Intellectual Property Rights and South-North R&D Linkages[†]

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A B S T R A C T

This paper explores the role of intellectual property rights (IPR) protection in the globalization of innovation and the formation of R&D linkages from emerging economies (South). Using both survey-based data on Chinese and Indian firms in the ICT sector and global bilateral patent data, we find the impact of IPRs to vary depending on the type of R&D linkages, the location of enforcement, the national identity of firms/researchers and the sector/sub-sector under study. Stringent IPR regimes abroad tend to discourage the formation of global R&D value chains and foreign patenting by firms in the South. On the other hand, IPR protection in the home country tends to play a crucial role for the engagement of domestic Southern firms in global innovation linkages. The results also emphasize how sector-specific characteristics determine the correlation between IPR protection and the internationalization of R&D. The ICT industry, particularly the hardware segment, relies on the IPR regime when engaging in the international outsourcing and offshoring of innovation or in patenting activities abroad. Finally, the harmonization of IPR protection across country pairs tend to foster South-North R&D linkages.

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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 knowledge generated at home 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.

As knowledge starts to flow more freely across the globe, Intellectual Property theft remains the most important risk for global innovation networks (OECD, 2008b). 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. With Newly Industrialized Countries (NICs, also referred to as South) taking a lead in developing technologies of global standards, the view of high-technology companies with headquarters in the South towards intellectual property rights (IPRs) takes a new meaning. Previous literature on the catching-up process of the South has mainly emphasized on North-South technology transfer highlighting the trickle-down effect from technological frontier (Acemoglu, Aghion and Zilibotti, 2006) or globalization arguments, such as decreasing transportation and migration costs, coupled with the non-rival nature of technology.

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

To address the issue we rely on a firm-level 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 experiences with regulation, practices and jurisprudence around IPRs faced in the internationalization of their innovation activities. We focus on Chinese and Indian firms active in the ICT sector in which the use and development of new technologies through innovation is more pervasive and sector specific.[2] Our empirical findings based on survey data suggest that depending on the definition of R&D linkages and the sub-sector under study, a credible IPR regime can influence Southern firms' engagement in internationalization of R&D. More specifically, IPRs tend to matter more for the participation of domestic Southern firms in global innovation networks. However, it proves more relevant for the offshoring or outsourcing of innovation in the hardware segment of the ICT sector.

To validate our findings on a global scale, We use an empirical gravity model designed to capture the extent of NICs involvement in the internationalization of innovation activity, in particular in OECD countries. To do so, we first define an appropriate variable to measure the phenomenon, related to the number of patents that NICs nationals file in OECD patent offices. We then regress this variable on country and country-pair specific variables such as IPR protection in both countries, degree of ICT-specificity of exports, together with 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 in a gravity framework, we show that the location of IPR enforcement also matters for South-North innovative activities. In particular, South-North foreign patenting is positively related to domestic IPR enforcement,

[2] This is partly driven by the survey design, which lets each partner-country select one sector of particular economic relevance. The ICT sector has been selected by both Indian and Chinese survey partners, letting us obtain indications for emerging economy-, country- and industry-specific policies. A description of the firm-level survey design and implementation is provided in Appendix 1.

whereas enforcement in the receiving country *discourages* patent applications from NICs. We relate this latter result to defensive patenting or a market power effect that obstruct entry by new firms, or the difficulty faced by NICs with less advance technologies to obtain patents in countries with a tougher IPR regime. Finally, the analysis confirms the crucial importance of IPR protection for international innovation activities in the ICT sector, primarily for the hardware segment.

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

2. IPRs and Innovative Activities: Recent Trends in China and India

The increase in the 'propensity to patent'[3] 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 was only 138. This number increased to 100,156 in 1999 (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. In some new technical areas, such as digital communication, telecommunication and high-speed trains, 20% of the total of PCT applications in the field of digital communications 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

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

came into force in China in 1985 and the two major rounds of modifications occurred in 1992 and 2000.

In India, the Patents Act, 1970 was amended in 1999, 2002 and 2005. Since the country became signatory to the PCT in 1998, patent filings in India have registered a sustained growth up to 43%.[4] 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 36,812 applications in 2008 (WIPO, 2010). If we look at the contribution of local inventors to foreign-owned patent applications, 65% of Indian inventors and 43.9% of Chinese inventors are associated with foreign PCT applications, ranking respectively 1st and 5th in the world.

Indian IT sector is estimated to aggregate revenues of 88.1 USD in 2011, with the software and service sector, excluding hardware, accounting for 86.4%.[5] 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).

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.[6] The sectors targeted were ICT (in China, India, Sweden, Norway and

[4] WIPO Magazine 10, 2002.

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

[6] 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.

Estonia), agro-processing (in South Africa and Denmark), and automotive (in Brazil and Germany), selected to represent a range from 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 that 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 or outsourcing abroad. These activities include product and process development, operations, procurement, logistics and distribution, building and maintenance of IT systems.[7]

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.[8] Looking at the correlation coefficients across sectors of the dependent variables, they all result particularly low, from 0.29 for ICT firms to 0.47 for agro-processing firms. This highlights that two variables capture different activities firms may perform in the internationalization of their innovative activities.

[Table 1 about here]

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[7] 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.

[8] 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.

The presence of R&D linkages prevails in the ICT sector if we look at *GIN*, but not in the case of *OUT*. Moreover, *GIN* is more widespread in the Indian ICT sector and in the German automotive only. It's worth noticing that having significant R&D activity does not necessarily mean a greater involvement in global innovation networks. The correlation coefficient between having significant R&D activity and the variables *GIN* and *OUT* resulted 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.

After having highlighted results for all countries and across all sectors represented in the survey, we focus now 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 part of an international R&D linkage while China in all cases results amongst the least involved. In our sample, Chinese ICT firms are amongst the most unsatisfied with regard to relevant labour force skills (68.3%). On the IPRs side, the Chinese sample presents the greatest percentage of firms requiring more stringent IPR regulations to consider future innovation activities (64.2%).[9] Alternatively, India results more open in conducting research activities with foreign partners even if it presents a lower R&D intensity compared to China.[10] These observations call for a more in-depth analysis of the Chinese and Indian ICT firms.

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[9] The relative value increases if we look specifically at those firms that make part of a global innovation network.

[10] Looking at the size of the R&D units (measured as number of full time R&D employees by firm size) 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. Chinese firms result more R&D intensive, employing a greater number of individual in R&D than Indian firms do. This may confirm recent studies on the Indian ICT sector that, despite public

3.2. Empirical analysis

Given the *open* nature of technology attainment, in what follows we concentrate on factors relevant for the internationalization of firms' innovative activities. These are (i) human resource development, the key area in supplying quality skilled workers for global and local markets, and (ii) the legal environment for IPR protection.

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

$$LINK_i = \beta_0 + \beta_1 HR_i + \beta_2 IPR_i + \boldsymbol{\beta_3 X_i} + \delta_c + \delta_s + \upsilon_i, \quad (1)$$

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' experience with regard to (i) HR: relevant labour force training and skills, (ii) IPR: regulation, practice and jurisprudence around IPRs. These are treated as dummy variables taking value one if the firm indicates a positive experience with above factors. $\mathbf{X}_i$ is a vector of further controls, such as type of ownership of the firm (domestic or foreign) and sub-sector (hardware or software). When the regression equation is performed with *OUT* we further control for the region of origin of its innovations partners. Finally, to control for unobserved heterogeneity, we include dummies at the country and sector levels, δ_c and δ_s, respectively.

After defining the main dependent and independent variables, we perform OLS estimates of Equation (1) for each definition of R&D linkages. We estimate our linear probability model for the Indian and Chinese sample, and control for country fixed effect in all estimations. 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

efforts, investments in R&D by the private sector is still relatively low and largely based on the outsourcing market (Bhattacharya and Vickery, 2010).

sector may rely differently on patents in the hardware segment compared to software programming, data processing and systems design.[11]

Table 2 reports the results of the OLS regressions to shed light on whether having had a positive experience with the analyzed factors 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. Chinese (Indian) firms are less (more) likely to be involved in a global innovation network, but there is not a differential effect of IPRs on GIN involvement among firms from a particular country. The control variable *hardware* resulted positive and statistically significant only when we looked 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 column [3] and [4] we control whether human resource availability can be another explanation for the involvement of Chinese and Indian firms in global R&D linkages and find IPRs to play a more important role for the *GIN* variable. We then investigate the extent to which the relevance of IPRs as a determinant of R&D linkages may vary according to the type of ownership. The control variable *foreign* indicates that being a subsidiary of an MNC increases significantly the probability of being part of international innovation linkages. The impact is greater when MNCs seek to establish innovative collaborations abroad than when they outsource and/or offshore innovation. 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

[11] 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.

a more essential factor for the participation of *domestic* firms in global innovation networks (*GIN*). It is important to notice that the same argument does not hold for international R&D value chains (*OUT*). Moreover, including the new arguments results in IPR losing its significance for the *OUT* variable.

[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 experience with the intellectual property framework (IPR) and to their need for more stringent IPRs 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 no 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, 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, even if foreign firms are in general more involved in R&D linkages. 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 while securing intellectual assets is a determinant of international R&D collaborations for the ICT industry, it proves more relevant for the hardware segment when engaging in international R&D linkages through outsourcing and offshoring activities

Even if the survey data allows us to differentiate between the type of global R&D linkages under study, it does not let us allow for considerations with regard to the location of IPR enforcement. 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 countries or sectors may confirm that stronger IPRs must be embedded in a broader set of complementary initiatives, such as human capital development, to be effective. Furthermore, they may indicate that there are emerging trends or new factors affecting innovation and decisions regarding the internationalization of R&D activities. Several issues that emerge from the above firm-level analysis could only be verified when accompanied by a more general analysis that applies global data. We undertake this task in the following section.

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

4.1. Data and Methodology

In this section we extend the analysis to a cross country level. Specifically, we try to generalize the firm-level findings in the previous section to the country level, while concentrating on the impact of IPRs on *South-North* R&D linkages. To this end, we look at the filing of patents in OECD countries' patent offices by researchers resident in NICs. We believe the foreign patenting activities of the South could at least partially capture the idea of internationalization of innovation activity in the spirit we have highlighted earlier: theoretically, 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. [12]

Given the nature of our analysis, i.e. looking at the determinants of NICs' R&D linkages with the OECD countries, we make use of an *oriented* empirical gravity model. Rather than considering bilateral flows, the 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).[13] 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.[14] Note the different pools from which i and j are taken and that, in general, $PAT_{ij} \neq PAT_{ji}$. The variable *PAT* has been constructed using data from the World Intellectual Property

[12] 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). See Appendix 2 for more details on our dependent variable.

[13] 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 (EPO, 2010).

[14] 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.

Organization (WIPO), that 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.[15] 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. We take averages for two reasons related to the IPR protection index. First, data 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 movement. Our framework partially draws from Yang and Kuo (2008), that use the same dependent variable. However, their analysis is limited to the 4 contiguous years of 1995-1998 and do not study South-North relations, but study bilateral relation between 30 chosen 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. The empirical model we estimate, written in general terms, is the following:

$$PAT_{ijt}=G_t+ D_i+ D_j+\boldsymbol{X}_{it}+\boldsymbol{Y}_{jt}+\boldsymbol{D}_{ij}+\boldsymbol{D}_{ijt}+u_{ijt} \quad (2)$$

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. The monadic terms $\boldsymbol{X}_{it}$ and $\boldsymbol{Y}_{jt}$ include variables common to both origin and destination countries, as well as variables only specific to either one or the other set of countries. [16] Among the monadic variables there are (logs of) GDP per capita and population: instead of having only GDP as mass variable, we separate size

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[15] 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.

[16] 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.

(population) and development (GDP per capita) effects as in 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 have a measure of IPR protection from Park (2008) for both the origin and the destination country.[17] 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. 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. We also have the counterpart of the firm-level analysis' variable human resources, 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.

$\boldsymbol{D}_{ij}$ includes all the time-invariant dyadic variables, collected by CEPII. 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 internationalization of innovation activity. The term $\boldsymbol{D}_{ijt}$ collects dyadic time-variant variables, that in some specifications will be the distance between IPR protection between country *i* and country *j*, or the impact of harmonization of the IPR regime between each country pair.

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

The theoretical number of observations should be $I*J*T$=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 patents filed in country *j* by an applicant residing in country *i* 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.[18] 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 represents country pairs that are not collaborating: they are 87, 68 and 57 in the 1995, 2000 and 2005 periods, respectively.

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 where 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.[19] 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 degree with which NICs should

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

[19] Data on the share of exports in the ICT sector (that exclude software) comes from World Bank's World Development Indicators Database. They are relative to year 2000.

care about IPR protection.[20] 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 ranks fourth in 13 with 1.4% while China ranks ninth with 18.9%.[21]

4.2. Empirical Results

We start estimating the parameters of Equation (2) in a parsimonious specification. First, we want to 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 is 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.[22] 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

[20] 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."

[21] The rank is over 13 instead of 14 NICs because no figures are available for Egypt.

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

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 level of development.[23]

[Table 4 about here]

In column 2 we introduce the IPR protection indices for both origin and destination country. The IPR protection index for the former country is positive but not significant, while the latter is negative and strongly significant. These results 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 defensive strategies by Northern firms that block access to important technologies needed by Southern firms to realize their own innovations. These could include the market power effect (a more concentrated market impeding entry by new firms) or increased incentives by firms in the North to engage in defensive patenting (Hall and Ziedonis, 2001), most common in the hardware and software industries. The strategy of defensive patenting, also referred to as 'patent blocking', aims at preventing rivals from applying for the same or similar coverage.[24] As suggested by Allred and Park (2007), while the market power effect may negatively impact both developed and

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[23] 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.

[24] An example of defensive patenting is the 17,000 patent portfolio held by Motorola Mobility Holdings Inc. and bought in August 2011 by Google to protect HTC Corp. and Samsung Electronics Co. who produce phones based on Google's Android software. Indeed, in April 2011, Apple sued Samsung in the US and subsequently claimed against it to prevent the imports of Galaxy Tab 10.1 and Galaxy Smartphones in Germany, Ireland, Netherland, Sweden and UK. (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)

developing countries' markets, defensive patenting is mostly associated with Northern countries. 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. 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).

Column 3 reports a specification in which we add to column 2 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.[25] 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 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 even if less significant in some cases, possibly due to the smaller sample. Specification in Column 5 add tertiary education measures for both origin and destination country to that in Column 2. Only education in the origin country turns out to be positive and significant. We tried to add the interaction term of tertiary education and ICT, paralleling the regression in Column 3, but nothing changes. In column 6 we replicate specification 1 while using the squared distance between IPR protection indices within

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

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 collects results using different specifications and different estimation techniques, that we perform in order to check for the robustness of our findings. Our main concern with the results obtained is that half of the observations are not used because PAT takes a value equal to zero, causing a missing value for its logarithm. Also, differently 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 turns out to be 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 large 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 origin country. 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 we did 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 similarity between IPR regimes are concerned. 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, the identity of firms/researchers and the (sub-)sector under study.

While the debate on the protection of IPRs has often been placed in a 'North-toward-South' perspective, this paper addresses innovation that originates in the South. The investigation attempts to answer the question whether stronger IPR protection home and away or its harmonization to global levels foster 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 revealed that IPRs do not necessarily foster innovation outsourcing and offshoring activities of Southern firms, our country level analysis showed 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. Finally, both levels of study also suggest the importance of sectors and subsectors in the role of IPRs in global R&D linkages. We found the ICT industry, particularly the hardware segment, to rely on IPRs when engaging in the international outsourcing and offshoring of innovation or in patenting activities abroad.

APPENDIX 1 - Survey Design and Implementation

The survey was administered online from November 2009 to June 2010 by the INGINEUS project,[26] 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.[27] Indeed, it was delivered electronically by mail or link, by face-to-face interviews, through telephonic interviews or by written mail. 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 behavior, 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.

[26] 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.

[27] 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.

In Table 1 we report the distribution of the sample across sectors, countries and firm size[28], as well as the response rate registered and the representativeness of each national sample within each sector group. The survey received 1214 responses from the 14620 companies contacted, which is a response rate of approximately 8.3%. China and Germany registered the lowest response rates of respectively 2.7% and 5.5%.[29] 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.[30] 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.

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

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[28] 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.

[29] 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.

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

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.[31] 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.

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 doesn't 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 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, this would be included in our observations as South African invention seeking protection in UK. Differently, if TATA consultancy services Ltd, set in

[31] 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).

Mumbai, applies for patent protection, for instance, on a new system for vehicle security able to monitor the cardiac activity of a driver,[32] 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 the Indian one. 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.

[32] International application number WO2111111056, date of publication 15-09-2011, priority date 12-03-2010.

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Table 1

Distribution across national samples of GIN and OUT.

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

Source: Authors' calculation based on INGINEUS survey.

Table 2: IPRs as determinants of global R&D linkages for Chinese and Indian ICT sector

Dep. Variable	*GIN*	*OUT*	*GIN*	*OUT*
	[1]	*[2]*	*[3]*	*[4]*
IPR	0.204	0.131	0.197***	0.105
	(0.058)***	(0.057)**	(0.070)	(0.067)
IPR_China	-0.059	-0.113	-0.062	-0.130
	(0.084)	(0.070)	(0.084)	(0.071)*
China	-0.150	-0.240	-0.087	-0.211
	(0.065)**	(0.055)***	(0.068)	(0.059)***
HR			0.092	0.146
			(0.051)*	(0.067)*
Foreign			0.327	0.170
			(0.076)***	(0.072)**
IPR_foreign			-0.183	-0.075
			(0.095)*	(0.091)
Hardware	0.001	0.106	-0.093	0.014
	(0.041)	(0.036)***	(0.061)	(0.047)
Constant	0.425	0.289	0.306	0.267
	(0.052)	(0.050)	(0.051)	(0.049)
Obs	567	567	544	544
R-sq.	0.0706	0.1460	0.1193	0.1460

Robust standard errors in parenthesis; (*) p-value<0.1; (**)p-value<0.05; (***)p-value<0.01

Table 3: IPRs as determinants of global R&D linkages for ICT sub-sectors

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

Robust standard errors in parenthesis; (*) p-value<0.1; (**)p-value<0.05; (***)p-value<0.01

Table 4: Determinants of strengthening South-North formation of GINs.

Dependent variable: log of number of patents filed in country j by residents in country i (all specifications include monadic country dummies and time dummies).

	(1)	(2)	(3)	(4)	(5)	(6)
DIST_ij	-0.59 (0.08)***	-0.59 (0.08)***	-0.58 (0.08)***	-0.49 (0.09)***	-0.59 (0.08)***	-0.59 (0.08)***
COM_LAN_ij	1.11 (0.15)***	1.12 (0.15)***	1.13 (0.15)***	1.25 (0.17)***	1.13 (0.15)***	1.12 (0.15)***
COM_BOR_ij	0.00 (0.31)	0.01 (0.31)	0.03 (0.31)	0.19 (0.32)	0.03 (0.31)	-0.00 (0.31)
POP_it	6.99 (1.73)***	6.44 (1.84)***	5.14 (1.85)***	4.88 (2.06)**	5.14 (1.93)***	6.37 (1.79)***
POP_jt	8.49 (2.25)***	7.74 (2.25)***	6.69 (2.25)***	5.09 (2.64)*	7.47 (2.25)***	8.59 (2.25)***
GDP_pc_it	1.04 (0.23)***	1.07 (0.22)***	1.02 (0.23)***	0.74 (0.29)**	0.90 (0.24)***	1.05 (0.22)***
GDP_pc_jt	-1.08 (0.40)***	-0.49 (0.43)	-0.49 (0.43)	-0.69 (0.50)	-0.47 (0.43)	-1.00 (0.41)**
IPR_it		0.05 (0.11)	-0.01 (0.11)	-0.23 (0.18)	0.05 (0.11)	
IPR_jt		-0.77 (0.21)***	-0.72 (0.21)***	-0.65 (0.25)***	-0.78 (0.21)***	
ICT_IPR_it			1.54 (0.49)***	1.83 (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

Standard errors in parentheses. (***) p-value < 0.01, (**) p-value <0.05, (*) p-value <0.1

Table 5: Determinants of South-North formation of GINs.

Dependent variable: number of patents filed in country *j* by residents in country *i* (all specifications include monadic country dummies and time dummies).PAT

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

Standard errors in parentheses. (***) p-value < 0.01, (**) p-value <0.05, (*) p-value <0.1

Table A.1: 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[33]	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[34]	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[35]	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	

[33] The Chinese sample was extracted from two regional databases: (i) the *Beijing database* and (ii) the *Schenzhen database*. 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.

[34] The Indian sample was extracted from the *NASSCOM Directory of IT firms 2009-2010*, 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%).

[35] 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