c_i $t \neq r$

The dependence between the unobserved individual characteristic and time invariant (c_i) and the regressors (X_j) is allowed (while this is not true for the Random Effect Poisson Estimation).

Finally, we are interested in evaluating the impact of IPR regimes for different level of GDP and Trade relation. Hence the last specification will be:

[13] When the dependent variable is a positive integer number, the most used choice of parametric function is $m(X_{j1},, \beta_0)=\exp(X_{j1},, \beta_0)$ (Wooldridge 2002).

$$\ln x_{ijt} = \alpha_{ij} + \alpha_t + \alpha_1 \ln PAT_{it} + \alpha_2 \ln GDP_{it} + \alpha_3 \ln PAT_{jt} + \alpha_4 \ln GDP_{jt} + \alpha_5 \ln FDI_{it\ j} + \omega \ln TP_{ijt} + \gamma_1 \ln IPR_{it} + \gamma_2 \ln Trade_{ijt} + \gamma_3(\ln IPR_{it} * \ln GDP_{it\ it}) + \gamma_4(\ln IPR_{it} * \ln Trade_{ijt}) + \varepsilon_{ijt}. \quad (2c).$$

5. Results

In this section we present the estimates of the gravity model on collaborative patents, i.e. knowledge spillovers captured by interpersonal links between co-inventors residing in different countries.

Table 3 displays the estimates of the gravity models for collaborations between the emerging countries and the G7 countries at the USPTO (in Appendix, table A3, results for the EPO are displayed). Columns 1 and 3 control for individual time constant factors (that is we set country dummies for both emerging and advanced countries); in column 2 we run fixed effect regressions (LSDV) which include fixed effects relative to each specific pair of countries. Column 3 run a OLS only for cases in which there exists a patenting relationship between countries (we have only 763 observations out 1153). Moreover regressions (1,2,3) contain a full set of time dummies.

Sharing a common legal origin has a significant positively effect in all the regressions, while distance is found to negatively affect the international inventive collaborations even if not always significant. Note that in the FE specification *distance* and *common legal origin* are eliminated because they are fixed over time; however they are not collinear with the country-pair specific effects and so they do not create any problem relating to the omitted variable problem[14].

The measures of inventive proximity (Technology Proximity) positively influences the international collaborations but this effect disappears when controlling for pairs fixed effect. The inventive mass (i.e. the number of patents) has the expected sign: in particular the number of patent signed in the emerging countries have a positive effect on the number of international collaboration, while the number of patents signed in the advanced countries seems to play no role. The economic mass is always positive and significant. In particular in the case of foreign GDP (again, the G7 GDP) an increase of 1% increases by 2,57% and 2,39% the international collaborative activity in the OLS model and LSVD respectively.

The amount of FDI received is positively correlated with the international technological collaborations, even if this effect disappears when controlling for the zeros. On the other side Trade has a positive and significant effect but it may be collinear with the individual pairs dummies (in the case of LSVD the effect of trade is no more significant although positive).

[14] However if we regress them on the country-pair effects from the FE model (column 2, Table 3) we obtain expected signs even if not both coefficients are not statistically significant: specifically, where the estimates of the country-pair effects are denoted as , and including the log of distance and the common legal origin dummies as independent variables, we obtain (standard errors in parenthesis): = - 80.77 (1.01)*** - 0.03 (0.11)DIST + 1.07 (0.12)LEG*** and the R squared is 0.066.

The provisional estimates highlight the effect of strengthening *IPRs* on collaborative innovative activities controlling for the indirect effect through bilateral import (IMP) and FDI: in all the models we observe a positive but not significant effect of IPR on the technological collaboration. Better IPR protection in the emerging countries seems not to improve internationalization.

In the previous section we pointed out the problem of OLS in the case of zero collaborations. Given that the model is expressed in logarithm, all the cases generate missing values and hence the truncation of the dependent variable could be a source of non consistent estimates[15]. To solve this problem we adopt the two step procedures popularly known as Heckit estimator (Heckman, 1979). The first step of the Heckit estimator is the probit equation calculated for each year of the sample. The Inverse Mills Ratio are all included in the main gravity equation estimated by OLS.

The Heckman procedure followed consists of estimating the Mills Ratio for each panel year; once calculated we use them to control for sample selection bias by inserting them in the main equation. The selection equation estimates the probability that two countries (in this case the emerging and the advanced country) share at least a patent, that is the probability that there exists at least a patent with two inventors residing in both the two countries. We argue that the main explanation of an existing technological collaboration between two countries refer to the geographical and sociological distance between them. Hence in the selection equation we considered all the principal equation covariates but IPR, as well as the Distance and Common Legal Origin Dummy[16].

The results of the Heckit main equation are displayed in column 4. They confirm the positive and significant role of the Inventive and economic Mass as in the OLS cases. Moreover it's worthwhile noting that we have a strong asymmetry in our gravity model. We find that only the size of the technological and economic activities in the emerging countries are a precondition to set up technological collaborations with the advanced countries. On the contrary the number of patents and the GDP of the advanced countries are never significantly positive in our regressions. The effect of trade is also confirmed: the implied elasticity of the internationalisation with respect of the volume of the bilateral imports is 29% (increase of 1% in the volume of bilateral imports increases by 0,29% the international collaborative activity). The effect of inward FDI is not significant while the role of the technology proximity seems to be reinforced.

Interestingly, controlling for the selection bias with the Heckit estimator, the results show that better IPR protection favour patenting international collaboration among emerging and advance countries. The coefficient of IPR index is now higher and significant (even if at 90% level of confidence).

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[15] With censored dependent variables there is a violation of the assumption of zero correlation between independent variables and the error term.

[16] The selection equations results, estimated for each years, are not displayed for clarity (but they are available upon request).

This result is confirmed using the Poisson estimator (columns 5 and 6, table 1): the IPR index is now significant at 99% level of confidence. The estimates of having a common legal origin and of the distance have the expected sign, as well as the mass (inventive and economic). Allowing for the dependence between the unobserved individual characteristic and time invariant (c_i) and the regressors (Poisson Fixed Effect, column 6, table 1) the role of IPR index is still positive and significant at 99% level. Moreover the same results for the Poisson estimations are obtained controlling for the EPO data (see in Appendix table A3).

Table 4 shows the role of IPR strengthening for different type of specifications using the Heckit estimator (in Appendix, see table A4 for the Poisson estimations). Column 1 shows the effect of IPR index controlling only for the economic mass (emerging and advanced countries' GDP): the magnitude is 0.40 and significant at 99% level of confidence. Clearly the IPR index has an indirect effect on the international technological cooperation through the inventive mass and the bilateral imports. Stronger IPR laws may have a positive effect on the level of the inventive activity in the emerging country. Controlling for this effect (column 2) we see that the coefficient of IPR fall to 0.31 (always significant at 99% level). Finally better IPR protection in emerging countries may lead to an higher level of bilateral imports. Controlling for this possibility we observe that the IPR coefficient is now 0.23 (significant at 90% level).

Finally, Table 5 shows the regression results when the IPRs variable is interacted with the level of bilateral import and with GDP. For what concern the interaction term between trade and IPRs the sign is positive and significant. This can be interpreted in two ways. It shows that the positive effect of the intensity of trade on international technological collaborations is particularly strong for those emerging countries that reinforce their IPRs. Secondly it can also be claimed that the effects of stronger IPRs in developing countries on international technological collaborations is more pronounced for those pairs of countries that have stricter trade relationships. Differently, the interaction term between the IPR index and emerging countries' GDP is not always significant. We find a small positive effect of IPR for high level of development only in the case of Fixed Effect Poisson estimation.

6. Conclusion

As innovation goes global, there is a rising demand for global knowledge governance. This issue is at the center of the political debate in advanced, as well as in emerging and developing economies. However, which mix of policies better supports the generation and diffusion of knowledge in global economies on a faire basis is still an open debate. Innovation is increasingly the result of the combination of knowledge, know-how, competences and techniques whose generation and diffusion occur usually involving international counterparts. Research and inventions with industrial applications will increasingly be a global phenomena. However, the possibility for catching up and emerging economies of profiting from increased opportunities of collaboration cannot rely on market forces alone. A mix of policies is needed to support the generation of domestic capabilities and to support a virtuous integration to the global knowledge economies.

In emerging countries access to foreign technologies, collaboration with foreign counterparts, both in the domestic country and abroad is a hot political issue. Scientific research increasingly involves international counterparts and mobility of researchers is on the rise. Collaborative links with foreign laboratories rely more on relational and capability proximity than on geographical distance. Also, multinationals are increasingly delocalizing R&D activities in host countries, spurring a debate on which are the conditions under which the local community of researchers and firms can learn by tapping into foreign collaborative networks.

Intellectual property regimes are, as all economic and legal institutions, context and time specific, and they are subject to change. Our paper contributes to this policy debate and our preliminary evidence suggests that there may be some positive effects on knowledge flows generated by the reinforcement of IPRs in emerging economies and in particular by the TRIPs agreements. In particular our preliminary results could suggest some efficacy of stronger patent protection to enhance technological collaborations in emerging countries, evidencing some role of IPR protection to stimulate knowledge based transactions with developed countries.

However these results have to be taken with extreme care because the impact of IPRs regime is extremely complex and can vary from sector to sector and country to country. Our additional results show that this positive result might be confined to pairs of countries that are close trade partners and to those countries with a higher GDP. We find that the impact of IPRs on technological collaborations is stronger if countries are also increasing the trade relationships and also that the effect of bilateral imports on technological collaborations is higher if emerging countries are strengthening their IPRs legislation.

Finally it's worthwhile noting that we have a strong asymmetry in our gravity model. We find that only the size of the technological and economic activities in the emerging countries are a precondition to set up technological collaborations with the advanced countries. On the contrary the number of patents and the GDP of the advanced countries are never significantly positive in our regressions. Additional results indicate also that geographical distance, technological proximity and the common legal roots could affect the probability of technological collaborations.

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TABLES AND FIGURES

Table 1. Patents and collaborative patents (by inventors), USPTO Data

	Argentina				Brazil				China				India			
	TOTAL PATENTS	COLLABORATIVE PATENTS with G7	G7over total collaborations	% of collaborative patents over total patents	TOTAL PATENTS	COLLABORATIVE PATENTS with G7	G7over total collaborations	% of collaborative patents over total patents	TOTAL PATENTS	COLLABORATIVE PATENTS with G7	G7over total collaborations	% of collaborative patents over total patents	TOTAL PATENTS	COLLABORATIVE PATENTS with G7	G7over total collaborations	% of collaborative patents over total patents
1990	29	3	75%	10%	46	4	67%	9%	65	14	82%	22%	39	16	89%	41%
1991	26	1	100%	4%	63	8	73%	13%	83	17	77%	20%	37	18	100%	49%
1992	26	2	67%	8%	66	16	89%	24%	85	24	86%	28%	49	29	100%	59%
1993	39	2	67%	5%	71	11	79%	15%	127	39	91%	31%	63	35	95%	56%
1994	49	17	81%	35%	115	40	89%	35%	115	47	78%	41%	70	39	95%	56%
1995	43	8	73%	19%	92	34	74%	37%	132	49	79%	37%	85	40	87%	47%
1996	53	12	80%	23%	91	22	88%	24%	149	43	88%	29%	118	46	92%	39%
1997	58	11	69%	19%	127	40	69%	31%	205	68	72%	33%	170	58	91%	34%
1998	63	8	89%	13%	128	37	80%	29%	248	74	65%	30%	212	97	97%	46%
1999	50	10	77%	20%	154	48	92%	31%	368	115	65%	31%	315	159	90%	50%
2000	80	21	91%	26%	162	58	78%	36%	545	151	65%	28%	452	135	93%	30%
2001	147	29	91%	20%	261	81	91%	31%	1215	338	64%	28%	983	305	92%	31%
2002	126	37	69%	29%	324	125	77%	39%	1572	451	63%	29%	1191	340	83%	29%
2003	94	30	79%	32%	289	94	80%	33%	1756	495	62%	28%	1134	375	87%	33%
2004	90	32	89%	36%	292	99	93%	34%	2676	668	47%	25%	1343	488	90%	36%
Total	973	223		23%	2281	717		31%	9341	2593		28%	6261	2180		35%

	Israel				Korea				Malaysia				Mexico			
	TOTAL PATENTS	COLLABORATIVE PATENTS with G7	G7over total collaborations	% of collaborative patents over total patents	TOTAL PATENTS	COLLABORATIVE PATENTS with G7	G7over total collaborations	% of collaborative patents over total patents	TOTAL PATENTS	COLLABORATIVE PATENTS with G7	G7over total collaborations	% of collaborative patents over total patents	TOTAL PATENTS	COLLABORATIVE PATENTS with G7	G7over total collaborations	% of collaborative patents over total patents
1990	359	61	97%	17%	525	24	96%	5%	7	2	100%	29%	44	14	93%	32%
1991	361	69	93%	19%	815	29	100%	4%	19	8	89%	42%	44	6	75%	14%
1992	431	99	92%	23%	933	28	93%	3%	11	4	100%	36%	55	8	89%	15%
1993	502	96	91%	19%	1068	36	100%	3%	21	13	93%	62%	50	13	81%	26%
1994	705	154	92%	22%	1662	67	91%	4%	16	5	71%	31%	70	21	88%	30%
1995	825	230	92%	28%	2198	99	88%	5%	30	10	56%	33%	92	38	84%	41%
1996	787	165	93%	21%	3556	84	81%	2%	38	14	58%	37%	91	34	85%	37%
1997	976	220	93%	23%	3943	100	83%	3%	57	26	68%	46%	93	23	74%	25%
1998	1106	241	94%	22%	4108	110	84%	3%	46	17	63%	37%	113	33	92%	29%
1999	1407	237	89%	17%	3859	127	78%	3%	81	34	49%	42%	134	70	92%	52%
2000	1641	311	90%	19%	4837	211	82%	4%	117	56	62%	48%	149	62	84%	42%
2001	2734	483	89%	18%	8782	311	79%	4%	198	63	59%	32%	256	87	96%	34%
2002	2408	398	86%	17%	10290	369	86%	4%	215	69	64%	32%	204	77	90%	38%
2003	1717	356	88%	21%	10771	322	89%	3%	295	89	64%	30%	220	111	97%	50%
2004	1907	347	91%	18%	9593	334	84%	3%	379	104	64%	27%	167	78	91%	47%
Total	17866	3467		19%	66940	2251		3%	1530	514		34%	1782	675		38%

	Singapore				South Africa				Turkey				All sample			
	TOTAL PATENTS	COLLABORATIVE PATENTS with G7	G7over total collaborations	% of collaborative patents over total patents	TOTAL PATENTS	COLLABORATIVE PATENTS with G7	G7over total collaborations	% of collaborative patents over total patents	TOTAL PATENTS	COLLABORATIVE PATENTS with G7	G7over total collaborations	% of collaborative patents over total patents	TOTAL PATENTS	COLLABORATIVE PATENTS with G7	G7over total collaborations	% of collaborative patents over total patents
1990	26	10	100%	38%	108	20	91%	19%	4	1	50%	25%	1252	169	92%	13%
1991	50	21	84%	42%	99	16	89%	16%	4	4	100%	100%	1601	197	90%	12%
1992	78	27	82%	35%	98	5	56%	5%	4	4	100%	100%	1836	246	89%	13%
1993	83	33	79%	40%	153	15	88%	10%	4	4	100%	100%	2181	297	90%	14%
1994	119	33	87%	28%	145	11	73%	8%	6	6	86%	100%	3072	440	88%	14%
1995	135	56	86%	41%	111	20	87%	18%	11	8	80%	73%	3754	592	86%	16%
1996	178	55	81%	31%	129	25	86%	19%	16	15	94%	94%	5206	515	86%	10%
1997	236	80	82%	34%	128	21	64%	16%	12	8	80%	67%	6005	655	82%	11%
1998	294	102	82%	35%	137	23	85%	17%	20	15	88%	75%	6475	757	85%	12%
1999	448	121	70%	27%	146	27	79%	18%	32	21	84%	66%	6994	969	79%	14%
2000	597	170	71%	28%	150	21	64%	14%	28	16	84%	57%	8758	1212	79%	14%
2001	1076	308	71%	29%	202	31	84%	15%	70	54	90%	77%	15924	2090	79%	13%
2002	1079	260	65%	24%	207	53	88%	26%	62	37	74%	60%	17678	2216	75%	13%
2003	821	220	60%	27%	209	43	80%	21%	33	14	82%	42%	17339	2149	76%	12%
2004	952	252	67%	26%	268	49	72%	18%	45	31	91%	69%	17712	2482	69%	14%
Total	6172	1748		28%	2290	380		17%	351	238		68%	115787	14986	78%	13%

Table 2 . Descriptive Statistics (Emerging countries)

Variable	definition and Source	Obs	Mean	Std. Dev.	Min	Max
Collaborative patents	number of patents with at least an inventor from the Emerging Country and an inventor from the Advanced Country (source: USPTO)	1155	12.97489	44.01262	0	520
Patents (by inventor)	number of patents by inventor (source: USPTO)	1155	701.7394	1670.146	4	10771
GDP	constant 2000, US$ (millions)	1155	332977.5	305500.1	44662.45	1715000
IMP (Bilateral Imports)	millions of US dollars, current prices	1153	4617.568	10195.53	6	111710
FDI (Inward)	millions of US dollars, current prices	1155	8528.489	12050.53	1	60630
IPR	Ginarte and Park Index (Ginarte and Park, 1997; Park 2008)	1155	3.004	1.03	1.03	4.25
PT (proximity_tech)	indicator of pairwise "inventive proximity"	1155	0.6412326	.1283821	.1283821	.9504014

Table 3. Baseline regression: The impact of IPRs on Collaborative patents (USPTO).

VARIABLES	OLS (with individual dummies) (1)	OLS FE (2)	OLS (only positive values) (3)	Heckman^ (4)	Poisson (5)	Poisson FE (6)
Patents (Emerging C.)	0.30***	0.30***	0.29***	0.30***	0.64***	0.64***
	(0.053)	*(0.044)*	*(0.076)*	*(0.076)*	*(0.040)*	*(0.080)*
Patents (Advanced C.)	0.30	0.23	0.13	0.12	0.47*	0.49
	(0.28)	*(0.23)*	*(0.40)*	*(0.39)*	*(0.27)*	*(0.48)*
GDP (Emerging C.)	0.86***	0.91***	0.53*	0.51**	0.53***	0.61
	(0.21)	*(0.18)*	*(0.30)*	*(0.30)*	*(0.20)*	*(0.42)*
GDP (Advanced C.)	2.25***	2.39***	2.09***	1.63***	-0.001	0.035
	(0.43)	*(0.35)*	*(0.56)*	*(0.55)*	*(1.18)*	*(1.16)*
FDI	0.090***	0.079***	0.003	0.004	-0.010	-0.0077
	(0.021)	*(0.017)*	*(0.029)*	*(0.029)*	*(0.018)*	*(0.028)*
IPR index	0.025	0.056	0.12	0.23*	0.22***	0.25***
	(0.097)	*(0.080)*	*(0.13)*	*(0.13)*	*(0.066)*	*(0.091)*
Bilateral Imports	0.12***	0.0085	0.22***	0.29***	0.073	0.010
	(0.033)	*(0.045)*	*(0.042)*	*(0.032)*	*(0.052)*	*(0.11)*
Distance	-0.096**		-0.027		-0.533***	
	(0.047)		*(0.061)*		*(0.147)*	
Common Legal Origin	0.21***		0.26***		0.58***	
	(0.038)		*(0.050)*		*(0.14)*	
Technology Proximity	0.91***	-0.032	1.10***	1.59***	0.236	0.15
	(0.17)	*(0.17)*	*(0.23)*	*(0.22)*	*(0.146)*	*(0.25)*
Constant	-74.1***	-80.7***	-65.9***	-55.72***	-9.183	
	(11.6)	*(10.0)*	*(15.9)*	*(15.6)*	*(11.78)*	
Host country dummy	Yes	No	Yes	Yes	Yes	No
Source country dummy	Yes	No	Yes	Yes	Yes	No
Pairs dummy	No	Yes	No	No	No	Yes
Year dummy	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1153	1153	763	763	1153	1153
R-squared	0.855	0.675	0.807	0.819		

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1; all independent variables (excluding Technology Proximity) are in log; time and individual dummies variable are not reported in order to save space.

^ The selection equations results, estimated for each years, are not displayed for clarity (but they are available upon request). In the selection equation we considered all the principal equation covariates but IPR, as well as the Distance and Common Legal Origin Dummy.

Table 4. Different specifications for IPR index (Heckman regression)

VARIABLES	Heckman (1)	Heckman (2)	Heckman (3)	Heckman (4)	Heckman (5)
GDP (Emerging C.)	1.43***	0.85***	0.85***	0.85***	0.58*
	(0.26)	*(0.33)*	*(0.33)*	*(0.31)*	*(0.30)*
GDP (Advanced C.)	2.35***	2.42***	2.42***	1.83***	1.63***
	(0.60)	*(0.60)*	*(0.60)*	*(0.58)*	*(0.55)*
IPR index	0.40***	0.31**	0.31**	0.32**	0.23*
	(0.14)	*(0.14)*	*(0.14)*	*(0.13)*	*(0.13)*
Patents (Emerging C.)		0.24***	0.23***	0.27***	0.30***
		(0.082)	*(0.084)*	*(0.081)*	*(0.076)*
Patents (Advanced C.)		0.17	0.17	0.17	0.12
		(0.43)	*(0.43)*	*(0.41)*	*(0.39)*
FDI			-0.00051	0.052*	0.0045
			(0.031)	*(0.030)*	*(0.029)*
Technology Proximity				1.89***	1.59***
				(0.23)	*(0.22)*
Bilateral Imports					0.29***
					(0.033)
Constant	-80.0***	-77.4***	-77.4***	-63.3***	-55.7***
	(16.7)	*(17.1)*	*(17.1)*	*(16.4)*	*(15.6)*
Host country dummy	Yes	Yes	Yes	Yes	Yes
Source country dummy	Yes	Yes	Yes	Yes	Yes
Year dummy	Yes	Yes	Yes	Yes	Yes
Observations	765	765	765	765	763
R-squared	0.775	0.778	0.778	0.798	0.818

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1; all variables (excluding Technology Proximity) are in log; time and individual dummies variable are not reported in order to save space.

Table 5. Interactions among variables

VARIABLES	OLS FE (1)	OLS FE (2)	Heckman (3)	Heckman (4)	Poisson FE (5)	Poisson FE (6)
Patents (Emerging C.)	0.22***	0.22***	0.37***	0.38***	0.64***	0.64***
	(0.040)	*(0.040)*	*(0.063)*	*(0.063)*	*(0.043)*	*(0.044)*
Patents (Advanced C.)	0.51**	0.50**	0.058	0.052	0.58**	0.54*
	(0.21)	*(0.21)*	*(0.31)*	*(0.31)*	*(0.278)*	*(0.28)*
GDP (Emerging C.)	0.91***	0.82***	0.48*	0.29	0.56***	0.15
	(0.16)	*(0.18)*	*(0.25)*	*(0.29)*	*(0.20)*	*(0.24)*
GDP (Advanced C.)	2.77***	2.77***	2.29***	2.29***	-0.05	0.007
	(0.32)	*(0.32)*	*(0.44)*	*(0.44)*	*(0.39)*	*(0.39)*
FDI	0.057***	0.052***	0.030	0.025	0.002	0.001
	(0.016)	*(0.016)*	*(0.024)*	*(0.024)*	*(0.018)*	*(0.019)*
Bilateral Imports	-0.50***	-0.50***	-0.21**	-0.21**	-0.19**	-0.17**
	(0.054)	*(0.054)*	*(0.092)*	*(0.092)*	*(0.07)*	*(0.07)*
Technology Proximity	-0.16	-0.15	0.051	0.067	0.21	0.36**
	(0.15)	*(0.15)*	*(0.22)*	*(0.22)*	*(0.15)*	*(0.16)*
IPR index	-3.06***	-3.06***	-1.21**	-1.21**	-0.85***	-0.55
	(0.23)	*(0.23)*	*(0.47)*	*(0.47)*	*(0.32)*	*(0.33)*
IPR index* B. Imports	0.42***	0.41***	0.19***	0.18***	0.13***	0.08*
	(0.029)	*(0.030)*	*(0.057)*	*(0.058)*	*(0.04)*	*(0.04)*
IPR index* GDP (Emerging)		9.7e-08		1.5e-07		2.62e-07***
		(8.6e-08)		*(1.2e-07)*		*(8.37e-08)*
Constant	-89.8***	-88.5***	-67.8***	-65.6***		
	(9.15)	*(9.22)*	*(12.6)*	*(12.7)*		
Host country dummy	No	No	No	No	No	No
Source country dummy	No	No	No	No	No	No
Pairs dummy	Yes	Yes	Yes	Yes	Yes	Yes
Year dummy	Yes	Yes	Yes	Yes	Yes	Yes
Observations		1153	763	763	1153	1153
R-squared	0.729	0.730	0.899	0.899		

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1; all variables (excluding Technology Proximity) are in log; time and individual dummies variable are not reported in order to save space.

APPENDIX

Table A1. Description of the database by source

Variable	source
PATENT APPLICATIONS	USPTO-KITeS and EPO (Patstat)-KITeS Database
TRADE	Stan Bilateral Trade Database (GRAND TOTAL)
GDP	WDI Online (World Bank)
IPR index	Ginarte and Park (1997), Park W. (2008)
FDI	Unctad
DISTANCE	CEPII dataset
LEGAL ORIGIN	La Porta et al. (1998)

Table A2. Countries considered for the analysis

We focused on emerging countries (host), such as Bascavusoglu (2005). In particular we considered 11 emerging countries in the list of Bascavusoglu (2005) which are those with more patent applications (excluding the soviet states). These are: Argentina, Brazil, China, India, Israel, South Korea, Malaysia, Mexico, South Africa and Singapore, and Turkey.

The industrialized countries (source) are: Canada, France, Germany, Italy, Japan, United Kingdom, United States.

Figure A1a. Frequency of collaborative patents (USPTO)

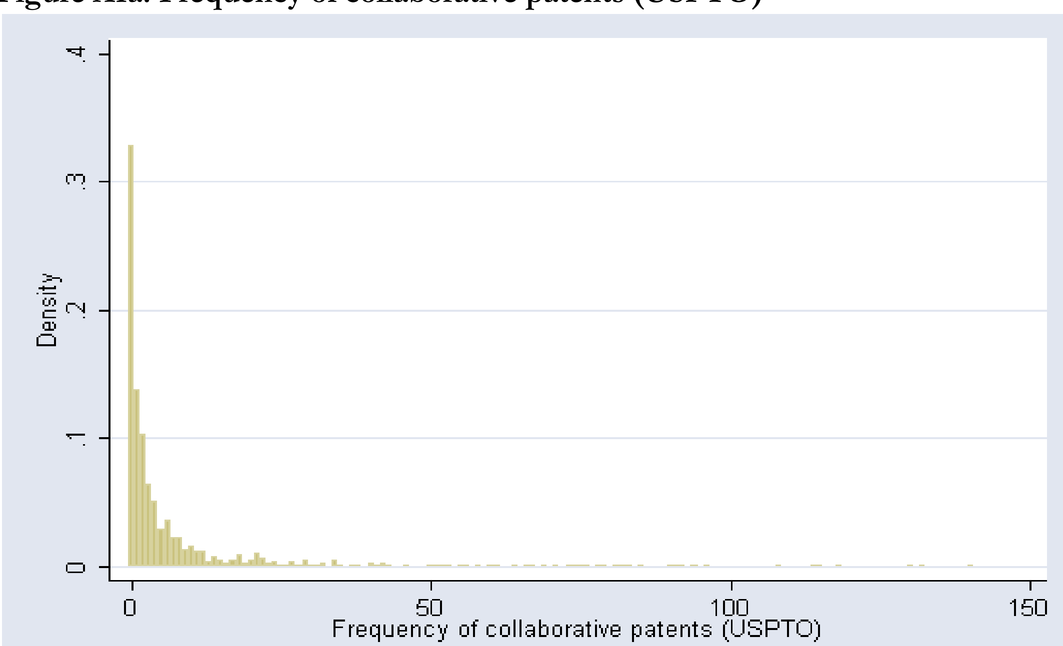

Figure A1b, Frequency of collaborative patents (EPO)

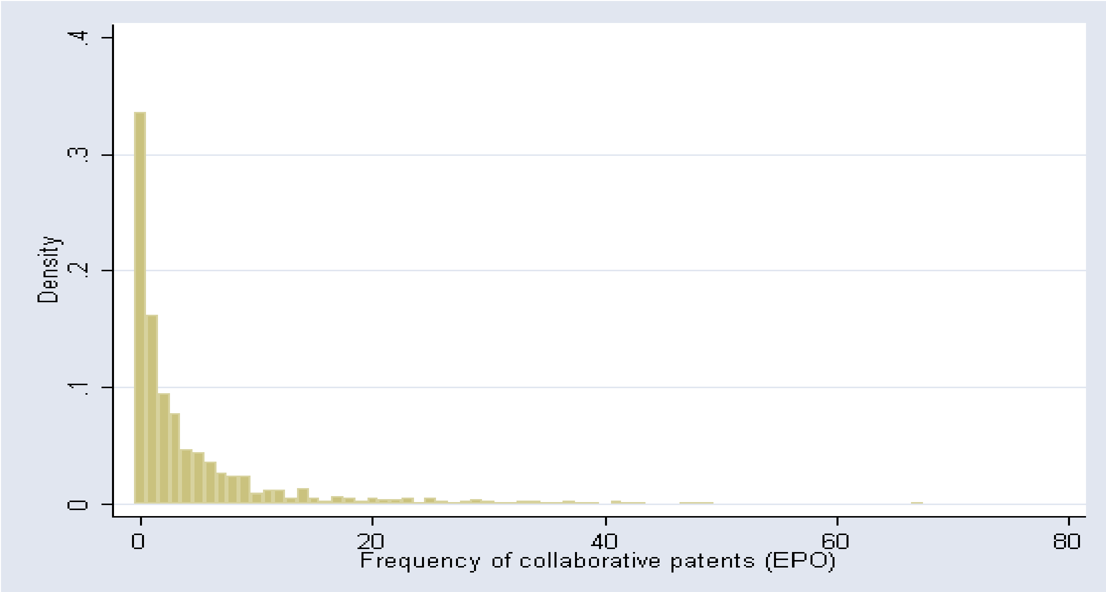

Table A3. Baseline regression: The impact of IPRs on Collaborative patents (EPO).

VARIABLES	OLS (1)	OLS FE (2)	OLS (only positive values) (3)	Heckman (4)	POISSON (5)	POISSON FE (6)
Patents (Emerging C.)	0.21***	0.24***	0.29***	0.32***	0.57***	0.57***
	(0.048)	*(0.038)*	*(0.069)*	*(0.070)*	*(0.05)*	*(0.11)*
Patents (Advanced C.)	-0.92***	-0.99***	-0.68***	-0.36	-0.16	-0.19
	(0.16)	*(0.13)*	*(0.25)*	*(0.26)*	*(0.29)*	*(0.55)*
GDP (Emerging C.)	0.84***	0.83***	0.48*	0.29	0.41	0.51*
	(0.19)	*(0.15)*	*(0.28)*	*(0.28)*	*(0.25)*	*(0.28)*
GDP (Advanced C.)	1.99***	2.13***	1.38***	1.30**	-0.49	-0.47
	(0.40)	*(0.32)*	*(0.53)*	*(0.54)*	*(0.44)*	*(0.80)*
FDI	0.069***	0.057***	0.019	0.0057	-0.002	0.0043
	(0.018)	*(0.015)*	*(0.027)*	*(0.027)*	*(0.025)*	*(0.033)*
IPR index	0.041	0.047	0.16	0.24*	0.38***	0.40***
	(0.091)	*(0.073)*	*(0.12)*	*(0.12)*	*(0.09)*	*(0.14)*
Bilateral Imports	0.085***	0.0095	0.19***	0.22***	0.05	-0.040
	(0.030)	*(0.040)*	*(0.040)*	*(0.031)*	*(0.02)*	*(0.083)*
Distance	-0.060		-0.016		-0.52***	
	(0.043)		*(0.059)*		*(0.14)*	
Common Legal Origin	0.17***		0.20***		0.53***	
	(0.034)		*(0.047)*		*(0.14)*	
Technology Proximity	0.72***	-0.052	1.20***	1.66***	1.01***	0.85***
	(0.16)	*(0.15)*	*(0.21)*	*(0.22)*	*(0.21)*	*(0.25)*
Constant	-57.7***	-61.4***	-40.4***	-39.5***	10.30	
	(10.8)	*(8.98)*	*(14.6)*	*(14.7)*	*(12.52)*	
Host country dummy	Yes	No	Yes	Yes	Yes	No
Source country dummy	Yes	No	Yes	Yes	Yes	No
Pairs dummy	No	Yes	No	No	No	Yes
Year dummy	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1153	1153	753	753	1153	1123
R-squared	0.823	0.669	0.730	0.735		

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1; all variables (excluding Technology Proximity) are in log. In the Poisson Pseudo Maximum Likelihood the dependent variable is not in log; time and individual dummies variable are not reported in order to save space.

Table A4. Different specifications for IPR index (Poisson estimator)

VARIABLES	Poisson (1)	Poisson (2)	Poisson (3)	Poisson (4)	Poisson (5)	Poisson (6)
GDP (Emerging C.)	2.81***	0.62***	0.61***	0.63***	0.63***	0.53***
	(0.13)	*(0.19)*	*(0.19)*	*(0.19)*	*(0.19)*	*(0.21)*
GDP (Advanced C.)	-0.27	0.12	0.12	0.059	0.074	-0.0014
	(0.36)	*(0.39)*	*(0.39)*	*(0.39)*	*(0.39)*	*(0.39)*
IPR index	0.50***	0.25***	0.25***	0.25***	0.25***	0.22***
	(0.060)	*(0.064)*	*(0.064)*	*(0.064)*	*(0.064)*	*(0.066)*
Patents (Emerging C.)		0.63***	0.63***	0.64***	0.64***	0.64***
		(0.044)	*(0.044)*	*(0.044)*	*(0.044)*	*(0.044)*
Patents (Advanced C.)		0.53*	0.53*	0.52*	0.52*	0.47*
		(0.28)	*(0.28)*	*(0.28)*	*(0.28)*	*(0.28)*
FDI			-0.010	-0.0039	-0.0044	-0.011
			(0.018)	*(0.018)*	*(0.018)*	*(0.019)*
Technology Proximity				0.25*	0.23	0.24
				(0.15)	*(0.15)*	*(0.15)*
Distance					-0.61***	-0.53***
					(0.14)	*(0.15)*
Common Legal Origin					0.60***	0.58***
					(0.15)	*(0.15)*
Bilateral Imports						0.073
						(0.053)
Constant	-26.1***	-18.3	-18.1	-16.7	-11.6	-9.18
	(9.78)	*(11.6)*	*(11.6)*	*(11.7)*	*(11.7)*	*(11.8)*
Host country dummy	Yes	Yes	Yes	Yes	Yes	Yes
Source country dummy	Yes	Yes	Yes	Yes	Yes	Yes
Year dummy	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1155	1155	1155	1155	1155	1155

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1; all variables (excluding Technology Proximity) are in log; time and individual dummies variable are not reported in order to save space.

Table A5. Technological internationalization activity in Emerging Countries: collaborative patents at EPO and USPTO with G7 countries.