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Intellectual Property Rights and South-North Formation of Global Innovation Networks

By **Maria Comune,** University of Siena, Italy
Alireza Naghavi, University of Bologna, Italy
Giovanni Prarolo, University of Bologna, Italy

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JEL Classification: F2, O1, O3

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Address for correspondence:

Alireza Naghavi
Universita di Bologna
Dipartimento di Scienze Economiche
Piazza Scaravilli 2
Bologna 40126
Italy
Phone: +39 051 2098873
Fax: +39 051 209 8040
E-mail: alireza.naghavi@unibo.it

Intellectual Property Rights

and South-North Global Innovation Networks[†]

Maria Comune[a], Alireza Naghavi[b,*], Giovanni Prarolo[b]

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Abstract

This paper explores the role of IPR protection in the emergence of R&D linkages from newly emerging economies. Using data from a new survey on Chinese and Indian firms in the ICT sector, we find IPR protection to be key in the engagement of Southern firms in global innovation networks. A complementary exercise uses global bilateral patent data to investigate the location-specificity of IPR enforcement for this phenomenon. We find that a stringent IPR regime in the North (South) discourages (encourage) foreign patenting activities of firms in the South, suggesting that a global convergence of IPRs can stimulate Southern innovation.

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[a] University of Siena.

[b] University of Bologna.

[*] Corresponding author. Postal address: Università di Bologna, Dipartimento di Scienze Economiche, Piazza Scaravilli 2, Bologna, 40126, Italy. Tel: +39 051 2098873; fax: +39 051 209 8040. *E-mail address:* alireza.naghavi@unibo.it

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1. Introduction

The growing demand for technology in an increasingly competitive global market is changing the geography of innovation. Today multinational enterprises (MNEs) seek not only to exploit their knowledge in other countries, but also to source technology internationally and tap into worldwide centers of knowledge (OECD, 2008a). We now observe a faster pace for the internationalization of R&D, a wider range of actors involved worldwide, and a greater scope of international innovative activities in the form of integrated networks.

While most R&D investments still go to OECD countries (also referred to as North), non-OECD countries have attracted an increasing amount of R&D investments in recent years (OECD, 2008b). As knowledge starts to flow more freely across the globe, the heated debate on the puzzle regarding the protection of intellectual property becomes more complex. A survey by the Economist Intelligence Unit (EIU) in 2004 revealed that 84% of all executives perceive the lack of intellectual property rights (IPRs) protection in emerging markets as a challenge when outsourcing their R&D. Branstetter, et al. (2006) further provided solid evidence that IPR enforcement encourages Northern firms to increase their R&D activities abroad (in terms of foreign patent applications as well as R&D expenditure and royalty payments). But does the same motivation apply for firms from the South? The issue is no longer a duel between developed and developing countries. With Newly Industrialized Countries (NICs, also referred to as South) taking a lead in developing technologies of global standards, the view of the South towards IPRs has taken a new meaning.

This paper sheds light on the development of innovation capacities and the internationalizing of R&D by the new class of firms in the South. It investigates the relevance of IPRs from a South-North perspective to study the incentives of actors in newly emerging economies to tap on to international knowledge networks. In so doing, we define different measures for R&D linkages to assess the degree to which Southern firms engage in global networks of innovation and find out how IPR protection contributes to or hampers this phenomenon.

To address the issue we start by relying on a unique firm-level dataset built from a recently completed survey that has been specifically designed to gather information on firms' behavior in terms of international innovation activity. Across four continents, firms were asked to provide information about their experience with regulation, practices and jurisprudence around IPRs faced in the internationalization of their innovation activities. The survey selected ICT as the representative high-tech industry, and narrowed the interviews in this sector down to firms located in China and India.[2] The novelty of the survey data used here compared to others on the IPR issue, such as the surveys by EIU on outsourcing innovation, is that it emphasizes the viewpoint of the South by interviewing executives from China and India. Our empirical findings suggest that a credible IPR regime can influence Southern firms' engagement in the internationalization of R&D. More specifically, IPRs tend to matter more for the participation of domestic Southern firms in global R&D collaborations. Moreover, it proves more relevant for the offshoring or outsourcing of innovation in the hardware segment of the ICT sector.

As instructive as firm-level surveys can be in understanding the behavior of individual firms, they generally tend to lack important information on a global scale. In this particular case, the survey results underline the need for a reliable IPR protection system also for innovative firms in newly emerging countries. But is the blessing of a strong IPR regime for Southern firms uniform across the globe, or is IPR protection viewed as location-specific? What is the impact of a 17000 patent portfolio held by Motorola (later bought by Google in August 2011 to protect HTC and Samsung who produce phones based on Google's Android software) on South-North R&D? Can the patent system be used to block South-North R&D, as Apple tried in April 2011 by suing Samsung in the US and subsequently claiming against it to prevent the imports of Galaxy Tab 10.1 and Galaxy Smartphones in Germany, Ireland, Netherland, Sweden and UK?[3]

To study the above unexplored issues, we use an empirical gravity model designed to capture the extent of NICs involvement in the internationalization of innovation activity in OECD countries. Using the number of patents that NICs nationals file in OECD patent offices as the variable of interest, we estimate the impact of country and country-pair specific variables such as IPR protection in both countries, together with

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[2] This is partly driven by the survey design, which lets each partner-country select one sector of particular economic relevance. A description of the firm-level survey design and implementation is provided in Appendix 1.

[3] Kwong, R. and Jung-a, S., "Google's Motorola deal a boon for Asia", Financial Times, 16 August 2011; Zeman, E., "Apple wins another round against Samsung in Germany", Information week, 09 September 2011.

standard gravity model specific controls such as distance, GDP per capita, common language and common border dummies. Using data on patents filed by nationals from 14 NICs in 31 OECD countries, we show that the location of IPR enforcement is crucial for South-North innovative activities. In particular, South-North foreign patenting is positively related to domestic IPR enforcement, whereas enforcement in the receiving country *discourages* patent applications from NICs.

The effect of IPR protection on the internationalization of R&D for economies in the catch-up phase is therefore heterogeneous and location-specific. The positive impact of a strong domestic IPR regime in countries that have overcome the developing stage works in a similar manner as in advanced economies. IPRs create incentives to innovate, promote growth and allow Southern firms to enter into the world market for knowledge through global innovation networks. The negative impact of IPR protection in the North for the entry of Southern patents can be associated to patent blocking. The latter is caused by defensive patenting (to avoid being 'invented around') or by a market power effect that obstruct entry by new firms, and the consequent difficulty faced by firms from NICs with less advance technologies to obtain patents in countries with a tougher IPR regime. Also, we use the degree of ICT-specificity of exports to parallel our firm-level analysis and confirm the crucial importance of IPR protection for international innovation activities of Southern firms, primarily for the hardware segment of the ICT sector.

This study contributes to the literature by considering the issue of IPRs from a new perspective by accounting for today's rapidly growing knowledge economies. Essentially, the conclusion drawn from the results reinforce the positive implications of IPR harmonization for the internationalization of Southern innovation. However, the empirical findings reveal that a more complex mechanism of harmonization is required for this to be effective in catch-up economies, placed in a limbo state between the developing and the developed world. In particular, the results suggest that a convergence of IPR enforcement in the two regions, that is weakening (strengthening) the level in the North (South), can be beneficial for Southern innovation. This is slightly but meaningfully different from the TRIPS obligations that requires the South to upgrade its IPR regime to the standards in force in the North.

The reminder of the paper is organized in the following way: the next section gives a number of stylized facts on recent patenting activities in major emerging economies along with a short literature review. Section 3 presents survey data and the related empirical analysis. In section 4 we report methodology, data, and results for the cross country estimation. Section 5 concludes.

2. Intellectual Property Right Standards and Innovation

2.1. Stylized facts: Recent trends in emerging economies

The increase in the 'propensity to patent'[4] by 20 percent in less than 20 years in OECD countries is generally attributed to technological change, economic transformations, and a shift of patent policy since the 1990s (OECD, 2004). The same trend has occurred in emerging economies after reforming their legal framework of IPR protection according to WTO standards. In 1985, the total number of patents granted in China (including both domestic and foreign patents and, not only inventions, but also utility models and industrial designs) was only 138: 20% was claimed by non-residents, but no patents for inventions were claimed by Chinese residents. Even if this number increased by seven hundred times in 1999, Chinese domestic enterprises were still not considered innovative compared to their foreign counterparts (Sun, 2003). The total amount of patent applications in China today exceeds 7 million ranking as the third largest patent office in the world and fourth in terms of Patent Cooperation Treaty (PCT) filings (WIPO, 2011).[5] In some new technical areas, such as digital communication, telecommunication and high-speed trains, 20% of the total of PCT applications have come from China in the years 2008-2010 (Tian, 2011). China accounts for 3.5% of triadic patents and aims to join the top five countries receiving triadic patents by 2015 (Zhao, 2006). The first Patent Law came into force in China in 1985 and the two major rounds of modifications occurred in 1992 and 2000.

[4] That is, the number of patents taken per dollar or euro of R&D, assuming the productivity of R&D constant.

[5] In 2009, SIPO received 17% of world patent applications, following only USPTO with 25% and JPO with 19%. While, the share of world PCT applications at WIPO by Chinese nationals is 7,5%, after US (27,4%), Japan (19,6%) and Germany (10,7%).

In India, the Patents Act 1970 was amended in 1999, 2002 and 2005. The stagnant level of patent applications in the country saw a marked change with a peak in 1997.[6] After 1999, a sharp decrease of first filing in the country was experienced. This has been attributed to the country becoming signatory to the PCT in 1998 after which both national and foreign inventors preferred to file PCT applications directly, designating India as one of the countries for the national phase (Ganguli, 2004). PCT applications by Indian inventors and industries registered a sustained growth up to 43% in 2001.[7] Today, the country stands higher than Japan, Korea and China in terms of patent filing abroad relative to resident patent applications (WIPO, 2011). Trends in ICT-related patent applications to the European Patent Office (EPO) show that India ranked second after China between 1995 and 2003. Over the period 2004-2007, the country presented the highest average growth rate in terms of patent applications (26.3%) reaching almost 37 thousand applications in 2008 (WIPO, 2010). If we consider the share of Indian and Chinese inventors in PCT applications by foreign-owned firms, the countries rank respectively 1st and 5th in the world, that is, 65% of Indian and 43.9% of Chinese inventors contribute to foreign-owned patent applications.

Indian IT sector is estimated to aggregate revenues of US$88.1 billion in 2011, with the software and service sector, excluding hardware, accounting for 86.4%.[8] Conversely, China accounts for 14.6% of the global electronics hardware production (Bhattacharya and Vickery, 2010). Indeed, the large share of Chinese patent applications in ICT-related areas is associated with the considerable focus on ICT hardware production (van Welsum and Xu, 2007).

2.2. Related literature: Theoretical background

The theoretical framework behind our empirical tasks and findings is built on existing literature with the purpose of showing how IPR protection may encourage or hamper innovation and the internationalization of R&D.

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[6] This can be mostly attributed to Indian accession to the WTO-TRIPS and the implementation of the transitional mailbox procedure before extending patent protection on pharmaceutical products.

[7] WIPO Magazine 10, 2002.

[8] NASSCOM cited by India Brand Equity Foundation, 2011.

A priori, IPR protection in the destination country could have either a positive or a negative impact on foreign patents: according to Allred and Park (2007), a positive effect of IPR protection on patenting in developed countries comes from increased appropriability of invention and a market expansion effect (i.e. a larger market creates innovation spillovers, so that new innovations are easier to produce), while negative effects can derive from defensive patenting or market power effect.[9] About the effect that IPR protection level in the origin country could have on innovation, Picci (2010) suggests that poor IPR protection could result both in less internationalization of innovation (due to standard appropriability considerations) or more, if the branches of MNEs located in NICs patent innovations in their headquarters.

The literature on the positive impact of IPR enforcement on innovation at home is abundant and rather well-known. The protection of patents provides firms with a temporary monopoly power and increases their incentives to innovate.[10] In the context of newly emerging economies, a strong IPR regime at home further helps disseminate the created knowledge by allowing firms to accumulate governance capabilities and better manage R&D agreements abroad. This can for instance be due to lower transaction costs a firm has to incur to protect itself from risk of opportunism by a third party (Martínez-Noya and García-Canal, 2011).

Perhaps, the less obvious side of the story is the impact of IPR protection abroad in the internationalization of R&D. On the one hand, protection in the host country could reduce imitation risks faced by multinationals and induce them to engage in foreign R&D activities by outsourcing innovation (Lai, Riezman and Wang, 2009). On the other hand, and perhaps more relevant in the viewpoint of today's rapidly-growing knowledge emerging economies, a stringent regime in the North can discourage the entry of foreign patents by creating a more concentrated market impeding entry by new firms (Boldrin and Levine, 2008). Increased incentives by Northern firms to engage in defensive patenting, most common in the ICT industry, is another channel suppressing R&D linkages (Hall and Ziedonis, 2001). As suggested by

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[9] For specific case studies on how this mechanism has affected the catch-up process in Korea see Lee and Kim (2010).

[10] See Maskus (2000) for a thorough discussion of the literature and the basics.

Allred and Park (2007), defensive patenting is mostly associated with Northern countries. The strategy of 'patent blocking', aims at preventing rivals from applying for the same or similar coverage (Chu, 2009).

We proceed in the next sections to study the above-mentioned trade-off created by IPRs for firms in NICs on the impact of IPRs on their incentives to engage in global R&D networks and activities. We then apply the results to describe the location-specificity of IPR protection and show situations under which the foreign engagement of Southern firms in international R&D activities is at its highest level. This allows us to draw conclusions with respect to the harmonization of IPR standards and differentiate between the dynamics through which it can be achieved.

3. IPRs and Global R&D Linkages in the South: Firm-level Analysis

3.1. The Survey data

We have obtained the data by administrating a survey to firms representing three sectors in 9 countries across 4 continents.[11] The sectors targeted were ICT (in China, India, Sweden, Norway and Estonia), agro-processing (in South Africa and Denmark), and automotive (in Brazil and Germany), selected to represent a range of high to low tech industries. The aim was to collect empirical evidence to study the determinants and the extent of globally dispersed innovation networks.

To assess the presence of R&D linkages in the sample, we define two different dependent variables. The first, *GIN*, defines firms responding that they have established collaborations with foreign actors for the development of their most important innovation, i.e. global innovation networks. Such actors could be indistinctively clients, suppliers, competitors, consultancy companies, governmental institutions, universities, research institutions or open source communities. Differently, *OUT* considers firms that perform some specific/core innovation activities through offshoring and/or outsourcing abroad. In this case, the interviewees were asked to indicate whether and in which region of the world they offshore and/or

[11] The sample of firms is not representative at the level of country or region, so the policy implication of the findings in this section should be treated carefully, without pushing too much issues of external validity.

outsource innovative activities. The activities include product and process development, operations, procurement, logistics and distribution, building and maintenance of IT systems.[12]

Table 1 presents the distribution of the dependent variables across countries in the sample. Comparing the distribution of *GIN* and *OUT* at country level, the latter provides a more restrictive definition of international collaborations for innovative activities, nonetheless with some exceptions.[13] Looking at the correlation coefficients across sectors of the dependent variables, they do not result particularly large, from 0.29 for ICT firms to 0.47 for agro-processing firms. This highlights that the two variables capture different activities firms may perform in the internationalization of their innovative activities.

[Table 1 about here]

The presence of R&D linkages prevails in the ICT sector if we look at the establishment of international collaborations as such (*GIN)*, but not in the case of offshoring and outsourcing innovative activities from abroad (*OUT*). It's worth mentioning that having significant R&D activity does not necessarily mean a greater involvement in global R&D linkages. The correlation coefficient between having significant R&D activity and the variables *GIN* and *OUT* result 0.32 and 0.14 respectively. Indeed, there is a relevant fraction of firms in the sample that outsource and offshore innovation abroad without conducting in-house R&D (21.7%), indicating that the core of their knowledge has foreign origin. This is also confirmed by looking at the most important source of innovation for firms. Among respondents, 40% of the sample do not consider their headquarters as the most important source of technology inputs and 29.4% have as technology source an entity external to the firm.

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[12] The selection of activities included in the set of 'innovation activities', has been conducted by looking at what firms defined as 'innovation'. Firstly, we looked at the set of firms that indicated to conduct 'offshoring innovation'. Secondly, we constructed dummies that included the possible combinations of functions that respondents perform through offshoring. The highest correlation coefficient was found in correspondence of the dummy including the group of functions listed above.

[13] We observe that *OUT* is more widespread than *GIN* in Germany and Brazil. This could be driven by sector peculiarities. Indeed, observing the distribution of the independent variable across sector, the difference between *GIN* and *OUT* is less pronounced for the automotive industry than for the ICT.

After having presented some general findings of the survey for all participating countries and representative sectors, we now focus on China and India, whose involvement in ICT is of primary importance. The survey reveals India to be the only emerging economy with a strong and positive probability of being a part of international R&D networks, while China in all cases results amongst the least involved. In our sample, Chinese ICT firms are amongst the most unsatisfied with regard to human resources availability: 68.3% of Chinese interviewees indicated "a negative or highly negative experience with relevant labor force training and skills as a factor for the internationalization of their innovative activities in the past three years".[14] On the IPRs side, the Chinese sample presents the greatest percentage of firms that "require more stringent regulations, practice and jurisprudence around IPR when considering their future innovative activities". 64.2% of Chinese firms in the sample expressed a very high need or a moderately high need for more stringent IPR regulations. This relative value of dissatisfaction with the present IPR system increases if we look specifically at those Chinese firms that are already engaged in global innovation networks. Alternatively, India results more open in conducting research activities with foreign partners even if it presents a lower R&D intensity compared to China. Indeed, when looking at the size of the R&D units in the ICT sector for the Chinese and Indian sample, in China they result on average larger than in India with only exception being very small firms with less than 10 employees.[15] Chinese firms result more R&D intensive, employing a greater number of individual in R&D than Indian firms. This may confirm recent studies on the Indian ICT sector that, despite public efforts, investments in R&D by the private sector results relatively low and is largely based on the outsourcing market (Bhattacharya and Vickery, 2010). These observations call for a more in-depth analysis of the Chinese and Indian ICT firms.[16]

3.2. Empirical analysis

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[14] INGINEUS survey was run between November 2009 and June 2010 (See Appendix 1). 'In the past three years' refers therefore to the period 2007-2009.

[15] Respondents where asked to provide number of full-time equivalent employees and full-time equivalent R&D employees.

[16] For more information on the establishment of the Chinese and Indian ICT sample please refer to Appendix 1.

In what follows we concentrate on the legal environment for IPR protection (*IPR*) as a relevant factor for the internationalization of firms' innovative activities.

In our simple linear probability model, our main regression equation is:

$$LINK_i = \beta_0 + \beta_1 \, IPR_i + \boldsymbol{\beta_2 X_i} + \delta_c + \upsilon_i, \qquad (1)$$

where $LINK_i$ takes our two definitions of R&D linkages *GIN* and *OUT*, and subscript *i* indicates firms. The main explanatory variables denote firms' positive or negative experience in the past three years with regard to regulation, practice and jurisprudence around IPRs as factors for the internationalization of their innovative activities. These are treated as dummy variables taking the value of one if the firm indicates a positive experience with above factors. Vector $\boldsymbol{X_i}$ contains further controls, such as a firm's experience with relevant labour force training and skills, type of ownership (domestic or foreign) and sub-sector (hardware or software). Finally, to control for unobserved heterogeneity, we include dummies at the country level, δ_c, (i.e. the China dummy) in all specifications.

After defining the main dependent and independent variables, we perform OLS estimates of equation (1) for each definition of R&D linkage.[17] We estimate our linear probability model for the Indian and Chinese sample. The aim is to look at the IPR environment as a determinant of R&D linkages at the country level, and observe whether the same conclusions can be applied equally to the domestic and foreign ICT firms located in China and India. We also conduct a sub-sector analysis considering that firms within the ICT sector may rely differently on patents in the hardware segment compared to software programming, data processing and systems design.[18]

Table 2 reports the results of the OLS regressions to shed light on whether having had a positive experience with IPRs has contributed to building international R&D linkages. Findings in columns 1 and 2 affirm that having had a positive experience with IPR regulations increases significantly the probability of networking with foreign actors for innovative activities, especially when *GIN* is the dependent variable.

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[17] Logit and Probit estimations give very similar results and are not reported for brevity.

[18] The *hardware* segment includes (i) the manufacture of communication equipment and (ii) other information technology and computer service activities, such as, computer disaster discovery, setting up personal computers and software installation.

Moreover, Chinese (Indian) firms are less (more) likely to be involved in a global innovation network. The control variable *hardware* results positive and statistically significant only when we look at *OUT*. This may indicate that in the hardware segment the activity of offshoring and/or outsourcing abroad is more widespread than networking with foreign partners.

[Table 2 about here]

In columns 3 and 4 we additionally control whether human resource availability (HR) can be another explanation for the involvement of Chinese and Indian firms in global R&D linkages by supplying quality skilled workers for global and local markets. We find that IPRs continue to play an important role with *GIN* as the measure of R&D linkages, but lose significance when *OUT* is the measure under study. We then control for type of firm ownership (i.e. *foreign* dummy) to investigate the extent to which it may affect the relevance of IPRs. The positive and significant coefficient of the control variable *foreign* in column 3 indicates that being a subsidiary of an MNC increases substantially the probability of being part of international innovation linkages. Differently, the negative coefficient of the interaction term *IPR*foreign* shows that, even if it turns out that foreign firms are *per se* more involved in R&D linkages than domestic ones, IPRs tend to be a more essential factor for the participation of *domestic* firms in global innovation networks (*GIN*). In other words, the relevance of a positive experience with IPRs for participating in global innovation networks is less pronounced for foreign firms set in China and India than for the local firms. The same argument does not hold for international R&D value chains (*OUT*). In this case, *IPR*foreign* is not statistically significant indicating the absence of a differential effect of IPR for domestic and foreign firms.

[Table 3 about here]

In Table 3, we focus on hardware and software firms when studying R&D linkages. Here we look at the relevance of their past experience with the intellectual property framework (*IPR*) and to their need for more stringent IPR protection when considering their future innovation activities (*fIPR*). Again, we control for country and type of ownership. Columns 1 and 3 indicate that IPRs remain a determinant of international networking activities, while the hardware segment is not, per se, more involved in global innovation networks or more reactive to IPRs. Perhaps more interestingly, columns 2 and 4 reveal that IPRs do not play a role in firm's activity of outsourcing and offshoring innovation abroad. The coefficient takes a negative, although insignificant, sign for both *IPR* and *fIPR*. However, coefficients for the interaction terms *IPR*hardware* and *fIPR*hardware* show that firms in the hardware sector react positively to IPR protection when deciding on the internationalization of their R&D value chains.

3.3. Conclusions of the survey-based research and limits

The conclusions from our micro-analysis are threefold: first, the analysis suggests that the protection of IPRs is among the determinants of the participation of firms in the South to global innovation networks, but not in the internationalization of their R&D value chain. Second, focusing on differences between the foreign and the domestic sector operating in these countries we found that IPRs are more relevant for domestic (hence Southern) than foreign firms. From a Southern perspective, these findings may indicate that the capability of introducing and securing new and sophisticated technology at home and/or abroad determines the opportunity for a Southern firm to be globally engaged in innovative activities. Finally, looking at both measures of experience and need of more stringent IPRs across ICT sub-sectors we find that while securing intellectual assets is a determinant of international R&D collaborations for the ICT industry, it proves more essential for the hardware segment when engaging in international R&D linkages through outsourcing and offshoring activities.

Although the survey data can differentiate between the type of global R&D linkages under study, they do not allow for considerations with regard to the location of the IPR framework. When engaged in the internationalization of innovative activities, is it more relevant having a positive experience with regard to the IPR system in the destination/partner country, in the country of origin or in both? Furthermore, the role of IPRs results ambiguous. On one side, the positive and statistically significance of its impact (when considered alone) may reflect the general argumentations on the impact of the IPR framework on the business environment and its relevance for the internationalization of R&D activities. However, its lower significance when considered in concomitance with other factors, under different definitions of R&D linkages, or if observed for specific sub-sectors may confirm that stronger IPRs must be embedded in a broader set of complementary initiatives, such as human capital development, to be effective. Last but not least, they may indicate that there are emerging trends or new factors affecting innovation and decisions regarding the internationalization of R&D activities.

The survey analysis, as limited to the two world largest emerging economies, bolster the general critics to the theoretical literature of North-South models (Park, 2008b). It represents an attempt to fill the gap in the literature on IPR and international innovation on Southern innovator sectors and Southern markets that represent a relevant share of Northern firms' world market. However, it cannot be used to advance policy considerations neither regarding the global IP reform that took place since the mid-1990s in Southern countries nor the ongoing debates and controversies that touch on the issue of IPRs in the Northern markets (Jaffe and Lerner, 2004). We therefore proceed to a more general analysis that employs global data in the next section.

4. IPRs and Internationalization of Southern R&D: Macro-level Analysis

In this section we try to generalize the firm-level findings to the country level, in particular to a setting consisting of time-varying data on country pairs. Essentially, we are interested in examining the impact of IPRs on *South-North* R&D linkages. To this end, we look at the filing of patents in OECD patent offices by researchers resident in NICs, using IPR protection in both NICs and OECD countries as the main explanatory variable. We start by a brief description of the main data before turning to the empirical methodology and the results.

4.1. Patent data and IPR measures

The variable for patent applications (*PAT*) has been constructed using data from the World Intellectual Property Organization (WIPO). Patent applications may refer to (i) PCT applications by NIC nationals designating one or several OECD countries to seek protection or (ii) direct filing in an OECD country by NIC residents (Paris Route).[19] We believe the foreign patenting activities of the South could at least partially capture the idea of the internationalization of innovation activity in the spirit of what we have highlighted earlier: this would include a (team of) researcher(s) working at the NIC-located branch of a MNC that files a patent through its headquarters in an OECD country.[20]

The complete WIPO dataset has information on 189 countries of origin of applicants and 139 countries (and groups of countries, such as the African Intellectual Property Organization or the European Patent Office) that host a patent office.[21] Information is available for years 1995-2008, so we construct averages for three periods: 1995-1999, 2000-2004 and 2005-2008, hereafter referred to as 1995, 2000 and 2005 respectively. The theoretical number of observations should be 1302, coming from 14 NICs, 31 OECD countries and 3 time periods. However, 3 countries are coded as both NIC and OECD (South Africa, Mexico and Turkey) so we exclude these pairs. The number of observations we have for the empirical work is therefore 1293 and for 649 of them the number of patents is positive. The distribution of *PAT* has a strong positive skew: it takes values between 0 and 3563.25, the average number of patents is 20.45, the median is 0.75 and standard deviation is 154.2.[22] Looking at the time dimension, the number of patents filed more than doubles every five years: in 1995 mean of *PAT* is 6.39, in 2000 it is 15.87 while in 2005 is 39.87, suggesting a remarkable increase in the international collaboration in patenting activity. The rise in average patents is due to both the intensive and extensive margin. The latter refers to the number of zeroes, that

[19] A detailed explanation of South-North foreign patenting is provided in Appendix 2.

[20] One could argue that foreign patenting could also represent for instance Chinese researchers working in Chinese firms who seek protection in a foreign market. However, over 90% of foreign (primarily OECD and the Asian NICs) applications for Chinese invention patents have claimed foreign priority, suggesting that patent applications had earlier been filed for the inventions with foreign jurisdictions (Hu, 2010).

[21] Since WIPO registers the residence of the *first* applicant of a patent, our measure could underestimate the real measure of patents whose applicants' reside in a country different by that of patent office. This is the case of multiple applicants of different residence, with the first applicant residing in the same country of the patent office in which the patent is filed.

[22] The number of patents can take fractional values because we take the average across years.

represents country pairs that are not collaborating: they are 20%, 16% and 13% in the 1995, 2000 and 2005 period, respectively.[23]

We have a measure of IPR protection from Park (2008a) for both the origin and the destination country. The IPR index ranges between 0 and 5 and it is constructed adding five zero-to-one components relative to (i) the patentability of different industrial sectors, (ii) the membership in international treaties, (iii) the duration of protection, (iv) the type and number of available enforcement mechanisms and (iv) the type and number of restrictions on patent rights.[24] The IPR index for the 14 NICs shows a mean equal to 3.17 and a standard deviation of 0.87. The pattern that it shows for the three periods is in line with the overall pattern that Park (2008a) spots for the whole sample of countries for which he constructed the index: it is increasing over time and the standard deviation is decreasing, indicating a convergence of IPR protection among NICs. In particular, mean and standard deviations are 2.52 and 0.81, 3.33 and 0.79 and 3.67 and 0.56 in the 1995, 2000 and 2005 periods, respectively. Turning to OECD countries, the IPR index is overall larger than that of NICs: it shows a mean of 4.19 and a standard deviation of 0.51. This indicates not only higher protection of IPRs, but also more compressed values of the index among OECD countries. The time pattern is similar to that of NICs: the index is increasing, though more moderately, and its standard deviation is decreasing over time.[25]

4.2. Methodology and other variables

Given the nature of our analysis, i.e. looking at the determinants of R&D linkages from NICs to OECD countries, we make use of an *oriented* empirical gravity model.[26] Rather than considering bilateral flows, the

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[23] We take 5-year averages for two reasons. First, data for the IPR protection index are only available for 5-year intervals and second, even if we had data on a yearly basis, IPR protection varies slowly in general, with large jumps when agreements are set in place: taking the averages helps to smooth out these irregular movements.

[24] The technical details related to the construction of the index can be found in Park (2008a).

[25] Mean and standard deviations are 3.95 and 0.61, 4.23 and 0.48 and 4.38 and 0.29 in the 1995, 2000 and 2005 periods, respectively.

[26] Our framework partially draws from Yang and Kuo (2008). However, their analysis is limited to the 4 contiguous years of 1995-1998 and do not study South-North relations, but bilateral relation between 30 selected WIPO members. While their aim is to uncover the influence of trade and IPRs in the destination country on outward patenting activities, we focus on the IPR regime on both sides of the activity and its harmonization between the country pairs.

standard practice in gravity estimation of trade flows (see, for example, Frankel and Rose, 2002) or international invention activity (see Picci, 2010), we specifically look at the number of patents filed in the patent office of an OECD country (the destination country) whose first applicant resides in a NIC (the origin country).[27] Succinctly, our dependent variable PAT_{ijt} is the (log) average number of patents filed in the time period *t* by an applicant residing in country *i* in the patent office of country *j*, where index *i* runs over 14 NICs and *j* runs over the 31 OECD countries.[28] Note the different pools from which *i* and *j* are taken and that, in general, $PAT_{ijt} \neq PAT_{jit}$.

The empirical model we estimate, written in general terms, is the following:

$$PAT_{ijt} = G_t + D_i + D_j + \boldsymbol{\beta 1}\, \mathbf{X}_{it} + \boldsymbol{\beta 2}\, \mathbf{Y}_{jt} + \boldsymbol{\beta 3}\, \mathbf{Z}_{ij} + \boldsymbol{\beta 4}\, \mathbf{W}_{ijt} + u_{ijt} \tag{2}$$

The monadic terms $\mathbf{X}_{it}$ and $\mathbf{Y}_{jt}$ include time-varying variables common to origin and destination countries, respectively. In particular they include IPR_{it} and IPR_{jt}, as well as variables only specific to either one or the other set of countries.[29] Among the monadic variables there are logs of GDP per capita and population: instead of having only GDP as mass variable, we separate size (population) and development (GDP per capita) effects in the spirit of Head et al. (2010), so to better interpret our results. We expect that both GDP per capita and population in the origin country should have a positive effect on innovation activity, including the filing of patents abroad. We also have the counterpart of the variable human resources used in some specifications of our firm-level analysis. That is, the Barro and Lee (2010) data on the share of 25+ year old people holding at least tertiary education in both the original and the destination countries. We are less

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[27] We decided to look at the number of patent applications instead of granted patents because has the advantage of allowing an analysis of more recent data. Indeed, although any application is published by eighteen months after the date of filing or the earliest priority date, the patent grant procedure takes about three to five years from the date of the application.

[28] Countries officially considered as NICs are: Brazil, China, India, Mexico, Malaysia, Philippines, Thailand, Turkey and South Africa (Mankiw, 2007). In our definition of NICs, we also included countries around which consensus in the economic literature is not yet reached. They are Argentina, Chile, Egypt, Indonesia and Russia, (Paweł Bożyk, 2006). OECD countries are Austria, Australia, Belgium, Canada, Switzerland, Czech Republic, Germany, Denmark, Spain, Finland, France, United Kingdom, Greece, Hungary, Ireland, Iceland, Italy, Japan, Korea, Luxemburg, Mexico, Nederland, Norway, New Zealand, Poland, Portugal, Sweden, Slovakia, Turkey, USA and South Africa.

[29] According to Baldwin and Taglioni (2006), we should include a full set of country times year fixed effects, but the short time variability would make it impossible to have enough degrees of freedom.

interested with trade-related issues because of endogeneity concerns and the lack of a theoretical underlying prior on their effects.[30]

The matrix $\boldsymbol{Z}_{ij}$ includes all the time-invariant dyadic variables, collected by CEPII and used by Head et al. (2010). We use (log of) distance between *i* and *j*, commonality of borders and commonality of language. These variables have proved to have strong explanatory power in gravity equations for trade flows, foreign direct investments and services. With this respect we want to compare the elasticities of the internationalization of innovation activities. The term $\boldsymbol{W}_{ijt}$ collects dyadic time-variant variables, specifically it will be the squared distance between IPR protection in country *i* and country *j* at time *t*, that should capture the impact of harmonization of the IPR regime within each country pair. The term G_t is a common year-specific factor and we use year dummies to capture for it. Similarly, D_i and D_j take into account country-specific fixed effects.

To look at specialization in the ICT sector, first recall from the previous section that the greatest percentage of respondents requiring more stringent IPR regulations were the Chinese firms. This could be driven by China's ICT sector's specialization in hardware production, which may rely on patent protection more than the software segment. To control for this, we will use the share of exported goods belonging to the ICT sector interacted with the IPR protection Index among other controls. We use the share of exported goods belonging to the ICT sector in 2000, obtained from World Bank's World Development Indicators, to account for the extent to which NICs are concerned about IPR protection.[31] As discussed above, *ceteris paribus* the more the production mix is biased toward technological goods, instead of software, the more IPR protection should be a factor that fosters innovation, since issues of appropriability of patents are more relevant. This measure varies a lot across NICs, ranging between 0% of Chile to 69% of Philippines. Within this group, India scores 1.4% while China 18.9%.

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[30] Picci (2010) finds no systematic effects of FDI measures on innovative collaboration, concluding that "The internationalization of productive activities and the internationalization of inventive activities are still two quite distinct sides of the globalization coin."

[31] The definition of this variable is: "Information and communication technology goods exports include telecommunications, audio and video, computer and related equipment; electronic components; and other information and communication technology goods. Software is excluded."

4.3. Empirical Results

We start estimating the parameters of equation (2) in a parsimonious specification. The idea is to first pin down the values that the coefficients of the standard independent variables used in empirical gravity model take, so to compare our results with those established in literature. Our results are collected in column 1 of Table 4, where OLS are performed using a specification in which distance, dummies for common language and common border, population and GDP per capita are included among the controls. In all the specifications reported in Table 4, the dependent variable is the log of number of patents, so only country pairs showing a positive number of patents are included in the sample. As in all the following specifications, two (out of three) time dummies are included, together with NICs and OECD country dummies.[32] Distance shows an elasticity of -0.59 that is comparable with the upper bound found by Picci (2010), even though he uses a different measure for patents. Language proves to be an important determinant, while the common border dummy does not, probably because of the low variability: only 11 out of 649 observations report a one. Size measures (population) of origin and destination country have a positive impact and comparable magnitudes, while income per capita has a positive effect in the origin country and negative in the destination. Referring to GDP per capita, the former effect could be the result of higher human capital and/or higher R&D spending, measures that are usually associated with higher GDP per capita. On the contrary, GDP per capita in the destination country negatively impacts on international patenting activity. This could be driven by the fact that NICs tend to collaborate with countries that are more similar to them in terms of the level of development.[33]

[Table 4 about here]

[32] These dummies already control for a lot of variation: a regression that uses only those delivers an R^2 of 0.74.

[33] A regression using the squared difference of GDP per capita of origin and destination country, rather than the two separate variables, gives a negative and significant coefficient.

In column 2 we introduce the IPR protection indices for both origin and destination country. The IPR protection index for the origin country is positive but not significant, while the one for destination is negative and strongly significant. We will take this into account in specifications that use the distance between IPR protection indices within each country pair. Note that the introduction of the indices results in the loss of significance of GDP per capita in the destination country, that could be due to the high correlation of this variable with the IPR index (0.70). Though this high correlation was expected, it is not so high to introduce collinearity issues. Even if it poses, to some extent, problems in correctly attributing the effects of IPR and GDP per capita on patents, it seems that IPR is a better predictor of patenting activity. The results we obtain are opposite to those obtained in Yang and Kuo (2008), who find a positive and significant relation between IPR regime of the destination country and foreign patenting activity that takes place there. The negative effect could be a symptom of increasing strategic uses of patent protection by Northern firms, for instance, to restrain the power of suppliers by owning key technology elements in another part of the technological chain or to build a thicket of patents around a key patented invention to block competitors (Guellec et al., 2007). This may block access to important technologies needed mainly by Southern firms to realize their own innovations. Also, since NICs are on average less technologically advanced than OECD countries, the former may find it easier to patent an innovation in OECD countries with weaker IPR regimes. This occurs because the technological frontier of the most developed OECD countries is difficult to reach, therefore few patent filings are recorded.

Column 3 adds the interactions of the IPR protection index with the share of exported goods belonging to the ICT sector in 2000 for NICs. As highlighted above, countries like China, whose production (and therefore exports) is oriented toward ICT goods, should benefit comparatively more from the protection of IPR. As expected, the interaction between the share of exports in ICT sector and the IPR protection index in NICs is positive and strongly significant.[34] In column 4 we replicate the last results excluding country pairs involving China or India, two countries that host many headquarters of MNCs. In these cases *PAT* would be a spurious mix between genuine cross-border innovation collaborations and

[34] The direct effect of the share of ICT cannot be estimated because it is collinear with NICs' country fixed effects.

innovations carried on within China (India) by Chinese (Indian) MNCs that only register their innovations in foreign patent offices, subsequent to filing a domestic patent. Results hold, but are less significant in some cases possibly due to the smaller sample size. Column 5 adds tertiary education measures for both origin and destination country to the specification in column 2, trying to further address the findings on human resource requirements obtained at firm level. Only education in the origin country turns out to be positive and significant. In another specification, not reported, we also add the interaction term between tertiary education and ICT, paralleling the regression in column 3, but results remain unchanged. In column 6 we replicate the specification in column 1 using the squared distance between IPR protection indices within each country pair instead of the two IPR indices. This variable is negative as expected but not significant at conventional levels.

[Table 5 about here]

Table 5 uses different specifications and alternative estimation techniques in order to check the robustness of our findings. Our main concern with the results obtained is that half of the observations are dropped because *PAT* takes a value equal to zero, causing a missing value for its logarithm. Also, different from the case of bilateral trade flows, *PAT* is a count variable, for which the Poisson estimator has been suggested, see Picci (2010) and Santos Silva and Tenreyo (2006) among others. In column 1 we report results for the Poisson version of the specification 2 in Table 4. The distance variable is precisely estimated and the point estimate is around 0.3. Signs previously found are consistent, while now the IPR protection in NICs becomes positive and strongly significant. The significance being driven by the inclusion of more than 600 zeroes in the analysis suggests that IPR protection works at the extensive margin. Our explanation is that MNCs open up research branches in NICs only if IPR protection is strong enough, while once research branches are operative, the level of IPR protection plays a limited role in defining the intensive margin of innovation activity.

In column 3 we add education variables to the previous specification. As in the OLS case, tertiary education in origin country is positive and significant and now also education in the destination country has a positive effect, even if ten times lower than the effect in the country of origin. In column 3 we replicate specification reported in column 4 of Table 4. There is little change with respect to the results in column 1 and the interaction term, as for the OLS case, is positive and strongly significant. In column 4 we substitute the two distinct measures of IPR protection (in NICs and OECD countries) with the distance between IPR indices within country pairs, as done in column 6 of Table 4. The coefficient is again negative but it is now strongly significant, suggesting the extensive margin of patent production to also be at play when the convergence of IPR regimes promotes outward innovation from the South. Finally, in column 5 we estimate the previous specification by means of the negative binomial method, that should improve estimates when the dependent variable is over-dispersed (Hausman et al., 1984), i.e. the variance to mean ratio is greater than one, as it is in our case. Results are broadly confirmed, together with the gain in significance of the positive effect of population in OECD countries.

5. Conclusions

This investigation can be viewed as an initial attempt to explore the different roles IPRs can play for the globalization of Southern innovation with respect to the location of enforcement. While the debate on the protection of IPRs has often been placed in a 'North-South' perspective, this paper addresses innovation that originates in the South. The investigation attempts to answer the question whether stronger IPR protection at home and away or its cross-borders harmonization could stimulate the internationalization of R&D from the South.

Using both survey-based data on Chinese and Indian firms in the ICT sector and country-level data on the foreign patenting activities of NICs in OECD countries, our analysis confirms IPRs to play varying roles in the formation of global innovation linkages. While the survey data stresses the importance of IPRs, our country level analysis reveals that they could indeed have a negative impact in foreign patenting by NICs. The firm-level tests pointed out the relatively higher importance of IPRs for domestic firms to engage in global innovation networks, whereas the macro-study showed the necessity of a strong IPR regime at home for MNE research branches to be operative there in the first place. Our evidence confirms the reliance of the ICT industry, particularly the hardware segment, on IPRs when engaging in the international outsourcing and offshoring of innovation or in patenting activities abroad. In contrast, strong IPRs in the North deter R&D activities originating from the South by *blocking* patents. South-North R&D linkages should hence be at their peak if we observe a convergence of protection levels in the two regions. By convergence of IPR protection levels we do not necessarily mean the need for relaxing IPRs in the North and upgrading them in the South, but a convergence of IPR systems. That is, reaching a rallying point in the implementation of an effective IP policy to encourage the participation of each country in *international* innovation activities and the diffusion and use of new technology *across* countries. A starting point could be cooperating for the development of reciprocal legal and technical tools aimed at lowering barriers to foreign-patenting activities and improving the quality and transparency of the global patent system in general.

APPENDIX 1 - Survey Design and Implementation

The survey was administered online from November 2009 to June 2010 by the INGINEUS project, [35] after significant work in designing and pre-testing the questions. The overarching goal of the survey was to establish the presence of global innovation networks: how global, how innovative and how networked the sample was. Each institute chose the survey delivering method according to past experiences and knowledge of the best methods utilised in the country for high response rates.[36] Indeed, it was delivered electronically by mail or link, by face-to-face interviews, through telephonic interviews or by written mail.

[35] INGINEUS is an international research project funded by the European Commission that studies global innovation networks. It involves 14 research institutes and universities in seven European countries plus Brazil, China, India and South Africa. For further information on INGINEUS project please see www.ingineus.eu.

[36] For instance, in both China and India, the survey was run mostly through face-to-face interviews or telephone interviews give the low electronic response rate experienced.

Furthermore, while in European countries and South Africa the survey was managed at national level, in Brazil, China and India, it was conducted at regional level.

The survey included a number of questions relating to the respondents' background, such as main product (goods or services), firm size, percentage of sales activity abroad and R&D activity. In addition, to extract information on firm behaviour, questions on (i) source of technology, (ii) geographic networks and collaborations established, (iii) factors determining offshoring activities and (iv) policy-factors for the internationalization of innovative activities were designed.

In Table A1 we report the distribution of the sample across sectors, countries and firm size[37], as well as the response rate registered and the representativeness of each national sample within each sector group. The survey design let each partner-country select one sector of particular economic relevance amongst ICT, automotive and agro-processing, it received 1214 responses from the 14620 companies contacted, which is a response rate of approximately 8.3% (Table A1). China and Germany registered the lowest response rates of respectively 2.7% and 5.5%.[38] The combined INGINEUS sample results dominated by the ICT sector (77%). This is due to the size of the Indian and Chinese markets, which represent respectively 26.7% and 20% of the entire sample (and 34.7% and 26% of the sample ICT firms), but it could be also attributed to the nature of the agro processing and automotive industries which tend to be more concentrated.

Observing the number of R&D active firms over total national sample, there is concern with regard to the presence of a response bias in favour of firms that perform R&D, mostly within the group of Indian and Chinese ICT firms.[39] Nonetheless, as we are interested in looking at the determinants that make an innovative firm go global, such response bias should not affect our analysis.

Establishment of ICT sample in China and India

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[37] Given the large number of small firms in the Swedish and Norwegian ICT databases, it was agreed that the minimum size of a firm for the survey would have been five employees, while no upper ceiling was defined.

[38] Low response rate in surveys conducted to assess international innovation by Chinese companies has been detected also in other studies. See: Chen J (2003), *Global Innovation,* Beijing: Economic Science Press.

[39] This could lead to affirm that the ICT sector in emerging economies is more R&D active than in Europe.

The Chinese ICT sample has been established by the Graduate University of Chinese Academy of Sciences (GUCAS), research partner of INGINEUS project. They used two regional databases: one focused in the region of Beijing and the other focused on Shenzhen (Guangdong province). The first database ("Beijing database") is owned by Sinotrust, a market research company located in Beijing, and renewed every three months. It consists mainly of firms published by the Beijing Administration for Industry and Commerce, as well as the Beijing Taxation Bureau. The second database ("Shenzhen database") is owned by CVISC, a similar research company located in Shenzhen, and consisting of firms mainly from several science and technology entrepreneurship service centres in Shenzhen, as well as Shenzhen small and medium enterprises service centre.

Since survey responses came from two databases, GUCAS conducted T-test in selected variables for the responses from the "Beijing database" and "Shenzhen database". There was no significant difference in the tested variables (including company size and the nature of the company) between the mean of the "Beijing database" and the "Shenzhen database". It was noted that companies from the "Shenzhen database" have more significant R&D compared with the "Beijing database". Finally, the questionnaire was distributed in the five most developed provinces in China: 146 questionnaires came from Beijing, which account for 60% of the total questionnaires; 51 came from Guangdong province, which account for 21%; 35 from Shanghai, 14%, 10 from the Zhejiang province, representing the 4%, and only 1 from Shandong province.

As with the Chinese sample, Indian firms database was established by one of the Indian research partner in INGINEUS project. The Centre for Development Studies (CDS) extracted the sample from the NASSCOM Directory of IT firms 2009-2010, which is released every year and covers all areas of software production and related industries such as IT Enabled Services. The 2009-10 Directory provided the information on 1380 firms. The questionnaire was distributed across the main cities and regions as it follows: 281 in Bangalore, which account for 21,8% of NASSCOM Directory; 256 in Delhi/Noida/Gurgaon representing the 19,9%; 185 in Mumbai, 14,4%; 72 in Pune, 5,6%; 147 in Chennai, 11,4%; 184 in Trivandrum, 14,3%; 107 in Hyderabad, 8,3% and 55 in Kochi, 4,3%.

APPENDIX 2 – South-North Foreign Patenting

We consider all (and only) foreign-oriented patent families of NICs looking specifically at the destination of their foreign applications, restricting such observations to OECD patent offices. As well-known, under the PCT, patent applicants may submit applications in multiple jurisdictions. This implies that a single application can, in theory, potentially lead to patent grants in 144 member states. For the purposes of the analysis of indicators of global patent activity by country of origin PCT applications may not be appropriate as they present duplicates.[40] However, this is not our objective. Our objective is to look at the determinants of demand for protection of emerging economies in high-income markets. The same is applicable to the case of NIC's residents that apply directly, through the Paris Route, at one or more OECD Patent Offices. This can occur for several reasons: the applicant may seek protection in only one OECD country or, more likely, the NICs is/was not yet part of Patent Cooperation Treaty. Argentina, for instance is not part yet of the PCT.[41]

Patent activity of NIC in multiple OECD jurisdictions can provide a proxy indicator for technological transfer and may let us advance considerations concerning its impacts on competition (i.e. exports) and other economic effects, such as rent transfers to the jurisdictions of patent holders. However, considering only the first applicant's country of origin in patent applications has some limits: our measure does not catch the participation of foreign inventors in the research process of a firm, that is, a German or Chinese engineering's contribution to an invention owned by an Indian firm is not taken into account. Our dependent variable *PAT* considers: (i) domestic firms set in NIC who seek protection in a foreign high-income market and (ii) foreign subsidiaries of an MNC set in NIC who seek protection in a market different from the one where they operate. Such foreign market could be the country where the HQ of the MNC is

[40] Over the years, the percentage of patent families covering at least two patent offices has increased considerably. Among the top countries, there is considerable variation in this share. For example, fewer than 7% of patent families created by residents of the Russian Federation (1.5%), China (3.4%) and Brazil (6.6%) contained at least two patent offices between 2003 and 2007. In contrast, more than half of all patent families created by residents of France (51.5%), Sweden (54.3%) and Switzerland (60.5%) include at least two offices (WIPO, 2010).

[41] Amongst the other NICs, Turkey, Indonesia, India and South Africa signed the PCT in 1996, 1997, 1998 and 1999 respectively, the Philippines in 2001, Egypt in 2003, Malaysia in 2006, Chile and Thailand in 2009.

set as well as other third markets. For instance, if one of the TATA steel production plants in UK or Netherlands apply for patent protection on a new rail steel in any European country or in India, such patent applications are excluded from our observations. While, if the new TATA steel production plant set in South Africa would apply for patent protection in UK (as priority or subsequent filing), this would be included in our observations as South African invention seeking protection in UK. Differently, if TATA consultancy services Ltd, set in Mumbai, applies for patent protection, for instance, on a new system for vehicle security able to monitor the cardiac activity of a driver,[42] and it applies first for patent protection in India, as it is generally done to save the priority date, and then through PCT procedure in UK, Germany, US, Japan and Korea, this application is considered as 'foreign-owned', namely Indian-owned, in each designated destination market, but not in the Indian market. Therefore, we focus on innovations (or potential innovations) developed in Southern countries that can meet the supply of Northern markets, including also innovations that both Northern and Southern MNC subsidiaries set in NICs develop not simply to adapt their products to the local markets, but that aim to meet the global demand of technology.

Another limit of our dependent variable *PAT* is set in the possible presence of more than one applicant in a patent application that differ in terms of country of origin. That is, joint ownerships of patents between a firm set in an OECD country and a firm set in an NIC is not grasped. This may lead to an underestimation of international collaborations in science and technology as well as an underestimation of NIC contribution to the global market of technology if they are listed as second applicant.

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Table 1: Distribution across national samples of GIN and OUT. Source: Authors' calculation based on INGINEUS survey.

	China	**India**	**Brazil**	**Denmark**	**Estonia**	**Germany**	**Norway**	**South Africa**	**Sweden**	**TOTAL**
GIN=1	35,80%	56,17%	21,74%	34,69%	52,94%	41,51%	29,83%	45,24%	47,69%	42,55%
OUT=1	11,11%	43,21%	23,19%	20,41%	17,65%	45,28%	13,26%	25%	25,64%	25,93%

Table 2: IPRs as determinants of global R&D linkages for Chinese and Indian ICT sector. OLS estimations. In columns 2 and 4 dummies for the region of origin of firms' innovation partners are added. Robust standard errors in parentheses. (***) p-value < 0.01, (**) p-value <0.05, (*) p-value <0.1

	(1)	*(2)*	*(3)*	*(4)*
Dep. Variable	*GIN*	*OUT*	*GIN*	*OUT*
IPR	0.177 (0.042)***	0.080 (0.036)**	0.169 (0.058) ***	0.050 (0.048)
China	-0.186 (0.041)**	-0.309 (0.034)***	-0.155 (0.043)***	-0.280 (0.036)***
HR			0.089 (0.051)*	0.190 (0.042)**
foreign			0.320 (0.075)***	0.160 (0.070)**
*IPR*foreign*			-0.176 (0.094)*	-0.079 (0.088)
hardware	0.002 (0.041)	0.108 (0.036)***	-0.022 (0.041)	0.105 (0.037)***
constant	0.443 (0.045)***	0.321 (0.041)***	0.337 (0.045)***	0.248 (0.048)***
Obs	567	567	544	544
R-sq.	0.0698	0.1425	0.1154	0.1542

Table 3: IPRs as determinants of global R&D linkages for ICT sub-sectors. OLS estimations. In columns 2 and 4 dummies for the region of origin of firms' innovation partners are added. Robust standard errors in parentheses. (***) p-value < 0.01, (**) p-value <0.05, (*) p-value <0.1

	(1)	*(2)*	*(3)*	*(4)*
Dep. variable	*GIN*	*OUT*	*GIN*	*OUT*
IPR	0.171 (0.060)***	-0.008 (0.043)		
fIPR			0.198 (0.060)***	-0.065 (0.053)
*IPR*hardware*	-0.015 (0.083)	0.157 (0.074)**		
*fIPR*hardware*			-0.070 (0.083)	0.153 (0.049)**
hardware	-0.020 (0.064)	0.003 (0.057)	0.010 (0.059)	0.017 (0.057)
China	-0.172 (0.042)***	-0.293 (0.035)***	-0.225 (0.042)***	-0.297 (0.036)***
foreign	0.205 (0.045)***	0.102 (0.042)**	0.217 (0.045)***	0.108 (0.042)***
constant	0.398 (0.053) ***	0.347 (0.049)***	0.415 (0.048)***	0.388 (0.035) ***
Obs	544	544	544	544
R-sq.	0.1031	0.1525	0.1043	0.1471

Table 4: Determinants of strengthening South-North formation of GINs. OLS estimations. All specifications include monadic country dummies and time dummies. Standard errors in parentheses. (***) p-value < 0.01, (**) p-value <0.05, (*) p-value <0.1.

	(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*
Dep. Variable	*Log(PAT)*	*Log(PAT)*	*Log(PAT)*	*Log(PAT)*	*Log(PAT)*	*Log(PAT)*
DIST_ij	-0.59	-0.59	-0.58	-0.49	-0.59	-0.59
	(0.08)***	(0.08)***	(0.08)***	(0.09)***	(0.08)***	(0.08)***
COM_LAN_ij	1.11	1.12	1.13	1.25	1.13	1.12
	(0.15)***	(0.15)***	(0.15)***	(0.17)***	(0.15)***	(0.15)***
COM_BOR_ij	0.00	0.01	0.03	0.19	0.03	-0.00
	(0.31)	(0.31)	(0.31)	(0.32)	(0.31)	(0.31)
POP_it	6.99	6.44	5.14	4.88	5.14	6.37
	(1.73)***	(1.84)***	(1.85)***	(2.06)**	(1.93)***	(1.79)***
POP_jt	8.49	7.74	6.69	5.09	7.47	8.59
	(2.25)***	(2.25)***	(2.25)***	(2.64)*	(2.25)***	(2.25)***
GDP_pc_it	1.04	1.07	1.02	0.74	0.90	1.05
	(0.23)***	(0.22)***	(0.23)***	(0.29)**	(0.24)***	(0.22)***
GDP_pc_jt	-1.08	-0.49	-0.49	-0.69	-0.47	-1.00
	(0.40)***	(0.43)	(0.43)	(0.50)	(0.43)	(0.41)**
IPR_it		0.05	-0.01	-0.23	0.05	
		(0.11)	(0.11)	(0.18)	(0.11)	
IPR_jt		-0.77	-0.72	-0.65	-0.78	
		(0.21)***	(0.21)***	(0.25)***	(0.21)***	
ICT_IPR_it			1.54	1.83		
			(0.49)***	(0.59)***		
EDU_it					0.12	
					(0.06)**	
EDU_jt					-0.02	
					(0.02)	
dist_IPR_ijt						-0.04
						(0.03)
Obs.	649	649	632	476	649	649
R^2	0.79	0.80	0.81	0.78	0.82	0.80

Table 5: Determinants of South-North formation of GINs. Poisson (1-4) and Negative Binomial (5) estimations. All specifications include monadic country dummies and time dummies. Standard errors in parentheses. (***) p-value < 0.01, (**) p-value <0.05, (*) p-value <0.1.

Dep. Variable	*(1)* *PAT*	*(2)* *PAT*	*(3)* *PAT*	*(4)* *PAT*	*(5)* *PAT*
DIST_ij	-0.27	-0.27	-0.28	-0.27	-0.63
	(0.02)***	(0.02)***	(0.02)***	(0.02)***	(0.07)***
COM_LAN_ij	0.53	0.53	0.54	0.55	1.06
	(0.04)***	(0.04)***	(0.04)***	(0.04)***	(0.13)***
COM_BOR_ij	0.19	0.16	0.17	0.17	-0.05
	(0.10)*	(0.10)	(0.10)*	(0.10)*	(0.28)
POP_it	2.98	1.29	3.52	3.50	7.41
	(0.56)***	(0.58)**	(0.56)***	(0.57)***	(1.74)***
POP_jt	1.86	6.18	2.92	-0.02	5.65**
	(1.07)*	(1.33)***	(1.07)***	(0.98)	(2.30)
GDP_pc_it	1.33	1.10	1.08	1.30	1.27
	(0.08)***	(0.08)***	(0.08)***	(0.08)***	(0.22)***
GDP_pc_jt	-0.99	-1.56	-0.97	-0.65	-1.08
	(0.16)***	(0.20)***	(0.16)***	(0.15)***	(0.39)***
IPR_it	0.61	0.59	0.43		
	(0.02)***	(0.03)***	(0.03)***		
IPR_jt	-0.41	-0.37	-0.49		
	(0.13)***	(0.13)***	(0.13)***		
EDU_it		0.20			
		(0.02)***			
EDU_jt		0.02			
		(0.00)***			
ICT_IPR_it			3.29		
			(0.15)***		
dist_IPR_ijt				-0.12	-0.07
				(0.01)***	(0.03)***
Obs.	1293	1293	1293	1293	1293
Pseudo-R^2	0.95	0.95	0.95	0.95	0.43

Table A1: Response rates and total sample distribution by sector, country and R&D activity.

Sector/country	dataset	responses	response rate (%)	% over total sector obs.	R&D active firms	% of R&D active firms over national sample
China	9119	243	2.7	26	181	74.5
Estonia	121	17	14	1.8	2	11.8
Norway	519	179	34.5	19.1	53	29.6
India	1287	324	25.2	34.7	195	60.2
Sweden	1662	171	10.3	18.3	76	44.4
Total EU	2302	367	15.9	39.3	131	35.7
Total emerging economies	10407	567	5.4	60.7	376	66.3
Total ICT	12709	935	7.3	100	507	54.2
Denmark	210	49	23.3	37.1	5	10.2
Norway	2	2	/	1.5	0	/
South Africa	325	81	24.9	61.4	27	33.3
Total EU	212	51	24	38.6	5	9.8
Total emerging economies	325	81	24.9	61.4	27	33.3
Total Agro-processing	535	132	19.6	100	32	24.2
Brazil[43]	241	69	28.6	46.6	17	24.6
Germany	963	53	5.5	35.8	31	58.5
South Africa	2	2	/	1.4	0	/
Sweden	168	24	14.3	16.2	13	54.2
Total EU	1131	77	6.8	52	44	57.1
Total emerging economies	243	71	29.2	48	17	23.9
Total Automotive	1374	148	10.8	100	61	41.2
TOTAL EU	3645	495	13.6	-	180	36.4
TOTAL emerging economies	10975	719	6.6	-	420	58.4
TOTAL	14620	1214	8.3	-	600	

[43] The Brazilian sample was extracted from the *Annual Registry of Social Information (RAIS),* a registry of social and balance sheet information collected by the Brazilian Labour and Employment Ministry. The total number of firms classified in the automotive sector in Brazil is 2,625. Out of these, 233 companies are located in the state of Minas Gerais and, of these, 107 (46%) have employed in 2008 30 workers or more. From the dataset all automotive firms from the state of Minas Gerais were selected, provided the firm declared over 30 employees.

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