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THE EFFECT OF INTERNATIONALISATION ON INVENTOR MOBILITY IN INDIA: AN EMPIRICAL LOOK AT KNOWLEDGE SPILLOVERS

ABSTRACT:

This research focuses on inventor mobility as a way of creating knowledge spillovers as externalities. Taking India as the country of study, a logit model tests how inventor mobility is affected by foreign co-authorship while controlling for the patent act implementation of 2005 and industry differentiation. A differences-in-differences-in-differences analysis portrays the main finding of an additional negative effect on intra-firm knowledge spillovers when an inventor has at least one foreign co-author relative to none, while working at the biotechnology industry relative to one working at any other industry and after the 2005 implementation of the Patent Act relative to before it.

KEY WORDS: Knowledge Spillovers, Inventor Mobility, India.

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ROTTERDAM, SEPTEMBER 2013

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Acknowledgements

I want to thank Prof. Bhaskarabhatla for his support, knowledge, dedication and patience as a supervisor and an educator; his insight and experience on the topic were of outmost aid for my research. Also, I want to thank Erasmus University and ESE for providing such a high quality environment for academics.

To all of those who had a positive influence in my work, your friendship and support means the world to me. Finally, a mis padres y hermano les agradezco por apoyarme, empoderarme, nunca dudar de mi y quererme tanto, sin ustedes no estaría en donde estoy ni sería ni la mitad de lo que soy, gracias infinitas.

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1. Introduction

Innovation has been a relevant topic in economics since Solow (1957) proposed technological progress as an external factor causing economic growth. From then on, many other theories have emerged signalling this progress as the main driver of economic advancement. In a diminishing return economy, resources are becoming scarce; there is a limit into which the population can benefit from adding extra labour and capital inputs for production (Lerner, 2012). Additionally, growing population and the change in structure and size of demand are proving real challenges in the near and long term future for all economies in the world. Adding one more worker or one more piece of machinery to increase productivity is becoming less of an optimal option and new sustainable production procedures are needed. Innovation of processes and products is one of the most viable ways to continue and foster economic growth because it implicitly has increasing returns as inventions reduce the cost of production or create completely new useful products (Griliches, 1990).

The characteristics and processes of innovation have gone a long way since its beginnings when a single brilliant man would experiment and create, often by chance or mistake, new products and processes (Lerner, 2012). Nowadays, innovation is considered an essential driver of success for organisations and nations alike. Even in some industries, companies' successes are determined by their return in investment of their research and development (R&D) schemes.

As the importance of innovation is commonly accepted, so is the fact that trying to measure it is challenging. This research focuses specifically on inventor mobility as a way of creating knowledge spillovers as externalities. As argued by several studies (Bottazzi et al., 2002; Audretsch et al., 1996; Saxeninan, 1991) the non-codified and embodied knowledge (intrinsic knowledge and experience in inventors) flows may signify relevant determinants for the process of knowledge spillovers. Additionally, Kim et al. (2006) argue that measuring migration of high-skilled workers may be one possible instrument by which knowledge is transferred and spread. Hence, following movements of inventors (in the specific case of this research, between firms) represent a strong alternative measure in the study of knowledge spillovers.

Since knowledge spillovers are associated with increase productivity and industry success (Allison et al., 1987 and Saxenian, 1994), the relevance of this research is linked to how mobility of inventors, and thus the subsequent assumption of knowledge transfer, has been affected by different factors and events in India during the last decade. This is a very broad and ambitious topic that will be narrowed down into specific determinants, trying to answer the precise question of what determines intra-firm mobility of inventors in India.

While globalisation becomes an unstoppable force and international distances are shortened thanks to technology, innovative processes have also been shaped to become more in tune with this reality. Hence, new practices have emerged to define how innovation is performed in the world. The Open Innovation paradigm proposed by Chesbrough (2003), argues that national frontiers have become irrelevant and consequently outsourcing has emerged as way of finding both cheaper and better solutions for organisations. This paradigm attests how innovative processes that once were characterised by individual works and closed-door lab settings have now changed into open (often international) networks of shared knowledge (Chesbrough, 2003a 2003b 2006).

From the premise of the internationalisation of innovation, this research will focus on innovation in India, a major multinational corporations (MNCs) outsourcing destination with booming information technology (IT) and biotechnology (biotech) industries.

Since its independence in the late 40s, India struggled with strict policies that brought the country to the verge of economic failure. Nonetheless, the late 1980s brought about different events that not only opened up the economy and brought recovery back to the country but also a handful of MNCs looking to reduce costs and to take advantage of the high-quality pool of human capital available. From then on, the outsourcing process has nothing but developed and evolved quickly. MNCs are no longer looking to set their *back offices*[1] in India, but also to move major operations there since the South Asian country offers a bundle of characteristics that no other developing country can: a large pool of high-skilled labour coming from highly praised academic institutions, low wages, the common use of the English language and a diaspora of Indian expats with international experience working as ambassadors and liaisons between the firms and local players. As a consequence, India possesses large high-tech hubs that are mainly driven by R&D. For these reasons, how

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[1] http://www.economist.com/node/610986

innovation occurs in India presents a case study with myriad of opportunities for analysis due to the many forces working rather rapidly in the country’s innovation hubs.

In support to the Open Innovation Paradigm, the world as a whole has seen a high increase in both co-authorship and foreign collaboration of inventions. This pattern implies that individuals rely on partnerships while innovating and this process generates social and intellectual networks. As described by Breschi et al. (2005), it is presumable that when an invention is co-authored the scientists know each other at a deep level and exchange knowledge. Furthermore, on their seminal paper about mobility of inventors and knowledge spillovers, Almeida et al. (1999) state that connections among firms, universities and inventors largely determine the extensiveness of knowledge transfer. The authors further attest that externalities are created unevenly across regions and that different consequences of these depend heavily on how transfer of ideas are supported by firm, institutional and inventors’ ties in the specific regions (Almeida et al., 1999). In this sense, inventor mobility should be more difficult when these strong ties exist. Thus, this research will focus its question on the role of international collaboration, i.e. when inventors are situated in different countries and work together to create a new product or process, and how these ties can affect inventor intra-firm mobility, and the subsequent transfer of knowledge spillovers.

In addition to the historical events that propelled India to become *the back office to the world,* the last decade saw more definite state efforts aimed to improve legislation on intellectual property (IP) and patents. In fact, the Indian Patent Act of 2005 signified a formal effort towards adaptation to international laws and regulations regarding IP. Hence, the period after 2005 represents an interesting time to study patent applications and mobility of inventors in India. It can be argued that after this legislation was implemented, patents were given a more important role and as stated by Agarwal et al. (2009), this causes less inventor mobility. Hence, the study will be extended to depict the effect of on inventor mobility post this law enactment.

Furthermore, the second part of the research will be add the factor of industry differentiation. The biggest industries present in India that invest heavily in R&D are the IT and the biotech ones. Thus, the biotech industry will be used as a case study for inventor mobility since it clearly depends on patenting in its innovative process and because it utilises very specific tacit knowledge that is not easily transmitted. Therefore, the final extension will seek to determine how much industry affects, if at all, inventor mobility.

Trying to answer *how much is inventor mobility affected by international co-authorship,* the econometrical approach employed will be the logit model testing for the probability of intra-firm inventor mobility. A differences-in-differences (DD) estimator interacting foreign co-authorship and the effect of the 2005 patent Act while accounting for inventor fixed effects will be firstly used. Consequently, the analysis will be furthered with the biotech distinction including a differences-in-differences-in-differences (DDD) estimator to depict the effect of these triple differences on knowledge spillovers.

The results yielded are very compelling on the production of knowledge spillovers as externalities in India. Foreign co-authorship, post effect of the 2005 Patent Act and the biotechnology differentiation all have negative effects while the DD interaction terms attest a positive effect on inventor mobility. The final DDD model portrays that the probability of intra-firm knowledge spillovers have an additional decline when an inventor has a patent application with a foreign co-author relative to one without a foreign co-inventor, coming from the biotechnology industry relative to one coming from any other industry after 2005 relative to before 2005

This thesis develops as follows: section 2 sets the historical background on India’s innovative sectors; section 3 explains the related literature; section 4 describes the data utilised; section 5 explains the main summary statistics; section 6 describes the methodology; section 7 portrays the main results; section 8 analyses and discusses the main findings and section 9 concludes.

2. Historical Framework: India as an MNC hub

This section opens up the discussion of the relevance of India as a case study for innovation. With a historical analysis, the bases in which further arguments will be built are constructed. A country characterised by rapid change, strong structures from where to build MNCs’ subsidiaries and quick growth; India proves an interesting case not only for mobility of high-skilled labour and knowledge spillovers, but for many aspects of innovation.

After achieving independence from Great Britain in 1947, India went through a lengthy process of adjustment to a new political and economic regime. Up until the mid 1980s, the country's economic agenda was run on strict closed market policies. In this period, tariffs amounted approximately to 200%, high quantitative import restrictions were the norm and foreign direct investment (FDI) was neither sought after nor welcomed (World Bank)[2]. Regardless of this, some Multinational Corporations (MNCs) already present in colonial India (beginning of the 20th century) managed to continue operations in the country during this time (Adhikari, 2013).

It was not until 40-some years later, when the country faced a very strong economic crisis in which the (in)balance of payments could not be sustained anymore that the government decided implement open economic policies. From then on, it only took a few years for the Indian economy to soar tremendously and for MNCs to start looking at India as a primary outsourcing destination. FDI started flowing and companies, especially from the IT sector, started moving in to the South Asian nation, making India the immense hub of outsourcing operations that it is today. Since those times, India has shifted from an ancient paradigm of government intervention towards a new one of liberalisation (Heitzman, 1999).

The fact that India was chosen as a major destination for MNCs outsourcing does not come as a surprise since it offers a bundle of characteristics that no other developing country can. It possesses a large pool of high-skilled labour while the education and research institutions in the country are acknowledged as some of the best in the world (Patiandla et al., 2002). Moreover, such labour is available at lower costs compared to home prices. Additionally, due to India's colonial past with the British Empire, the use of English as an official language for education and other activities facilitates communication between MNCs and employees or licensees. Finally, many 1960-1970s expatriates working at big MNCs have played an important role in taking business back home (Patibandla et al., 2002). All these characteristics sum up to result in what can be seen as a perfect canvas to send investment and operations abroad as well as for absorptive capacity to happen. Cohen et al. (1990) argue that such capacity is the reflection of previously related knowledge; this can be a shared language (English in the case of India) and/or technological know-how (acquired in the top Indian educational institutions, in previous experiences with state-owned technological organisations and with expatriates that had worked in MNCs and had returned to India or live between India and another country).

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[2] http://web.worldbank.org/WBSITE/EXTERNAL/COUNTRIES/SOUTHASIAEXT/EXTSARREGTOPINTECOTRA/0,,contentMDK:20592520~menuPK:579454~pagePK:34004173~piPK:34003707~theSitePK:579448,00.html

Overall, the most determinant input for India's success has been human capital (Patibandla et al., 2002). In the early years after independence, policies were aimed to intensively subsidize higher education. Furthermore, in the early 1970s specific policies were created in order to propel software and computer education and training by easing import duties on hardware (Basant, 2006). These, in turn have produced a large pool of a highly educated and qualified workforce trained at some of the most renowned research institutions (Patibandla et al., 2002). India is known to house what are considered some of the world-class educational institutions; for example the Indian Institutes of Technology (IITs), the Indian Institutes of Management (IIMs) just to name a few (Kaur, 2005). In fact, in their study Patibandla et al. (2002) find that the main reason for having a R&D lab in India for Hewlett and Packard (HP) is to take advantage of the big amount of highly trained workers. To attest this further, one executive stated that the quality of R&D work carried out in India is similar to that of the US. Nonetheless, many scholars assert there is a growing need for reforming the educational system in order to make it more accommodating and internationally competitive (Kaur, 2005).

Another positive factor that made India a magnet for MNC outsourcing is that labour costs were comparably low to those in the home countries while delivering top quality returns (Arora et al., 2001). As industries mature and MNCs settle in India, business models and targets also evolve. What started as an outsourcing action to exploit low labour costs and a highly educated workforce has now become a hub for innovation where companies have upgraded technologies and expanded operations (Patibandla et al., 2002).

Additionally, India has been somewhat benefitted by the fact that the long-standing colonisation history with Great Britain left them English as one of official languages giving the country an incredible communicational advantage over others since the language barrier is non-existent.

Finally, the diaspora of expatriates from India that now occupy high rankings in several MNCs has been of great help to bring outsourcing to the country. These "non-resident Indians (NRI)" (Dossani et al., 2003) have played a role of business clairvoyants and ambassadors in convincing their firms in the US or elsewhere to move business home (Basant, 2006). This was the case with Texas Instruments (TI), where Mohan Rao, and Indian expat and one of the senior vice presidents at the moment, propelled the project of moving operations to the South Asian nation. Another similar example occurred at Nortel when several Indian expats senior managers at the Canada offices also pushed forward the project of outsourcing to India (Patibandla et al., 2002).

On the legislative side, it is important to denote the somehow slow, but reformative, road the Indian government undertook regarding the allowance of FDI and intellectual protection. The period after independence and up until the 60s was characterised by state monopolies in numerous industries (Basant, 2006). In early 1970s some duty concessions were granted as well as the ease of import duties on certain products for training and educational purposes. However, this decade can be seen as a rocky period due to the implementation of the Foreign Exchange Regulation Act (FERA). This Act was extremely restrictive for MNCs and many of them, e.g. International Business Machines (IBM), decided to stop operations in the country. Later in 1980 further export-import liberalisations occurred (Basant, 2006). Nonetheless, the period of 1983-1984 signified an important turning point in the Indian IT industry. In 1983, liberalisation started by de-licensing the electronic sector and cutting import tariffs (Sharma, 2009). In 1984, the IT Revolution really took shape under Rajiv Gandhi´s mandate when the New Computer Policy was announced (Rai, 2002). With the implementation of this policy, the Indian government formally acknowledged software development as an industry. At the same time, the state approved exports of software exports via satellite; which in the years to come would become a milestone encouraging MNCs to enter India (Sharma, 2009). These liberalisation actions had very positive macro effects: growth was accelerated, new foreign firms entered the market and India opened its doors and trust to foreign technologies (Alam, 1990). In continuation with this open market policy line, the years to follow were characterised with further liberalisation, import deregulation, abolition and exemptions of restrictive taxes, allowance of FDI, etc. (Basant, 2006).

Regarding IP protection, legislation history has also been a somewhat rocky and unstable road. The Indian Patent Act of 1970 was a very restrictive piece of legislation for the biotech industry since it did not offer product protection and the process patents were granted for a period much too short to develop any innovation. Nonetheless, during 2005 India saw a major legislative move towards the improvement of its IP regulations. There had been other attempts before (i.e. Patents Amendment Act of 1999, 2002 and the Bill of 2003) but were not successful due to constant changes in the Indian political arena (Basheer, 2005). The 2005

Act signified a formal effort in achieving full compliance with the World Trade Organisation's (WTO) Agreement on Trade Related Aspects of Intellectual Property Rights (TRIPS) of 1995 in which pharmaceutical firms would be granted complete patent protection on their products in developing nations as well as to prohibit local firms from creating generic copycats of their medicines (Gehl, 2005). This Act brought about an enormous change in the patent legislation in India since it legalised product patents for pharmaceutical inventions (Basheer, 2005). This policy change was seen with different eyes by the public and MNCs. On one hand there was the debate of whether this new legislation would destroy the generic medicine industry and deprive the Indian (and other) population of cheap medicines. On the other, corporations praised this law as peremptory to promote innovation and even help domestic firms to become more R&D oriented organisations. In this act, there were also some attempts to change the patent definitions for the IT sector (Basheer, 2005), but the major impact of the Act was on the biotechnology and pharmaceutical industries. In fact, it is a common belief that without the introduction of product patents in these industries, India would not have become the FDI destination it is today. Additionally, the effort to compel with international regulations has helped the restructuring of the Indian industry to become more competitive in the global markets (Nair, 2010).

India's IT and biotechnology industries have evolved to become important players in the global markets. India's software industry is unique in the sense that it is mainly an export industry; most of the products and services are aimed to be sent elsewhere rather than to be sold in the local market (Patibandla et al., 2002). The industry has achieved export competitiveness over an almost non-existent domestic market with a base of inefficient input industries as well as low telecommunications infrastructure (Ghemawat et al., 1999; Patiblandla et at, 2000). It is safe to say that India has evolved from a body-shopping centred industry to a service hub attending main markets such as US, Europe and the rest of the world (Khomiakova, 2007). In fact, India's evolution of the exports of software services industry has been more than tremendous. In the period 1990-1991 such exports were US $128 million; by 2001 they accounted to US $8.3 billion (Nasscom Report, 2000) and by 2012 it reached a value of US $69 billion representing almost 8% of the nation's GDP[3]. Additionally, its pharmaceutical sector also ranks among the most well-known in the world, for example it has the most FDA approved manufacturing plants outside the US, it is capable of producing some

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[3] http://www.nasscom.in/indian-itbpo-industry

of the most high-tech products of the industry and is one of the developing countries with the most approved for global markets (Nair, 2010).

Regardless of all these positive characteristics and evolution, India still has many barriers to overcome if it is to develop as the world leader many augur it to be. For one it has aggravated infrastructural problems (Collato, 2010, Khorniakova, 2007, Heitzman, 1999). Additionally, the real estate market, sought after by investors due to low costs, is experiencing rising costs due to high demand and lately a shortage of high skilled professionals has posed a new challenge to businesses (Khorniakova, 2007). On top of this, bureaucracy, *red tape*[4] and corruption found at local, state and federal levels are detrimental to the smooth flow of operations with MNCs (Heitzman, 1999). In sum, these become *hidden costs* to many MNCs that now have become evident (Heitzman, 1999) and of great concern for these giant corporations that may consider to set up shop elsewhere.

3. Literature Review

After developing the historical events that make India relevant in the study of innovative processes, this section encompasses the main topics discusses throughout the research while supporting evidence from previous studies will be set forward. Section 3.1 looks at patents as data sources for innovative activity, section 3.2 discusses the evolution of innovation, section 3.3 studies knowledge, knowledge spillovers and their geographical extent and movement of inventors as a quantifiable measure of knowledge spillovers and the concept of tacit knowledge, section 3.4 elaborates on international co-authorship, section 3.5 argues the importance of the Patent Act of 2005 and section 3.6 explains the line of thought behind differentiation of industries for the study. At the end of all the discussions and argumentations, the main hypotheses will be stated.

3.1 Patents as measurement of innovative activity

In some countries inventions are given legal recognition and protection from potential duplicators. One of the most used instruments for invention protection is patenting. It is often believed that patent rights are a crucial stimulus to Research and Development (R&D) because they assure the appropriation of returns on such investments (Cohen et al., 2000). Patents are rights given by the state to either the inventor or the organisation—the assignee,

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[4] http://www.economist.com/news/business/21573551-meet-next-generation-indian-technology-firmsand-obstacles-they-face-screen

for a determined period of time (approximately 20 years). The purpose of the patent system is to foster technological progress via two channels: (1) by granting a temporary monopoly to the inventor and (2) by forcing the early disclosure of the information on how to create or carry out the new art (Griliches, 1990).

When a patent is granted, the government essentially gives the right of a temporary monopoly to the assignee in exchange of making this invention public. The United States Patent and Trademark Office (USPTO) defines patents as follows:

> *A property right granted by the Government of the United States of America to an inventor "to exclude others from making, using, offering for sale, or selling the invention throughout the United States or importing the invention into the United States" for a limited time in exchange for public disclosure of the invention when the patent is granted.*[5]

When an individual creates an invention, she can decide to apply for a patent in order to create a temporary monopoly on the product or process. The patent application process is a lengthy and costly one, it takes an average of 3 years to grant a patent and the price of obtaining it can go up to the tens of thousands dollars. Furthermore, the USPTO grants patents under specific guideline. For a patent application to be successful the invention must be original, it should not seem trivial for a specialist of the technological field and it must have a commercial application (Jaffe et al., 1993).

In the field of innovation research, there are very limited quantifiable measures that explain technological progress and how it changes over time. In fact, economists are often trapped with the inability to measure directly the contributions of technology to society (Grilliches, 1990). Nonetheless, patents −and the data they contain− are regarded as a proxy that offers objectivity and myriads of information. They indicate the invention has both surpassed time and monetary investment on the inventor (or assignee) side, indicating expectations of future profitability, and the institutional inspection of the patent office, proving its novelty and utility. Patents are considered to be a rich source of information and data because each patent has very comprehensive information about the product or process itself, its technological area, the name and location of the inventor(s) and assignee(s), the dates of application and

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[5] http://www.uspto.gov/main/glossary/

granting, number of claims, citations, etc. Additionally, information on patents granted in the US reflects not only the inventive capacity of domestic entities but also of foreign ones. As there are a limited number of countries that have strong patent laws, it is interesting to see the pattern of patent citations in the US since it is the country with the highest number of patents in the world.

The USPTO is the institution in charge of the patenting process in the US. It receives both domestic and foreign patent applications. US patent data is widely known to reflect almost the whole spectrum of patent innovations (Kim et al., 2006) since firms usually apply for patents in the US as well as their home country. As the patent application process is a very lengthy and costly one, foreign patent applications that are introduced in the USPTO are thought to be extremely relevant inventions. Otherwise, as profit seeking entities, companies would not go through all the trouble if they did not see a profitable future for the invention. Moreover, the higher the expected value of the foreign invention, the most likely it will be patented abroad (Harhoff et al., 1999).

Scholars have long relied on patent data to study innovation using different tools and measurements. Since the USPTO has records of patent grants since 1976 and many international inventions are patented in the US there is a very large number of patents from many technological fields. Most importantly, inventors provide data on patents voluntarily and their incentives for supplying such information is not ambiguous; therefore, contrary to other economic information, patents are a relevant and veridical platform for research purposes.

Regarding methodological approaches, in the early years patent counts were seen as a tool that would measure innovative activity. Later on, as research on patents and innovation was refined, patent citations (both patent cited and patent citing), patent claims, patent renewal data and additional international patent applications were seen as more accurate measures of innovation.[6] In this research I will rely on patent data to measure inventor mobility and how this can be translated to carry knowledge transfers and externalities.

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[6] For further literature on measurement of innovative activity, refer to Schankerman. [1986], Trajtenber [1990], Tong et al. [1994], Harhoff et al. [1999].

Patent applications in the USPTO office have continuously experienced an interesting shift pattern towards internationalisation. International patent applications have increased from 20% in 1960s up to 50% in 2012[7]. More importantly for this research, patent data offers the opportunity to measure if an invention has been created by more than one inventor and whether these are located in the same city, state or country. This relational data can be used as a means of investigating clusters that may be assumed to be dynamic hubs of knowledge sharing (Breschi et al., 2005).

Nevertheless, not all is peachy with patent data. Patents also have constraints as sources of information in the sense that not all inventions are patented. Not all innovations are patentable and not all inventors choose to patent their innovations since they may strategically decide to rely on other sources of intellectual protection such as secrecy (Crespi et al., 2008; Jaffe et al., 2000; Cohen et al., 2000). In a survey study Cohen et al (2000) find that many firms decide not to patent because of the difficulty to prove the novelty of an invention; the considerable amount of information that will be publicly disclosed; cost of applying; cost of defence in court; and the lack of difficulty to legally innovate around the patent. There are many spillovers that cannot be traced via patent citation due to the mere fact that some inventions, being too basic, cannot be patented. If these are the cases, there is no possible way to track such inventions. Additionally, it is not feasible to know how representative patents are in the scope of inventions and there is no data on inventions that are not patented (Hall et al., 1999). Thus the observed numbers of patents may very well understate the number of total inventions (Lanjouw et al., 2004). Nonetheless, more and more are knowledge spillovers not occurring randomly and accidentally; through the creation of networks such knowledge is travelling deliberately to other parties (Henderson, 2006).

Moreover, it has been argued that patents may not be the best instruments to foster innovation. Since the late 1950s, empirical findings have shown that patent protection is not very relevant to many industries, noting that pharmaceutical firms are the clear exception[8]. There are other tools that have proven to be more effective in the creation of new products and processes. In fact, many companies choose other ways of keeping their innovations secret. For example, firms now engage in what is called defensive disclosure[9], which in

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[7] http://www.uspto.gov/web/offices/ac/ido/oeip/taf/us_stat.htm

[8] For related literature, refer to the following literature Scherer et al. [1959], Mansfield et al. [1981], Mansfield [1986] and Levin et al. [1987].

[9] See Baker et al. [2005]

simple words means that the organisation is willing to make a technology public, often maintaining some information in secret, in order to preclude possible competitors from patenting a similar product as well as giving the opportunity to external sources to develop and improve the invention. Adding to this is the fact that knowledge can be transferred without patents depending on the basic technological nature of the process. For example, many academic journals are rich sources of information that do not require patent citation; hence knowledge transfers are not documented. Likewise, it is very likely that such art is published in journals articles and has a broader geographical scope (Jaffe et al. 19993). Also, since many countries do not have the same laws and regulations regarding patenting innovative incentives may not be the same for inventors and firms in the international scope.

On their NBER working paper, Cohen et al. (2000) conduct a survey to approximately 1500 R&D labs in the manufacturing sector in search of why firms patent innovations when most of them deem patenting ineffective. They first find that such entities rely mostly on patents, secrecy, lead-time advantages and complementary usage of marketing and manufacturing aptitudes to protect their inventions. However, of all these, patenting was found to be the least emphasised instrument. Their results also suggest that the motive for patenting goes beyond the actual purpose of patents - profiting from a temporarily monopolised innovation. In fact, many firms use it as an instrument to block competitors from patenting similar inventions, to use the protected property in negotiations and to inhibit suits. Although patents are not found to be the main instrument used in order to achieve appropriability, Cohen et al. (2000) do suggest that firms use a combination of such instruments to protect their inventions, seeing a complementarity that may change over time and depends on industry structure. In industries such as drugs and medical equipment, patents are signalled to have more than 50% effectiveness on appropriability; they are, nonetheless, never the top ranked effective mechanism (Cohen et al., 2000). The results of this survey summarise on how respondents think patents can be protective instruments to ensure competitive advantage to the firm. Further, in an earlier paper, Schmookler (1966) suggests that in the post WWII period there was an increase of industries that deemed patents less important since they relied more on secrecy and first mover advantage. Thus, it can be inferred that other instruments aimed to safeguard inventions have emerged since the early twentieth century and thus have evolved to become reliable protective instruments alongside patents.

On the knowledge spillovers scope, although these patent data offer the possibility of depicting if an invention has more than one author, it fails to measure the many other external influences the inventor has had in order to achieve the final product (Breschi et al., 2005). The inventor may have been in contact with academics, colleagues and other scientists that are unseen in the data but that can have played an important role on the innovative process.

Regardless of the downside of patent data, these statistics are a rich source of information when investigating technological change. In fact, there are no other instruments that offer such industrial, organisational and technological potential insight that are both so readily available and accessible (Griliches, 1990). As described by Bottazzi et al. (2002), patents can be seen as the closest to the ideal data to measure ideas that are economically profitable for testing innovation. Thus, in the big grey area that innovation measurement still is, these data still represent a rich source of research opportunities and information.

3.2 The Era of Open Innovation: the Open Innovation Paradigm

The term *Open Innovation* was brought about by Henry W. Chesbrough (2003a) with the book titled under the same name. He explains the evolution of innovative processes with an extensive analysis on the modern history of innovation and exemplary cases of specific companies and research laboratories.

The need for central research laboratories emerged since the beginning of the 20th century. These laboratories housed thousands of scientists and inventors that were left free to research and develop processes and products not really taking into account how relevant these would be for society, the market or how in line these will be with the firm's business plan. In fact, many labs failed because such centres were not delivering innovation as effectively as previously thought (Lerner, 2012). Organisations and institutions alike relied heavily on a closed and internal R&D system (Chesbrough, 2003a). It was a process characterised by control, conducted on what can be seen as a nationalistic sentiment since it was believed that the best research was the one carried out in-house. Likewise, these centres were characterised with the famous "Not-Invented Here" (NIH) syndrome in which technologies created in other research houses were not considered valuable, either due to self-interest or over-confidence (Katz et al., 1982). Additionally, R&D was mainly seen as a valuable asset to create competitive advantage and block competitors (Chesbrough, 2003b).

Nevertheless, this process started to change in the late years of the 20th century. Two clear phenomena occurred for the closed innovation system to be broken. Firstly, mobility of employers became more frequent, and with that knowledge spillovers. Secondly, the increasing availability of venture capital funding allowed for smaller firms to commence research and gain market power against the major research powerhouses (Chesbrough, 2003a).

Nowadays, companies and organisations alike are moving towards what is defined as *The Open Innovation Paradigm.* This paradigm is based mainly on the use and equal relevance of internal and external knowledge in order to innovate. It is contrary to the close innovation system since it breaks with the vertically integrated R&D model in which everything is internalised (Chesbrough, 2006). The Open Innovation system attests that industries and companies carrying out R&D have evolved from tightly closed entities to open institutions that outsource, licence and look externally for new ideas, products and processes (Chesbrough, 2006). Sturgeon (2002) corroborates this line of thought by attesting that since the 1990s industrial organisation in the US has changed to become characterised by specialisation, outsourcing and networking. Likewise, Kim et al. (2006) find a new trend in which technological firms are moving to foreign countries to employ researchers with foreign experience instead of the inventors migrating to the firms' headquarters. In connection to my research, India is one of the most authentic examples of this trend since, as explained before, MNCs have moved to the country in search of quality high-skilled labour.

Another important factor that has aid the open innovation system is reduction of trade barriers; which has facilitated market coordination (Langlois, 2003). Again, India is a vivid example since the country has emerged as a top destination for outsourcing promoted in part to the liberalisation measures taken in the early 90s (see Historical Framework).

Although this paradigm brought about a novel concept, similar ideas were already floating around academic circles. Some years back, Cohen et al. (1990) conceptualised the term Absorptive Capacity (Cohen et al., 1990); which is closely related to the open innovation system. In their seminal paper, Cohen et al. (1990) attest that the capacity with which a firm identifies valuable external ideas, appropriates it and finally employs it is of outmost importance in their innovative process. Additionally, this absorptive capacity is historically defined in the sense that what has been built up in the past in such area will aid to have more or less capabilities to absorb this external knowledge (Cohen et al., 1990). Corroborating this idea, Almeida et al. (1999) attest many factors must be present in the process of knowledge spillovers, among the most important are previous gained experiences, the ability to capture and create knowledge, and strong social potential.

As opposed to the close innovation system, Intellectual Property (IP) is not so much a tool for competition blockage but an enabler of further growth and revenues (Chesbrough, 2006). Hence, this paradigm is characterised with externalisation, strategic outward looking and outsourcing. Previously, many discoveries would go idle since the centralised lab could not find an appropriate use for the technology or they simply would not fit in the line of work of the organisation. With the Open Innovation Paradigm, this pattern has been broken and firms are now licensing, spinning-off, or openly disclosing certain information and inventions that may otherwise have sat in the shelves of oblivion (Chesbrough, 2003b).

Even though the shift to the open innovation system has signified radical changes in markets and organisations alike (Chesbrough, 2006); large firms have managed to transform into huge players in this new era of vertical disintegration in which externalities benefit all the parties involved as knowledge spillovers materialise.

As mentioned before, the open innovation paradigm is based on the fact that outside knowledge is as relevant and important as inside knowledge. When this concept is embraced and applied, firms are believed become inherently more innovative than the closed ones.

Almost a decade from the birth of this paradigm and it is openly recognised that ideas are created and disseminated through a process in which knowledge comes from diverse places and organisations (Breschi et al., 2005). Hence, the Open Innovation Paradigm is a concept that will remain valid for many years to come as geographical distances shorten due to the advancement of technological communication, economic and educational development and globalisation.

3.3 Knowledge

Knowledge has very specific characteristics and much research has been carried out about it as a major driver of economic growth. It is said to be non-rival because it is a public good, meaning that although one person uses it, is impossible to prevent another person to use it as well. Hence, knowledge as a productive asset fosters the possibility of spillovers. In this instance, innovations foster the creation of other processes and products (Jaffe et al., 2000); these new ones, at the same time, may also encourage other new inventions and so on. Alas, given that knowledge is a public good, companies are less involved in R&D and consequent production of knowledge than the optimal level society would prefer (Lerner, 2012). Nonetheless, knowledge can be an excludable good as well; hence there is a possibility that the owners of such knowledge will prevent its use by others. This feature highly depends on the characteristics of the knowledge itself and on the government institutions that overlook property rights; the first one having more weight.

Furthermore, some knowledge is either too simple or too difficult to be kept secret. If knowledge is completely non-excludable, then there is no economic gain and hence no economic incentive to produce it. This usually occurs with basic scientific research, which is often supported by governments, charities and private donors and has traditionally been made obtainable in a relatively free manner. Since this knowledge is produced at zero costs and benefits society, it is a common belief that it should be subsidized due to the positive externalities it produces (Romer, p. 118). On the contrary, if knowledge is somewhat excludable (for example via patenting), it gives economic incentives for its development. This development is motivated by economic gain and increase in market power.

3.3.1 Knowledge spillovers: a geographical reach

A channel through which organisations apply the open innovation paradigm is a network, whether formal or informal, these allow knowledge flows from outside sources to the firm (Simard et al., 2006). In this instance, geographical networks are of extreme importance for the transfer of knowledge. Even though nowadays technology allows for easy global communication and national and international travels are a feasible possibility, these networks continue to be relevant for the transfer ideas (Simard et al., 2006).

Since the late 19th century, economists have theorized the importance of geographic proximity for economic activity; economist Alfred Marshall introduced the concept of knowledge spillovers in 1920 stressing the importance of geographical proximity and concluding that vicinity of inventors was imperative for the process to occur. Afterwards, Arrow (1962) and Romer (1986) reinforced this concept connecting geographical proximity with economic growth. Furthermore, previous inventions created in a near geographical area are believed to be the most relevant technologies for the creation of new inventions; for example Jaffe et al. (1993) empirically proved that patent citations are more likely to occur in the same area and that it takes a few years for knowledge to surpass international barriers. On a more micro-economic view, Audretsch et al. (1996) found evidence indicating that at the beginning of the industry life cycle, innovative activity has the tendency to cluster. Furthermore, Bottazzi et al. (2002) measure the effect of R&D spending in creating innovations (measured as patent counts) from the period 1975-1995. The authors find a statistically significant localisation of R&D spillovers in a distance no larger than 300km.

Social networks are relevant because they allow certain contact necessary to transpose non-codified knowledge (Breschi et al., 2005). The beneficial consequences of regional clusters (networks) on innovation are possibly greater (Simard et al., 2006) especially in the open innovation paradigm where knowledge from different sources is a necessary piece for the innovative process to occur. Following this, some literature discusses how MNCs' headquarters absorbs knowledge from its outsourced offices or licenses (Singh, 2007, Kogut et al. 1993). Further, in two different studies, Breschi et al. find that mobile inventors and the creation of small social chains are the main drivers of localisation of knowledge spillovers for Italian (2006 study) and US patent data (2009 study).

This thesis is based on how the open innovation paradigm has given way to the creation of high-tech industries in developing countries focusing on outsourcing as well as the forces that impact mobility of high-skilled workers and their embodied knowledge. Since the 1980s companies have set up camp in India while indigenous firms have both grown and emerged as a consequence of the concentrated activity (and thus knowledge) in the area. In recent years, the growth of high-tech clusters in India (Khomiakova, 2007) has corroborated this concept since they have originated in very specific regional areas of the country.

3.3.2 Inventor mobility: a quantifiable form of knowledge spillovers

In the innovation-reliant industries, where labs, research institutions and firms crowd the R&D landscape, scientists, engineers and inventors are main drivers in the creation of externalities and knowledge transfers (Almeida et al., 1999).

In the later years of the 20th century, mobility of high skilled workers (and inventors) started to increase (Chesbrough, 2003a). Not only did this mobility help birthing the aforementioned

Open Innovation Paradigm but it also generated a new phenomenon that is now very much seen in many industries. When an individual moves (either from one company to another or even from one industry to another), the person brings along an invaluable amount of knowledge obtained at the previous workplace and/or that are a consequence of prior networks, experiences and research. This is a "non-codified" or embodied knowledge that is not as easily accessible as other knowledge because it is directly attached to the experience of the inventor (Bottazzi et al., 2002) and can only be transmitted by the person herself.

In a geographical-patent citation analysis, Agrawal et al. (2004) study whether patent citations come from individuals that are closely located to one another or that used to work at the cited institution. They find both factors matter when it comes flow of knowledge; moreover, the authors argue that social relationships are of outmost importance in knowledge flow patterns. Likewise, Song et al. (2003) study patenting patterns of engineers who have moved abroad. They suggest that only if the personnel are hired to develop non-core technologies of the companies; clear knowledge flows occur.

On an in-depth study of localisation of knowledge and mobility of engineers, Almeida et al. (1999) set forward the argument that mobility of inventors between firms has an influential effect on knowledge spillovers since through movement of individuals ideas are diffused. They argue, nonetheless, that such transfers are intrinsically attached to regional labour networks (Almeida et al., 1999).

In India's case, the aforementioned diaspora of India's expats have contributed to knowledge spillovers in various ways (Basant, 2006). Some high-skilled Indian workers either move back home or work between their home country and the US or Europe; these mobile human capital represents a source of non-codified knowledge that is diffused to others through imitation (Kapur, 2002).

3.3.2.1 Tacit knowledge: "We know more than we can tell"[10]

Knowledge also shares different characteristics that determine its nature and how it can translate into externalities that will further innovation and economic development. Some knowledge is tacit, meaning that is intrinsic in an individual and cannot be easily replicated.

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[10] Polanyi, 1966.

As this may signify a source of competitive advantage it is also often seen as an obstacle that deters further knowledge learning (Lawson et al., 1999). Other than by mobility of inventors, there are not many (effective) options for the codification of knowledge; hence the study of this phenomenon represents a relevant topic in the innovation and economic literature since moves represent quantifiable sources of knowledge creation and diffusion. Nonetheless, several authors put forward the argument that tacit and codified knowledge work complementarily since in order to understand any process, an individual must possess some intrinsic knowledge that allows her to internalise the new ideas (Senker, 1995, Howells, 1996 and Lawson et al., 1999,).

On the difficult quest of appropriating and exploiting such embodied knowledge, team-work has proven to be a helpful tool to capture this complex knowledge (Zucker et al., 2002). On this premise, the Open Innovation Paradigm and co-authorship steps in one more time to demonstrate the patterns of the modern innovative process.

In its complexity, tacit knowledge additionally offers an implicit safe-gate on the information it contains (Zucher et al., 2002). Hence, together with formal property rights (e.g. patents), firms can join both forces with the aim of effectively safeguarding their IP.

Tacit knowledge is used very differently depending on the industry. For the scope of this research it is of outmost importance to denote these differences since not all sectors rely as heavily on un-codified knowledge and in turn, mobility (and how knowledge is transferred) differs in both reasons and volume.

Although innovative processes of high-technology industries involve multidisciplinary and complex knowledge (Lawson et al., 1999), the biotechnology industry is known have a broader use of tacit knowledge. On a study, Senker (1995) conducts interviews to industrial researchers from the biotechnology, advanced engineering ceramics and parallel computer processing industries about the knowledge utilised in a day-to-day basis. The author finds researchers in biotechnology relied more heavily in tacit knowledge, often taking as quotidian the state of the art facilities and other procedures otherwise complex. On the contrary, the IT sector is known to support its innovative process on a more codified type of knowledge, for example software, hardware, and certain processes (Leonard et al., 1998).

3.4 International co-authorship of inventions: furthering the Open Innovation Paradigm

Inventions can have more than one author. If such is the case, many scenarios are possible: the inventors may be two (or more) independent individuals, they may come from different firms or institutions, they may be situated in different locations (e.g. countries), etc. (Breschi et al., 2005). In fact, innovation is more often than not a group enterprise (Leonard et al., 1998).

Even though literature on co-authorship of inventions may be limited, co-authorship of scientific articles can be seen as an adequate proxy from which to derive information on co-inventions since the work related to academic papers in which knowledge flows among scientists may be regarded as similar as the process of invention. McDowell et al. (1983), Durden et al. (1995), Hollis (2001) and Brien (2012) all argue that there is strong evidence showing an increased share of co-authored articles in the last 5 decades in many research fields. Likewise, in a study that involved analysis of approximately 20 million papers and 2 million patents in a period of 5 decades, Wutchy et al. (2007) argue that teamwork is increasingly being used as a way of doing research; additionally, this method is proving more effective (as measured with number of citations) than the ancient *solo-author* work style. Further, it is an accepted fact that innovation has evolved to become a very collaborative process; in fact, Kim et al. (2006) assert that from the period 1975 to 2002 patented inventions yielded an average of 2.05 inventor per patent.

As collaboration becomes ubiquitous in innovation, the creation of networks among inventors becomes an inevitable consequence. Breschi et al. (2009) study the characteristics of these networks and knowledge spillovers focusing on mobile inventors (i.e. inventors who have patents with more than one organisation). They find that such networks tend to be geographically localised since inventors do not move in space and their network is thus geographically limited. Additionally, Singh (2005) finds stronger knowledge flows and networks in an intra-firm and intra-regional level; arguing, nonetheless that interpersonal ties are found to have more importance in knowledge diffusion.

As studies show determinant evidence of localisation of knowledge flows and networks while mobility of inventors is determined to be somewhat limited, I hence will put forward the argument that this may well be the case in India. The creation of ties through international collaboration among workers from MNCs and its subsidiaries can be a strong force determining mobility of individuals. As knowledge is shared and connections, both personal and work related, are created, inventors may be less likely to move to other firms since these ties offer opportunities most likely unattainable elsewhere.

3.5 The Indian Patent Act of 2005

As explained in the historical framework, the Indian Patent Act of 2005 signified a formal move towards patenting strengthening in India (Gehl, 2005). As the government attempted, for the third time (Basheer, 2005), to adjust to international laws with the aims to become more competitive in the international spectrum, this law spiralled numerous effects in the Indian high-tech sector.

The reinforcement of the WTO rules may have caused different effects on inventor mobility. On one side, the legislation may have increased intra-firm inventor mobility since the growing importance in both inventive activity and inventors may have created a larger pool of employment opportunities. On the other hand, since this legislation brought about much reassurance on the relevance of product patents as a recognised tool of IP protection, inventors may have found further incentives to stay in their current firms since innovative processes found a new-born boom. In fact, in a previous study, Agarwal et al. (2009) show that patent enforcement (on a firm scope) causes a negative effect on inventor mobility. Hence, I will extend the argument that this law exogenously affected movement of inventors having a negative effect on knowledge spillovers as externalities.

Deriving from the arguments supporting foreign co-authorship as a determinant of inventor mobility in India and the 2005 Patent Act as a reformative event in the inventive process in the country, I will derive the following hypotheses:

Hypothesis 1a: Inventors with foreign collaboration are less likely to move from one firm to another ceteris paribus.

Hypothesis 1b: Inventors are less likely to move from one firm to another after the 2005 Patent Act in India relative to before.

As patents were given more importance in after 2005 and India continued to become the ultimate outsourcing destination, it may be likely that the creation of international networks between MNCs and its subsidiaries also increased. Thus, taking the study further with an interactive approach of the factors influencing intra-firm mobility, the following hypothesis is put forward:

Hypothesis 2: Inventors of patents with foreign collaboration after the 2005 Patent Act in India are less likely to move relative to before.

3.6 The biotechnology industry in India: a focused analysis

As a platform of MNCs subsidiaries, India’s high-tech cluster is in itself an interesting case to study how the use of different knowledge affects inventor mobility and the diffusion of knowledge spillovers. In order to narrow down the reach of my investigation I will direct the extension of the analysis to the biotech industry since it possesses very particular qualities that extremely differentiates it from the other industries present in India. For one, it has been stated that tacit knowledge is highly used in this industry (Senker, 1995) and that there are few ways of diffusing this type of knowledge other than by personal contact and movement of inventor (Lawson et al., 1999).

In conjunction with the previous statement, the complex and lengthy nature of product invention in this sector makes it more reliant on patenting as a protection tool (Cohen et al., 2000) than other sectors. Further relating this distinction to the scope of my research, it will be interesting to depict the impact of the 2005 Patent Act on intra-firm mobility working for inventors in the biotechnology industry since the act specifically enforced product patents as a tool for IP protection for the pharmaceutical sector (Gehl, 2005).

Due to its distinctiveness between the other industries present in India, the biotechnology industry offers a clear platform for the analysis of mobility of inventors with patent data in this specific time frame. Hence, the extension of my analysis will involve singling out the biotechnology industry and seeing what effect it has in inventor mobility as a single factor as well as when interacted with the other two factors.

Following the claims made in section 3.4, 3.5 and 3.6, I will essay to explain mobility of inventors among firms using foreign co-authorship, the effect of the Patent Act of 2005 and the differentiation of the biotechnology industry (against the rest of the industries) as determinant factors, putting forward the last hypothesis of this research:

Hypothesis 3: Inventors with foreign collaboration are less likely to move from one firm to another relative to other inventors in the biotechnology industry relative to other industries for patents applied for after the 2005 Patent Act in India relative to before.

4. Data

This section provides information on the data set, its general characteristics, where it was obtained and most importantly, the arrays of opportunities it presents. At the same time, the limitations it possesses are explained and set forward in order to create a transparent framework when analyzing the results.

The data set used for the empirical analysis comprises USPTO aggregate patent application data from 2001 to 2012. Patent application information is publicly available from the USPTO.

When a patent is applied for in the USPO office, the information on the invention will be publicly disclosed after 18 months of its introduction to the Office, regardless of it being granted or not. Therefore, this application dataset is more informative than a patent grant dataset since it comprises a greater number of inventions (i.e. all of those applications that may or may not be awarded a patent but that were deemed economically relevant by the inventor and or company).

The dataset includes information on inventor name as well as city and country of residence, assignee name, which is usually the employer of the inventor, city and country where the assignee is registered, technological classification of the invention, industry and day, month and year of application. The data are organised at inventor level; which gives the opportunity to geographically and organisationally follow the steps of each inventor throughout the inventions. With this rich dataset, it is possible to measure migration of high-skilled workers; which, as argued previously, may be one possible instrument by which knowledge spills over (Kim et al., 2006), generates more innovations and furthers economic growth.

4.1 Limitations

Besides the general limitations of the data explained in section 3, this specific dataset presents limitations that must be denoted and taken into account for the econometrical analysis. In principle, the dataset is an unbalanced panel since not all inventors are represented each year. An inventor name will only appear if this individual applied for a patent in that certain year; therefore, there is the possibility that an inventor appears only one time in the dataset or that appears more than one time per year.

Additionally, although the patent application information has been filled voluntarily and the scientist has all the intentions to give as straightforward and correct information as possible, there are some underlying errors in the personal information provided. For example an inventor name may be filled with no middle name in one patent but it may be filled with the middle name and second last name in another. In an effort to clean up and homogenise the data, company and inventor name and city were checked and edited; nonetheless there may still be some margin of error that must be kept in mind in the analysis.

Moreover, this dataset presents a panel with several dimensions (e.g. inventor name, company name, application year) but for simplifying reasons and time constraints the models only take into account two dimensions; therefore it may be left for further research to create more extensive models that take into account more than two dimensions in the data to shed clearer and more detailed results on what may be the determinant(s) of inventor mobility.

Although the dataset comprises a relatively short span of time, the information it contains is very recent and rich. Thus, the empirical results will show up-to-date and relevant patterns of the innovation process and the parties involved (i.e. inventors and assignees). A further issue with the time spam is the element of truncation. In this specific dataset, the early and later application years present truncation (Hall et al., 2001); for example there is only one patent application for 2001 and in 2012 patent intensity reduces significantly compared to previous years. This could be due because not all 2012 applications were processed and made public at the moment when the dataset was constructed.

Another peculiar aspect of these data is that many companies are diversified and fall in different industries depending on the invention. As the data is aggregated at the inventor level, it is possible that one company is both in the IT and biotechnology industries in different years and/or inventions.

In spite of the obstacles and limitations, the empirical study carried out achieved a certain level of significance and relevance. Therefore this research can be seen as a prelude to further studies on the knowledge spillovers topic and more specifically in the case of developing countries.

5. Summary Statistics

This section will depict the most important descriptive statistics derived from the data set. More specifically, general information on patent applications, inventors and firms is explained. Additionally, statistics, both general and industry specific, about inventors' moves and foreign co-authorship throughout the framework are described.

The whole data set has 4,786,571 observations from all the USPTO patent applications from the period 2001-2012 (both US and non-US applicants). As I am focusing my research on the movement of inventors among firms in India, I have reduced sample to those inventors who have listed India as their country of residence at the moment of the application and that have registered a company as the invention's assignee. This results in a reduced data set of 13,692; the broken down statistics are portrayed in table 1.

In the dataset there are 8950 unique inventors with a mean of 1.52 inventors per inventions and standard deviation of 1.51. As it is usual for patent application data, it is skewed; the maximum unique inventions per individual inventor is 37 (occurring only for 1 inventor) and the minimum is 1 time (occurring for 6,673 inventors).

As depicted in Table 1, there are 894 unique firms in the data set with a mean of 6.58 and a high standard deviation of 32.47, again showing the skewed nature of the data. In fact the company with the most inventions is IBM (662 unique inventions) followed by General Electric (with 475 unique inventions) while there are 504 unique firms with only 1 patent application.

Table 1. Patent applications of Indian residing inventors 2001-2012

	Observations
Total	13,692
Unique Inventions	5,884
Unique Inventors	8,950
Assignees	894
Companies	782
Universities and Research centres	112
Inventors per invention (only accounting for Indian inventors)	1.52
Inventors per assignee	10.01
Inventions per assignee	6.58

5.1 Foreign Co-authorship

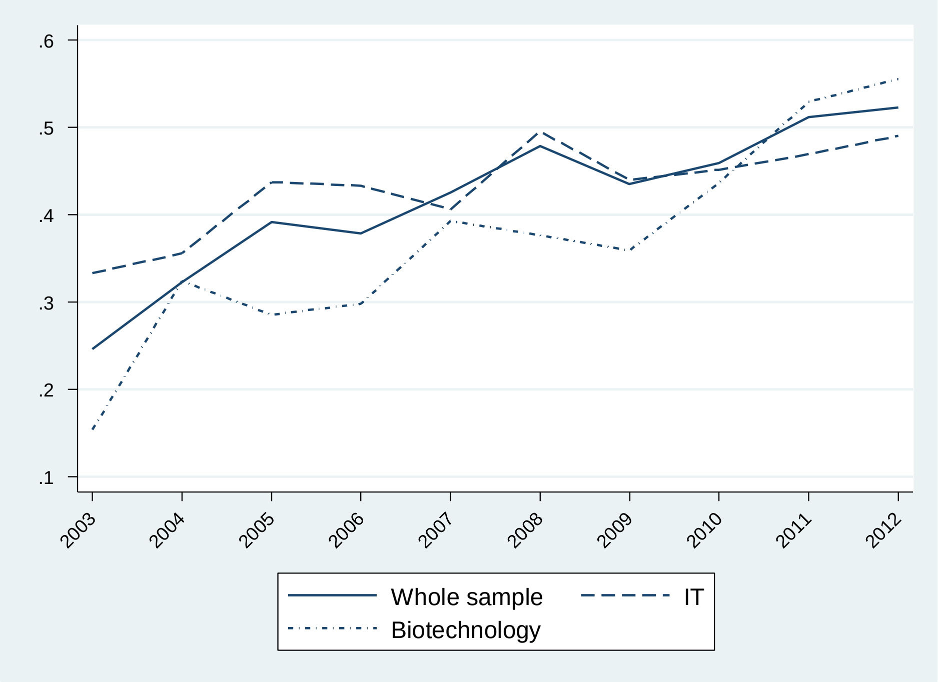
Out of 5854 unique patent applications, only 854 of them have only 1 inventor and no foreign co-author, corroborating the Open innovation paradigm in which innovative processes are no longer limited to individuals, closed-door work styles and national barriers. Further, 45% of the patent applications in the dataset possess at least 1 foreign co-author with a mean of 0.45 and a standard deviation of 0.49. Graphs 1 shows the increasing ratio of foreign co-authorship experienced in India throughout the years. Foreign co-authorship increased from 23% in 2003 to 52% in 2012. This trend goes in connection with the literature that asserts the overall increase in international collaboration of papers and inventions explained in section 3.

The dataset is a very rich source of information to study innovation and many are the studies and analyses that can be carried out. The next section explains in detail the econometric models used to in search to explaining mobility of inventors and how different trends and events affect it one way or another.

Table 2. Number of inventors per industry

Industry	Total	Percent	Cum.
IT	4,950	55.31%	55.31
Bio	3,149	35.18%	90.49
Rest	851	9.51%	100
Total	**8,950**	**100**	**100**

Graph 1. Ratio in foreign co-authorship



Furthermore, Table 3 shows how in the dataset the majority of foreign co-authorships are carried out in the IT sector with an overwhelming majority of almost 63% again indicating very diverging trends among industries.

Table 3. Foreign Co-authorships by Industry

Industry	Patents with foreign co-author
IT	1658 62.6%
BIO	635 24%
Rest	356 13.4%
Total	**2649**

5.2 Industry differentiation

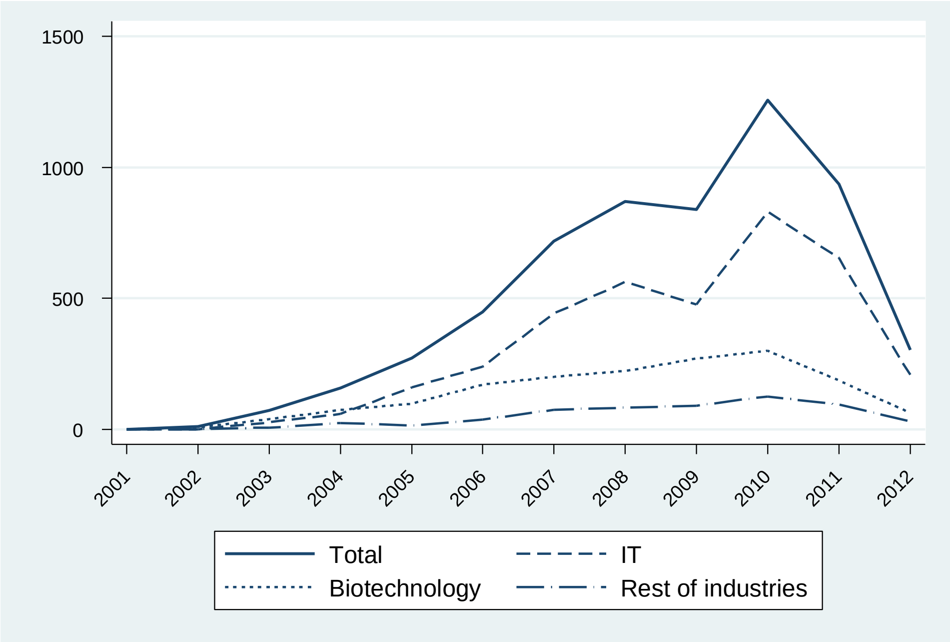
In India, the industries that invest more heavily in R&D and apply for the most number of patents are in the Information Technology (IT) and Biotechnology (biotech) industries. Table 4 describes the number of unique inventions for each industry, corroborating that the majority of patent applications (90%) are from the IT and biotech industries. Industry definition was based on patent classification the procedure will be described in more detail in the methodology (section 6).

Table 4. Total patent application by Industry

Industry	Applications	%	Cum
IT	3,663	62.2	62%
Biotech	1,634	27.7	90%
Rest	587	9.9	1%
Total	**5,884**	**100**	**100%**

Graph 2 shows how patent applications had a clear increasing trend up until 2008 when a decline in applications is obvious. This may be due to the 2008 economic crisis that spread around the globe consequently affecting FDI and overall investment, especially from MNCs and foreign parties. Nonetheless, when the patent application trends are looked at on an industry basis, this decreasing trend occurred only in the IT sector, while the biotech industry continued to have a slow but steady increase. After 2009, a rapid recovery can be seen where patent applications spiked again to reach 1,256 unique applications in 2010. From then on, a sharp decrease in patent application is depicted in the sample, but this due mostly to the truncation in the data. In fact, looking at USPTO patent grants updated statistics from 2010-2012, there is no reason to believe such a sharp decrease occurred naturally. [11]

Graph 2. Applications per year per industry



5.3 Inventor mobility among firms

As this paper is focused on inter-organisational inventor mobility, it is interesting to depict the trends occurring in the data. There have been 520 unique organisational moves which represent 3.80% of the total population with a standard deviation of 19%. This means that organisational movement among inventors is very varied. Moves oscillate from 0 to 7 times in the sample where 8557 inventors have not moved at all, 307 inventors have moved once, 60 twice, 17 have relocated 3 times, 6 have moved 4 times and only 3 inventors (1 per each occasion) moved 5, 6 and 7 times. A total of 393 inventors, representing 4.6%, moved inter-organisationally at least one time between 2001 and 2012. These figures highlight the fact

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[11] http://www.uspto.gov/web/offices/ac/ido/oeip/taf/us_stat.htm

that there is a trend developing in the mobility of inventor population in India and from this premise I will base my research on the fact that these moves signify potential knowledge spillovers that could translate on further development of innovative processes.

From the 520 total moves, 206 moves occurred within the first year of applying for the first patent, 334 within two years and 405 within the first three years. In total, 75% of the moves occurred in the first three years after the first patent application; seeing a clear trend of short term movement. Nonetheless, these statistics must be looked at cautiously since the shortness of the dataset may not show long-term mobility trends. As in many economic studies, as time goes by long-term trends become more definite and shed more light on different issues; however, for now is interesting to study such up-to date movements in order to clarify inventor mobility and how knowledge is transferred.

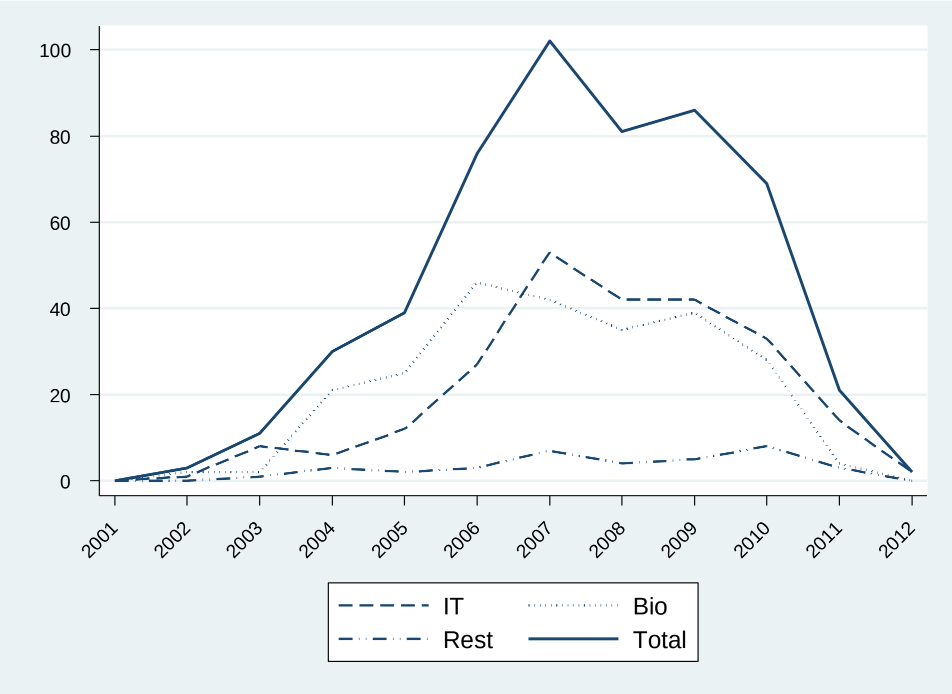
On an industry differentiation basis (Table 5), as expected, the IT and Biotech industries present the most moves (approximately 46% each in every pattern). Even though the number of moves in the IT and biotech sectors are almost the same, mobility in the biotech industry is more pronounced since there are less inventors in this industry (table 4). As explained before, the nature of knowledge used in the biotech industry may be an important reason for this pattern.

Table 5. Moves by industry and per period.

Industry	Moved from company whole sample	Within 1 year	Within 2 years	Within 3 years
IT	240	98	161	190
	46.10%	47.50%	48.20%	46.90%
Bio	244	93	148	188
	46.90%	45.10%	44.30%	46.40%
Rest	36	15	25	27
	6.90%	7.20%	7.40%	6.60%
Total	**520**	**206**	**334**	**405**

Observing the mobility count per year and industry (Graph 3), it increased up until 2007. As described earlier, the Patent Act of 2005 may have had a negative effect on inventor mobility since product patents were acknowledged as intellectual property tools and the inventive processes became more important for firms. Additionally, due to truncation, after 2010 the mobility trend decreases immensely.

Graph 3. Mobility of inventors per year by industry



To summarise, Graph 2 shows the increasing trend of patent applications in the sample years. At the same time applications from the biotech industry have had steady growth and do not seem to be affected by the 2008 economic slowdown as the IT industry was. Additionally, inventor mobility shows an interesting trend since it increases until 2007. More specifically, the biotech industry presented growth in mobility up until 2006 when mobility count decreased significantly. Graph 1 shows how international co-authorship has become more important throughout the years up to the point where almost half of the patent applications have at least one international co-author.

All these trends corroborate that there have been several forces shaping inventor mobility in India and, consequently, external knowledge diffusion has been affected. In the next section I will explain the methodological model used and the analytical approach taken to explain the effects on inventor mobility.

6. Methodology

This section comprises the explanation of the econometric approach in order to answer the research question stated in the introduction (section 1) and developed in the hypotheses. First the logistic regression model will be described. Then, in section 6.1 the first model will be described specifying the econometric regressions and variables used as well as the differences-in-differences estimator and section 6.2 further explains the following extension of the analysis with the triple-differences approach.

As explained before, this research is focused on movement of inventors between companies in India as a direct measure of knowledge spillovers focusing on the effect of foreign co-authorship. In a nutshell, it is aimed at studying the probability that an inventor will move from one company to another when the inventor has at least one foreign co-author, while controlling for the legislative change brought by the patent Act of 2005 and industry. This section will explain in detail the steps taken and methods used in the quest to answer the query of how knowledge spillovers are affected in India.

In that sense, the methodological approach used will be a logistic regression. The logit model is a binary choice model with a discrete or semi-discrete dependent variable (Verbeek, p. 206). Such discrete variables may be decision (e.g. to hire one more worker or not) or state (e.g. if the inventor moved or not) variables and take finite numbers, i.e. 1 if inventor moved to another company and 0 otherwise. This model is appropriate to use in the present research because it is most commonly used to answer problems of micro-economic nature (Verbeek, p. 206), in this specific case inventors, their mobility between organisations, employer, city of residence, etc. and because it will measure if inventor mobility occurred or not after controlling for certain specific patterns and characteristics.

Since the data used is micro-data, there exist intrinsic behaviour assumptions. From these, a latent variable representation of the model is derived (Verbeek, p. 210) since de decision of moving or not involves many different parameters than can often be inventor-specific. In such representation the independent variable is unobservable (Verbeek, p. 210, Hoetker, 2007). From this latent patent model, a binary choice model that depends on an assumed distribution for the error term is obtained. For the logit model the standard logistic distribution is calculated and the parameters in this model are estimated by the maximum likelihood (ML) methodology (Verbeek, p. 210).

An advantage of the logit model is that the predicted frequency is indeed the real frequency (Verbeek, p. 212); which generates a very accurate estimator. Additionally, the logit distribution is very attractive for empirical studies since it shows the different propensities of individuals with different underlying characteristics to carry out an action (Hoetker, 2007), e.g. for an inventor working at company Y, living in city X, with a foreign co-author and from industry Z, to move or not.

One important aspect of the logit model is that the coefficients yielded in regression results cannot be readily interpreted. A commonly used solution is to look at the marginal effects of changes in the independent variables (Hoetker, 2007, Verbeek, p. 207); once calculated they are easy to analyse. These marginal effects are, by concept, the partial derivatives of the probability that the dependent variable equals 1 (Verbeek, p. 207), i.e. if inventor mobility between companies has occurred in the specific case of this research and therefore they describe the effect on the dependent variable.

Regarding goodness of fit, binary models do not present easy to interpret tests such as the R squared test for OLS (Hoetker, 2007). There is though, a goodness of fit test called the McFadden's pseudo R-squared and there has been a large academic debate on whether to use it or not[12]. Although the pseudo R-squared are a measure to prove goodness of fit in binary models, they must be looked at with caution (Hoetker, 2007) and economic intuition plays a very important role when interpreting results and goodness of fit.

6.1 Modelling inventor mobility in India

As explained in the literature review, the open innovation paradigm has given way to new forms of innovation and collaborations between organisations and inventors. In this new era, ideas are shared and external collaboration is seen as essential for the innovative process. For this research I want to stress the relevance of international co-authorship in India and how on inventor mobility is affected by it. If social networks are created between scientists across countries, it can be argued that such ties could become strong enough to deter organisational migration since such connections may possess intellectual ties unattainable elsewhere.

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[12] See Bowen et al., 2004 and Long, 2007 for insights on the positive and negative sides of the goodness of fit tests in logit models.

Throughout the research the time benchmark used will be the patent application year because it represents the closest, publicly known date from which an invention is created. On this line, while using the application date the issue of the lag time between patent application and patent granting (approximately 3 years according to Kim et al., 2006) is also avoided. In this line, the implementation of the 2005 Patent Act marked a definite change in patenting and inventive processes in India; hence I expect to see a definite trend on patent applications starting in 2006.

Since the dataset contains information in all the institution that have applied for a patent, a distinction was made between companies and universities through the creation of the dummy *University* that takes the value of 1 if the assignee is an educational centre. As I am interested in studying mobility at company level (both multinationals and local Indian companies), I excluded academic centres when running the regressions.

In order to define the foreign co-authorship (*Foreign)* variable I started with the complete data set of about 4 million observations and signalled all the patent applications that had at least one author residing in India (which are all present in the reduced data set used for the study). Then, I singled out those of which had at least 1 co-author not residing in India assigning them the value of 1. Therefore, *Foreign* takes the value of 1 if the invention has at least 1 co-author residing outside of India and 0 otherwise. Consequently, to denote the effect of the implementation of the Patent Act of 2005, I have included the variable *After2005* that takes the value of 1 if application year starts from 2006.

As many forces were coming together affecting inventor mobility and knowledge spillovers, I extend the analysis implementing the Difference-in-Differences (DD) estimator. The DD estimator allows analysing for group and time-specific effects occurring in the sample. However, it is imperative to be cautious regarding the unbiasedness of the estimator since changes could be consistently related to other elements affecting the dependent variable that are unaccounted for and absorbed by the error term. This estimator possesses several advantages in empirical analyses; it offers a more efficient estimator when the treatment is carried at random and when some of the unobserved characteristics are persistent over time (e.g. gender) (Stock et al., p.386). Additionally, it offers the advantage that it does away with any pre-treatment differences in the dependent variable. That is, the DD gets rid off the difference in means before the treatment started; thus yielding a more accurate result between effects of the control and treatment groups (Stock et al., p. 386).

Table 6. Variables used in the main models

Name	Variable	Description
Moved	Dependent variable	Dummy with value of 1 if inventor moved to another company in the next period
Moved_1year	Dependent variable	Dummy taking the value of 1 if the inventor moved to another company in less than 1 year after her first application
Moved_2year	Dependent variable	Dummy taking the value of 1 if the inventor moved to another company in less than 2 years after her first application
Foreign	Independent variable	Dummy with value of 1 if invention has at least 1 international co-author
After2005	Independent variable	Dummy with the value of 1 of application year after 2005
BIO	Independent variable	Dummy with the of 1 if industry is Biotechnology
*Foreign*After2005*	Interaction term (DD)	Counts all the inventions with foreign co-authors applied for in 2005
*BIO*After2005*	Interaction term (DD)	Counts all the inventions from the Biotechnology industry applied for after 2005
*Foreign*BO*	Interaction term (DD)	Counts all the inventions from the biotechnology industry that have at least 1 foreign co-author
*Foreign*BIO*After2005*	Interaction term (DDD)	Counts all the inventions from the biotechnology industry applied after 2005 with at least 1 foreign co-author

I will essay to answer hypotheses 1a, 1b and 2 with the following models; variables are described in table 6. Note that models [1] and [2] are also tested when the inventor moved within 1 and 2 years of the patent application.

$$[1]$$
$$Moved = \beta_0 Foreign + \beta_1 After2005 + \varepsilon$$

$$[2]$$
$$Moved = \beta_0 Foreign + \beta_1 After2005 + \beta_3 Foreign * After2005 + \varepsilon$$

The approach in model [2], will empirically illustrate how the after 2005 period influenced mobility of inventors if the patents a foreign co-author. Thus, the treatment group represents all those patents with at least one foreign co-author, while the control group comprises all the inventions without foreign collaboration. The DD interaction term depicts the difference between patents with foreign co-authors relative to those without during the post 2005 period relative to those pre 2005. Hence, coefficient β_3 shows the effect these differences had on inventor mobility and knowledge spillovers.

6.2 Industry specification: an extension

It is necessary to stress how industries present different characteristics in regards with the knowledge they use. As explained in section 3 it is often argued that the pharmaceutical and biotechnology industries rely more heavily on tacit knowledge while knowledge in the IT industry is of a more explicit and codified nature not needing direct personal contact to transmit it. Hence, I want to test if industry differences play a determinant role in inventor mobility in India as the IT and biotech sectors are the predominant line of business when it comes to innovation.

In this extended model I will add a variable for the biotechnology sector *BIO* taking the value of 1 if the patent is from the biotechnology sector and 0 otherwise. The study will be focused on the biotechnology industry because patent protection is widely used to safeguard innovations (Schrerer et al., 1959; Cohen et al., 2000). Otherwise, if this same definition is carried out for the IT sector (creating a dummy with the value of 1 if IT and 0 otherwise), much ambiguity will appear since this sector may rely less on patents and more on other tools such as secrecy for the protection of their inventions. Moreover, although the majority of applications come from the IT and biotech sector, some 10% of Indian applications are from other industries such as automotive or garment sectors. If the value of 1 would be given to a dummy for IT inventions and 0 for the rest industries; which completely differ from each other (biotech and auto, for example), this would yield misleading results[13]. Hence, defining biotech as the main industry of study tackles this issue since the other industries are somewhat more similar in their IP protection patterns.

The definition of industry was based on patent classification. When inventions are introduced in the USPTO for review, they are assigned a classification number according to their technology, processes, and structural and functional characteristics that concern the spectrum of the class. Consequently, patent class, can be a good determinant of the type of industry these inventions come from. Patent classification usually is a three-digit number (e.g. 726); the first number of this figure usually holds a general spectrum of the industry the invention comes from. Therefore, guiding industry definition by USPTO patent classification yields 10 different industries (from 0-9) in which inventions fall into.

Nonetheless, several of these industries can be considered one big industry. Therefore, when defining the IT and Biotech industries for my empirical tests I looked at the description of inventions falling on the different numbers. From this analysis I concluded that patents with a starting number of 3 and 7 could be considered from the IT sector and patents with starting number of 4 and 5 could be defined to hold inventions for the biotechnology industry. As explained in section 5, the sum of the patent applications of these two industries account for 90% of all the inventions in the data set.

Regardless of the somewhat straightforward industry definition, there are some limitations to this approach. When patent classification is looked by only seeing the first number of the figure, some ambiguity arises. The three-digit figure describes very specific processes or products encompassing very specific sciences understood by few and even if as a researcher I would have tried to look at every single three-digit classification I would fall short in both time and knowledge if I attempted to correctly and accurately match certain invention to

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[13] In fact, the same model for the IT sector was carried out following the procedure of patent classification to define industry (results are portrayed in the appendix, table 19) and although some interaction terms continue to be significant the DDD estimator yielded insignificant results.

certain industry. Hence, despite of the limitations that this definition may contain it offers both a concrete and easy way to separate inventions by sectors. Since this definition is done on the invention level, many companies may be categorised in both the IT and biotech industries since their research scope may be diversified into different sectors.

The model testing this extension is as follows (not that it was also regressed with dependent variables counting moves within 1 year and within 2 years of the application; variables are explained in table 6):

[3]

$$Moved = \beta_0 Foreign + \beta_1 After2005 + \beta_2 BIO + \beta_3 Foreign * After2005 + \beta_4 BIO * After2005 + \beta_5 Foreign * BIO + \beta_6 Foreign * BIO * After2005 + \varepsilon$$

In this final model the focus will be directed not only to the effect of the addition of the industry dummy but also to the interactive effect of the 2005 patent act on inventions coming from the biotechnology industry with foreign co-authors (the triple-differences estimator $Foreign * BIO * After2005$). As in the DD estimator, the triple-differences time effects are accounted for with the pre and post 2005 period denoting the change in legislation of product patents in the Patent Act of 2005. As explained before, this event had a strong effect on inventions coming from the biotechnology industry; which is denoted as the treatment group, while the control group comprises all the other industries (IT, automotive, etc.). All of this is at the same time controlled for depending if patents had a foreign co-author or no.

The triple-differences estimator shows the additional difference on mobility of an inventor with at least one foreign co-author relative to one with none, coming from the biotechnology industry relative to one coming from any other industry, from the period after 2005 relative to one from the period previous to 2005. The coefficient of interest for the analysis is then β_6. This DDD estimator exploits further differences than just year and foreign co-authorship alone. Thus, by adding the industry (and third) differentiation it may yield more convincing results (Angrist et al., 2008) on inventor mobility and knowledge spillovers in India.

7. Results and analysis

This section summarizes the results of the methodological analysis and at the same time puts forward several claims and arguments that may serve as explanations for the results obtained.

Section 7.1 does these for the first 2 models (models [1] and [2]) and section 7.2 does the same for the DDD extension

7.1 Whole model:

In order to first establish a relationship between inventor mobility, foreign co-authorship and the effect of the implementation of the 2005 Patent act, I estimate model [1] with a simple logit regression. Table 6 depicts the results for the dependent variables *Moved*, *Moved within 1year* and *Moved within 2years.* The model is run without adding a constant term and controlling for inventor fixed effects. The table displays the marginal effects of the logit model (see table 12 in appendix for complete set of results).

For the dependent variables, all coefficients are highly significant at the 0.01 level and with the expected negative signs. From these results, the first hypothesis is corroborated and the simple analysis is already indicating the explanatory power of the variables used. The probability that an inventor with a foreign co-authorship will move is reduced by 3.4 percentage points for the whole sample, by 2.7 percentage points for those who have moved within 1 year and 3.2 for those who have moved within 2 years. The results show how the evolution of outsourcing and the open innovation era is affecting different elements of the market, in this instance high-skilled labour mobility that translates into the possible transfer of knowledge. At the same time, the creation of networks among inventors may create intangible and strong ties among individuals; which will make them less likely to move to another firm (Breschi et al., 2005).

In regards of variable *After2005*, it may be probable that the Patent Act may have triggered higher inventive activity in firms. For the simple model, an inventor has 38 percentage points less probability to move in the whole moved count, 32 percentage points if she has moved within 1 year and almost 36 percentage points if she has moved within 2 years. Even though several attempts were made before 2005 in order to improve the IP rules and regulations of India, this year signified a true and relevant attempt to put India on track with WTO rules and international players.

Already Graph 2 (see section 5) showed how movement of inventors started to decrease after 2007. This effect may be explained with the argument that with the act implementation, product patents were given much more relevance in the innovative process hence creating incentives for innovative processes to develop. This legal enforcement, created a much more inviting environment for local scientists and inventors to remain at a firm or to even stay in India instead of migrating to foreign countries. This finding can be related to that of Agarwal et al. (2009) since they find patent enforcement in US firms has a negative effect on inventor mobility.

It can be contested that many events occurred after 2005 that could have affected inventor mobility. It can be argued that there may be non-compete agreements among firms affecting mobility of inventors. Nonetheless, as India is a developing country in many senses, the non-competes' implementation is at a much too early stage to play a significant factor determining mobility[14]. Another possible explanation to the decline of mobility after this date could be the aftermath effects of the financial crisis of 2008. For example, local IT firms are known to have high rate of employee mobility since individuals look for higher wages and faster moves on the managerial ladder. However, the global economic slowdown of 2008 had some contagion effects in the industry and made employees less mobile due to uncertainty (Einhorn, 2010). Nonetheless, this factor can be deemed to have played a secondary role since the data shows a sharp decline on mobility since 2007 rapidly regaining an increasing trend in 2009. Moreover, this decline was mainly driven by the IT industry since the biotech industry perceived such decline since 2006 (graph 1). Finally, the data set shows clear truncation after 2010, therefore the effects of the Patent Act can be seen only for approximately four years. It can be claimed that the complete effects of this legislation have not been grasped entirely yet since that the Act has some ambiguities and grey areas in its definitions as described by Basheer (2005).

On the second column of table 7, the model is extended adding the DD estimator. The independent variables continue to have a negative effect on mobility while being highly significant but their magnitudes are increased. For example, the probability that an inventor will move at all in the second model is decreased by 10.7 percentage points while in the simple model is decreased by only 3.4 percentage points. More interestingly, the newly added interaction term also results significant but positive. Hence the DD estimator portrays that there is an additional increase in the probability to move between firms for inventors that

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[14] See Choudhry, Tathagata (2011) and Kalra, Ajay (2012) for specific reports on non-compete agreements from the Competition Commission of India

have at least one foreign co-author relative to those who have none from 2006 relative to those before then.

Table 7. Simple logit and DD estimator

Marginal Effects

	[1]			[2]		
	Moved	Moved within 1 year	Moved within 2 years	Moved	Moved within 1 year	Moved within 2 years
Foreign	-0.034**	-0.027**	-0.032**	-0.107**	-0.517**	-0.118**
	[0.003]	[0.002]	[0.002]	[0.011]	[0.015]	[0.017]
After_2005	-0.380**	-0.322**	-0.359**	-0.449**	-0.422**	-0.449**
	[0.008]	[0.012]	[0.010]	[0.010]	[0.009]	[0.013]
Foreign*After_2005				0.184**	0.907**	0.241**
(DD)				[0.028]	[0.009]	[0.048]
Observations	12,553	12,553	12,553	12,553	12,553	12,553
Log-likelihood	-2406	-1542	-1970	-2320	-1452	-1874

Robust standard errors in brackets
Significance levels ** $p<0.01$, * $p<0.05$, + $p<0.1$

This result is contrary to my second hypothesis since patents with foreign co-authors applied for after 2005 will have a positive effect of 18 percentage points in the whole sample, 90.7 percentage points if the inventor moved within 1year and 24.1 percentage points if it moved within 2 years. This positive outcome may be largely due to the increase in both number of applications and foreign co-authorship after this period, in fact 42% of the unique inventions were applied for after 2005 and have a foreign co-author; additionally 43% of the total moves were from applications after 2005 with a foreign co-author. Also, even if an inventor possesses foreign co-inventors the networks involved may not be as strong, possibly due to localisation of networks (Breschi et al., 2005) thus giving the inventor incentives to move if she finds better opportunities elsewhere. Additionally, the period after 2005 may have induced an increase in employment opportunities making mobility easier.

Although these results indicate that hypothesis 2 may be rejected, it yields a whole new spectrum of possibilities both for this analysis and further study. This first analysis is indeed very broad since it included all the industries involved in innovative processes in India regardless of how different they may be regarding knowledge and intellectual protection usage. For this reason, and as explained previously, I will extend the study by adding industry differentiation of the biotechnology industry.

7.2 Model extension: industry definition, DD and DDD estimators

As an extension, a dummy for the biotechnology industry is included as well as the respective DD interactions and the DDD interaction of the new variable and previous ones. Table 8 reports a step-by-step regression path using the three dependent variables. The last three columns labelled as [3] (for model 3 depicted in the methodology section) show the results for the triple-differences estimator. Note that only the marginal effects are reported (see table 13 in appendix for full results)

It is important to note that for the dependent variable that measures if the move occurred within 1 year of the application, I was unable to regress the functions in column (d) and (f) with the logit model. The function was reported as not concave and could not be maximised. This may be due to possible multicollinearity of variables. Nonetheless when running a simple OLS regression all variables are reported (see table 14 in appendix for results); which would not be the case in the existence of this issue.

In a further attempt to optimise the function, I tried to change the maximisation algorithm of the model. Firstly, using a command that would indicate the program to change it automatically and later with the iterative methods of Berndt-Hall-Hall- Haussman (BHHH), Newton-Raphson (NR), the David-Fletcher-Powell (DFP) and the Broyden-Fletcher-Goldfarb-Shanno (BFGS) unsuccessfully. Due to time constraints and lack of further options, the results for the Moved within 1 year dependent variable in columns (d) and (f) are the marginal effects of a probit model. Even though is not completely consistent for the study, the probit model is quite similar to the logit counterpart, only differing in the distribution of the error term. Therefore it can be argued that results could still be used for the study at hand nonetheless.

Table 8 portrays very interesting and rich results derived from the model. The previous inference that the biotechnology industry in India could be an interesting case study is therefore justified. All explanatory variables continue to be highly significant and with the expected sing. The addition of industry distinction also adds explanatory power to the model and the variable itself is highly significant portraying a negative effect on inventor mobility. Although it has been stated that the biotechnology sector may present higher mobility of inventors due to the nature of the knowledge utilised, it can be possible that inventors' co-invention network may be highly localised in the firm (Breschi et al., 2009) deterring individuals to move. Additionally, it may be possible that some of the patent applications contain very rare and sophisticated technology. If an invention comprises a technology, and knowledge, that only a few specialised firms support and carry out, it is very possible that this inventor in particular will move less since she has less employment options.

The DD estimators are all significant and affect inventor mobility positively. As stated before, the DD estimator that interacts foreign co-authorship with the period after 2005 may show a positive effect since the majority of the patents were applied for in this time and international co-inventorship also spiked; additionally the strength of such networks may diminished by geographical distance and other employment opportunities.

Likewise, the interaction term *After2005*BIO* depicts a positive and significant effect on inventor mobility. Although it could be possible that after the 2005 Patent Act, mobility of inventors from the biotechnology industry would be reduced due to the increased importance in patenting, it may also be possible that the Patent Act implementation induced a labour and general market improvement creating more employment opportunities. Further, the tacit nature of the knowledge used in this industry which requires direct interaction to transfer knowledge may be causing this positive effect.

The last interaction term *Foreign*BIO* also portrays a highly significant and positive effect. This can be due to the fact that in all the patents with foreign co-authorship only 23% (amounting for 11% in the total sample) are from the biotech industry while almost 63% come from the IT sector. This effect may again be induced by the nature of the knowledge used in the industry, as knowledge is highly uncodified and transfer may require personal interactions, foreign co-authorships may not generate the strong networks created in other industries, hence the positive effect on knowledge spillovers as externalities.

The triple-differences interaction term is by far the estimator that shows the most compelling results. The triple-differences coefficient shows the expected negative effect, corroborating hypothesis 3. With highly significant coefficients, the marginal effect of the DDD estimator shows that there is an additional decline in the probability to move from one firm to another of an inventor with a patent application with a foreign co-author relative to one without a foreign co-inventor, coming from the biotechnology industry relative to one coming from any other industry after 2005 relative to before 2005.

In fact, the interaction term decreases the probability of an inventor moving intra firm by 5.8 percentage points for all the moves, 2.5 percentage points if the inventor has moved within 1 year of the application and 4.7 percentage points if she has moved within 2 years. The negative effect may be because this legislation mostly affected the biotechnology industry with the enforcement of product patents as IP protection tools. This means biotech (and pharma) firms were guaranteed protection on their inventions from possible copy-cats, more specifically from the generic medicine industry which has a huge industry in India and represents a main source of concern for innovative firms. Likewise, it may also be possible that the implementation of stronger patent laws generated incentives for MNCs to set shop in India or to outsource other operations, thus creating better working environments for inventors and as well as incentives to remain in the firm. Moreover, foreign co-authorship may have gained relevance once interacted as a treatment effect showing how the professional, social and intellectual ties created internationally deter inventor mobility after 2005.

For all the models, the log-likelihood continues to approach to zero, indicating that they are better predictors than the simple logit regressions. Also, as it would be expected, the results with *Moved_2year* are quite similar to those of *Moved* since the majority of the moves occur in the first three years of the application.

Although the results achieved are very significant and corroborate most of the hypotheses of the paper; they must be looked at with caution since there may be fixed effects that have not been accounted for and that could play an important role in inventor mobility in India.

Table 8. Logit model Industry differentiation, DD and DDD

Marginal effects

	(a)			(b)			(c)			(d)			(e)			(f)			[3] (g)		
	Moved	Moved 1 year	Moved 2 years	Moved	Moved 1 year	Moved 2 years	Moved	Moved 1 year	Moved 2 years	Moved	Moved 1 year++	Moved 2 years	Moved	Moved 1 year	Moved 2 years	Moved	Moved 1 year++	Moved 2 years	Moved	Moved 1 year	Moved 2 years
Foreign	-0.464**	-0.487**	-0.476**	-0.034**	-0.027**	-0.032**	-0.028**	-0.019**	-0.024**	-0.091**	-0.521**	-0.091**	-0.078**	-0.928**	-0.086**	-0.080**	-0.485**	-0.086**	-0.146**	-0.515**	-0.171**
	[0.003]	[0.002]	[0.002]	[0.003]	[0.002]	[0.002]	[0.003]	[0.002]	[0.003]	[0.011]	[0.018]	[0.015]	[0.010]	[0.007]	[0.013]	[0.009]	[0.015]	[0.013]	[0.026]	[0.015]	[0.056]
After_2005				-0.380**	-0.322**	-0.359**	-0.328**	-0.234**	-0.283**	-0.392**	-0.345**	-0.354**	-0.473**	-0.359**	-0.452**	-0.456**	-0.417**	-0.449**	-0.476**	-0.424**	-0.460**
				[0.008]	[0.012]	[0.010]	[0.010]	[0.013]	[0.012]	[0.013]	[0.013]	[0.015]	[0.015]	[0.021]	[0.018]	[0.016]	[0.016]	[0.020]	[0.018]	[0.016]	[0.021]
BIO							-0.027**	-0.019**	-0.027**	-0.024**	-0.018**	-0.026**	-0.066**	-0.047**	-0.069**	-0.067**	-0.071**	-0.069**	-0.079**	-0.074**	-0.080**
							[0.003]	[0.002]	[0.002]	[0.003]	[0.002]	[0.002]	[0.006]	[0.008]	[0.007]	[0.006]	[0.009]	[0.007]	[0.007]	[0.009]	[0.009]
Foreign*After2005										0.148**	0.912**	0.173**	0.128**	0.999**	0.167**	0.117**	0.900**	0.164**	0.308**	0.918**	0.432**
(DD)										[0.025]	[0.010]	[0.039]	[0.023]	[0.000]	[0.037]	[0.024]	[0.010]	[0.042]	[0.072]	[0.009]	[0.157]
After2005*BIO													0.188**	0.265**	0.241**	0.171**	0.317**	0.237**	0.252**	0.324**	0.325**
(DD)													[0.024]	[0.066]	[0.040]	[0.027]	[0.048]	[0.047]	[0.034]	[0.049]	[0.056]
Foreign*BIO																0.018	-0.002	0.003	0.627**	0.412**	0.809**
(DD)																[0.012]	[0.004]	[0.009]	[0.122]	[0.061]	[0.143]
After2005*Foreign*BIO																			-0.058**	-0.025**	-0.047**
(DDD)																			[0.005]	[0.002]	[0.006]
N	12,553	12,553	12,553	12,553	12,553	12,553	12,553	12,553	12,553	12,553	12,553	12,553	12,553	12,553	12,553	12,553	12,553	12,553	12,553	12,553	12,553
Log-likelihood	-6063	-5643	-5851	-2406	-1542	-1970	-2348	-1406	-1860	-2283	-1387	-1791	-2167	-1208	-1667	-2165	-1208	-1667	-2136	-1208	-1647

Robust standard errors in brackets
Significance levels: ** p<0.01, * p<0.05, + p<0.1
++ Results from probit estimation

8. Conclusions

This final section will serve as a conclusive part of the whole research. While concretely the most important information and points discussed throughout the pater, this conclusion looks to serve somewhat as a summary and as an open invitation for further research.

Ever since India achieved independence in 1947 the country went through a political and economic transitional period ruled by tight and strict measures that praised nationalism. Some forty-odd years later, the country experienced several events that propelled the economy and allowed international investment to the nation. In 1985 Texas Instruments moved operations to Bangalore and in the early 90s India liberalised its economy. Consequently, looking at TI's success and at the many favourable factors present in the country, any other MNCs followed suit and outsourced operations to the back office of the world. The emergence of India as an MNC magnet did not come by chance though; the strong State emphasis in education created an enormous pool of highly skilled quality workers, together with low wages, the common use of the English language and a group of expats willing to give a chance back to their country made India one of the most adequate centre for outsourcing in the developing world. The IT and biotechnology sectors became predominantly present in the country and as the years went by operations and departments were moved to India. What started as a cost strategic move expanded to what now are established subsidiaries of MNCs.

My research focused on mobility of Indian inventors among firms as a source of knowledge spillovers. Using US patent application data I was able to track domestic inventor movement from the period 2001-2012 and analysed how this was affected by very specific variables and events. Focusing on foreign co-authorship, the patent act of 2005 and the biotechnology industry I test the effect these variables have in inventor mobility both individually and interacted among each other.

The econometrical study yielded many interesting results in regards of the effect of international co-authorship in inventor mobility in India. For one, it was demonstrated all three variables have a negative effect in inventor mobility. Secondly, when interacted among each other, the DD estimators depict an additional increase in the probability of knowledge spillovers that there is an additional for those inventors that have at least one foreign co-author relative to those who have none from 2006 relative to patents applied before then. Thirdly, the triple interaction term demonstrates that there is an additional decline in the probability to move from one firm to another of an inventor with a patent application with a foreign co-author relative to one without a foreign co-inventor, coming from the biotechnology industry relative to one coming from any other industry after 2005 relative to before 2005.

It can be argued that the increasing number of collaboration among inventors residing in different countries has decreased the propagation of knowledge spillovers as externalities. Further, it may be possible that inventor mobility in India was deterred after 2005, most probably due to the Patent Act of 2005 and the fact that product patents were acknowledged as legitimate tools for IP protection. Additionally, if an inventor applies for patents from the biotechnology sector she may be less probable to move; probably since it is an industry that clearly relies on patents as an IP protection tool due to its complex and lengthy innovative process.

The extensions of the models with the DD and DDD estimators demonstrate different effects playing in inventor mobility. The positive effects of the DD coefficients may be due to the large increase in both patent applications and foreign participation the period hence stimulating movement of inventors in search of more competitive salaries. In fact the interaction term after 2005 and foreign co-authorship may be mostly driven by the majority of IT patent applications; an industry in which mobility is known to be very high. Further, the biotechnology industry is known to work with a tacit and un-codified base of knowledge; this means that knowledge cannot be easily transferred in written form and human interaction is needed. Therefore, it can be argued that the interaction effects with biotechnology have a positive effect because the tacit knowledge greatly influences inventor mobility. Finally, the triple-differences coefficient shows how these three forces work negatively in inventor mobility because the formation of international ties along with the legalisation of product patents and the probable complex nature of research in the biotech industry makes it less likely for inventors to move and create externalities as knowledge spillovers.

Although this research shed some lights on the determinants of inventor mobility in India, there is still much room for improvement in the study. It is important to denote the relevance of different fixed effects that may be otherwise absorbed by the error term and were not accounted for (e.g. firm fixed effects, further industry fixed effects, etc). Additionally, the Patent Act’s total effect still remains to be seen for the longer term. Nonetheless, I can attest that the forces working in the innovative process in India for this specific study created different effects in knowledge spillovers seen as externalities.

Due to the high rate of co-authorship (both domestic and international) knowledge spillovers inside the firm may still be occurring and it is possible that in years to come employees will spin off creating new firms with the previously acquired knowledge. Thus, the topic of knowledge spillovers India still offers numerous opportunities for further studies since it is a country known for its rapid market changes and adaptation. Time and industry evolution will shape these patterns into more concrete behaviours; for now, however, it is interesting to see the drastic changes a country can face in just a few decades while trying to determine what factors play important roles in such relevant topics as innovation and knowledge spillovers.

It is important to note that even though it has been shown that several growing factors and events in India deter the generation of knowledge spillovers, this analysis uses its concept as an externality and knowledge transfers may still be occurring in an inter-firm manner. Although the inventor is less likely to move, when these international co-authors interact to create new products or processes there is an obvious share of knowledge occurring in the process and intra-firm networks not accounted for in this study may be a representation of transfer of ideas (Simard et al., 2006) but they are simply not externalities. Therefore, although no externalities are occurring, ideas and knowledge are still being transferred from one scientist to another; which in turn may be transferred to other inventors in the firm or in broader social networks (Breschi et al., 2005). Nonetheless, this last statement is based on many assumptions and the quantification of these types of spillovers is very limited.

Lastly, even though this research focuses on very novel topics, it only essays to model transfer of knowledge spillovers but does not look into the consequences this process has on the innovative process, success of a firm or economic development; topics which have far more interesting connotations for industries and policy makers alike. Hence, a window of opportunities for further research is open in the study of innovation in developing countries.

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10. Appendices

Table 9. Movement of inventors detailed by year

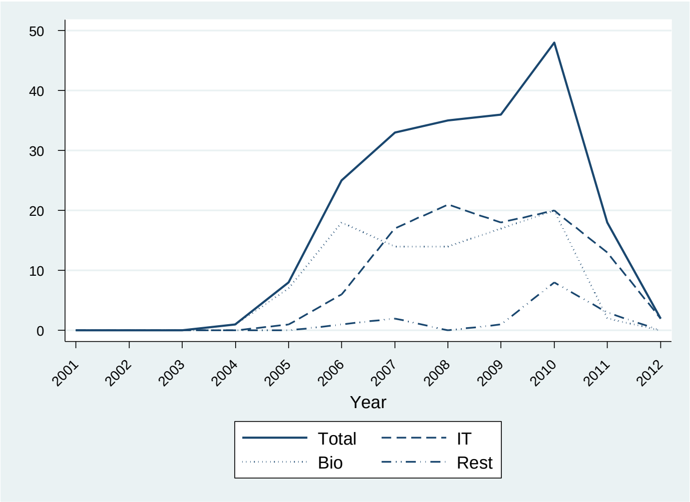
Year	Moved from company whole sample	Within 1 year	Within 2 years	Within 3 years
2001	0	0	0	0
2002	3	0	0	0
2003	11	0	0	0
2004	30	1	7	8
2005	39	8	17	23
2006	76	25	35	45
2007	102	33	52	77
2008	81	35	56	75
2009	86	36	78	85
2010	69	48	66	69
2011	21	18	21	21
2012	2	2	2	2
Total	**520**	**206**	**334**	**405**

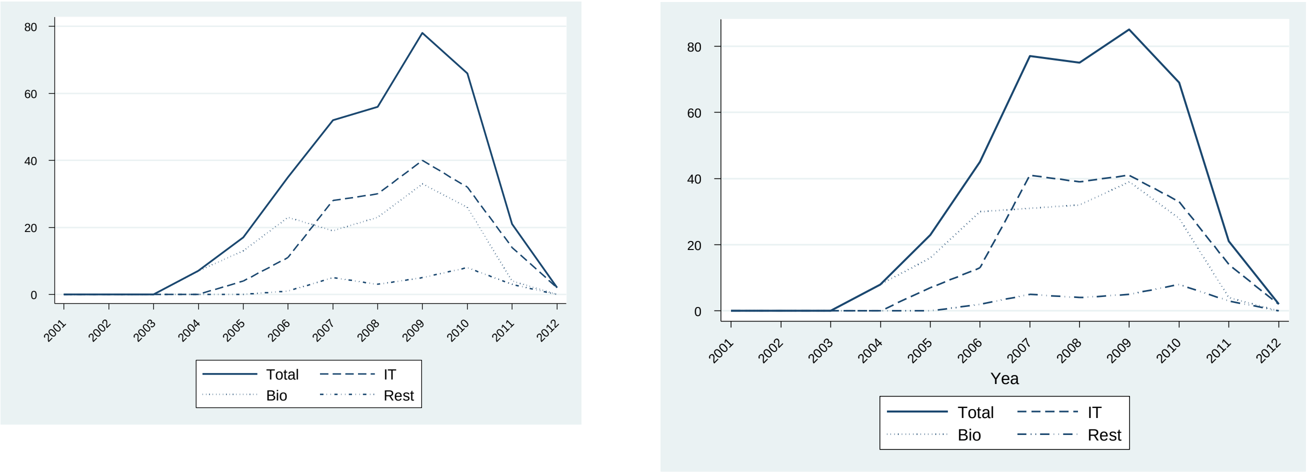
Table 10. Moves by industry

	Moved from company whole sample							Within 1 year							Within 2 years						
Year	IT		Bio		Rest		**Total**	IT		Bio		Rest		**Total**	IT		Bio		Rest		**Total**
2001	0		0		0		**0**	0		0		0		**0**	0		0		0		**0**
2002	1		2		0		**3**	0		0		0		**0**	0		0		0		**0**
2003	8		2		1		**11**	0		0		0		**0**	0		0		0		**0**
2004	6		21		3		**30**	0		1		0		**1**	0		7		0		**7**
2005	12		25		2		**39**	1		7		0		**8**	4		13		0		**17**
2006	27		46		3		**76**	6		18		1		**25**	11		23		1		**35**
2007	53		42		7		**102**	17		14		2		**33**	28		19		5		**52**
2008	42		35		4		**81**	21		14		0		**35**	30		23		3		**56**
2009	42		39		5		**86**	18		17		1		**36**	40		33		5		**78**
2010	33		28		8		**69**	20		20		8		**48**	32		26		8		**66**
2011	14		4		3		**21**	13		2		3		**18**	14		4		3		**21**
2012	2		0		0		**2**	2		0		0		**2**	2		0		0		**2**
Total	**240**	**46.10%**	**244**	**46.90%**	**36**	**6.90%**	**520**	**98**	**47.50%**	**93**	**45.10%**	**15**	**7.20%**	**206**	**161**	**48.20%**	**148**	**44.30%**	**25**	**7.40%**	**334**

Graph 4. Moves by year by industry

(a) Within 1 year



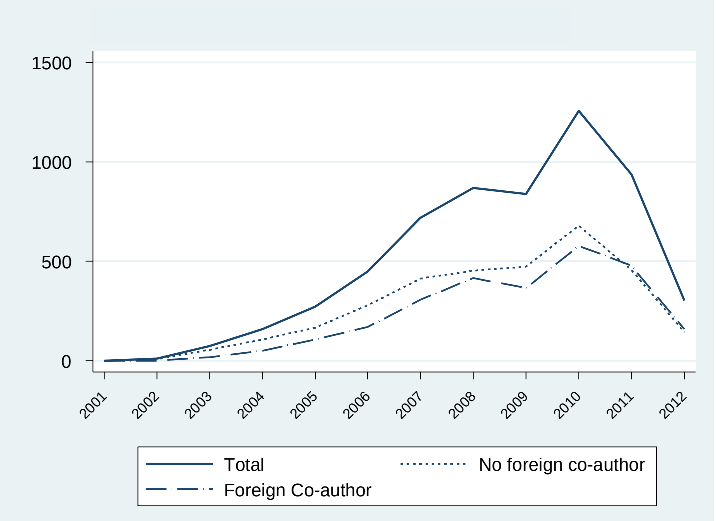


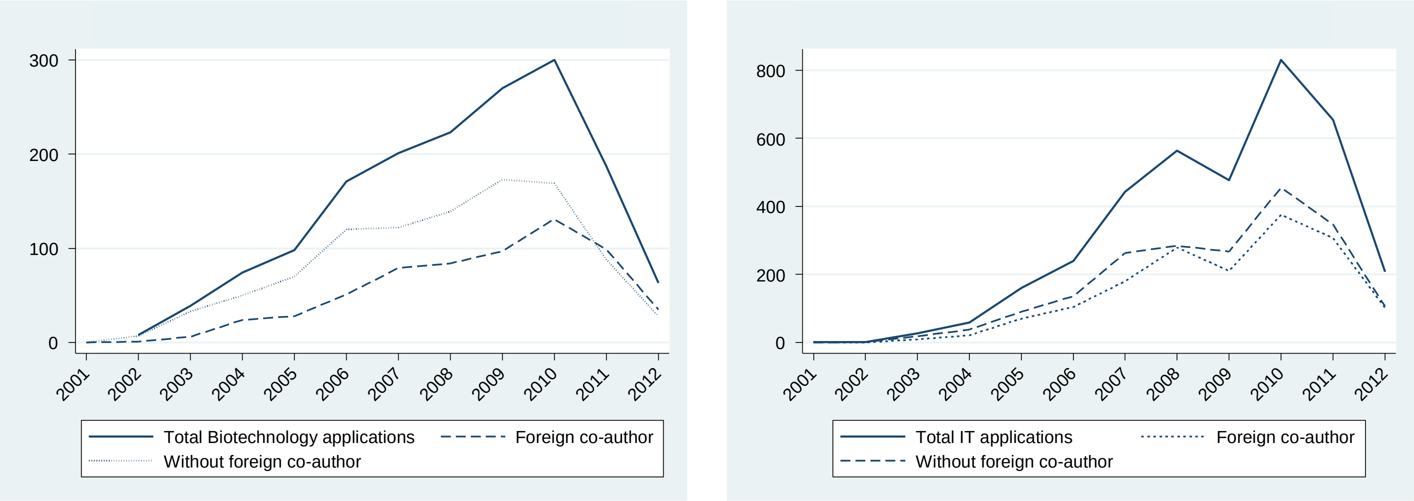
(b) Within 2 years

(c) Within 3 years

Graph 5. Foreign co-authorship

(a) Whole sample





(b) Biotechnology Industry

(c) IT Industry

Table 11. Number of patent applications with foreign co-authors per year

Year	Total patent applications	With foreign co-author	%
2001	1	1	100
2002	10	1	10
2003	73	18	24.65
2004	158	51	32.27
2005	273	107	39.19
2006	449	170	37.86
2007	719	306	42.55
2008	869	416	47.87
2009	838	365	43.55
2010	1,256	577	45.93
2011	936	479	51.17
2012	302	158	52.31
Total	**5,884**	**2,649**	**45.02**

Table 12. Logit model whole sample

Models [1] and [2]

													[1]						[2]					
	Moved		Moved 1 year		Moved 2 years		Moved		Moved 1 year		Moved 2 years		Moved		Moved 1 year		Moved 2 years		Moved		Moved 1 year		Moved 2 years	
	Coeff	Mfx	Coeff	Mfx	Coeff	Mfx	Coeff	Mfx	Coeff	Mfx	Coeff	Mfx	Coeff	Mfx	Coeff	Mfx	Coeff	Mfx	Coeff	Mfx	Coeff	Mfx	Coeff	Mfx
Foreign	-3.280**	-0.464**	-4.311**	-0.487**	-3.713**	-0.476**							-0.901**	-0.034**	-1.767**	-0.027**	-1.244**	-0.032**	-2.743**	-0.107**	-5.483**	-0.517**	-3.781**	-0.118**
	[0.084]	[0.003]	[0.141]	[0.002]	[0.106]	[0.002]							[0.095]	[0.003]	[0.149]	[0.002]	[0.116]	[0.002]	[0.238]	[0.011]	[0.011]	[0.015]	[0.383]	[0.017]
After_2005							-3.319**	-0.465**	-4.114**	-0.484**	-3.673**	-0.475**	-3.043**	-0.380**	-3.706**	-0.322**	-3.333**	-0.359**	-3.312**	-0.449**	-2.112**	-0.422**	-3.651**	-0.449**
							[0.064]	[0.002]	[0.100]	[0.002]	[0.079]	[0.002]	[0.062]	[0.008]	[0.094]	[0.012]	[0.074]	[0.010]	[0.080]	[0.010]	[0.047]	[0.009]	[0.097]	[0.013]
Inter_Foreign_2005																			2.726**	0.184**	5.402**	0.907**	3.724**	0.241**
(DD)																			[0.257]	[0.028]	[0.065]	[0.009]	[0.398]	[0.048]
N	12,553	12,553	12,553	12,553	12,553	12,553	12,553	12,553	12,553	12,553	12,553	12,553	12,553	12,553	12,553	12,553	12,553	12,553	12,553	12,553	12,553	12,553	12,553	12,553
Log-likelihood	-6063	-6063	-5643	-5643	-5851	-5851	-2466	-2466	-1671	-1671	-2058	-2058	-2406	-2406	-1542	-1542	-1970	-1970	-2320	-2320	-1452	-1452	-1874	-1874

Robust standard errors in brackets
Significance levels: ** p<0.01, * p<0.05, + p<0.

Table 13. Logit model with biotechnology differentiation

Model 3. DDD estimator

																											[3]			
	Moved		Moved 1 year		Moved 2 years		Moved		Moved 1 year++		Moved 2 years		Moved		Moved 1 year		Moved 2 years		Moved		Moved 1 year++		Moved 2 years		Moved		Moved 1 year		Moved 2 years	
	Coeff	Mfx	Coeff	Mfx	Coeff	Mfx	Coeff	Mfx	Coeff	Mfx	Coeff	Mfx	Coeff	Mfx	Coeff	Mfx	Coeff	Mfx	Coeff	Mfx	Coeff	Mfx	Coeff	Mfx	Coeff	Mfx	Coeff	Mfx	Coeff	Mfx
Foreign	-0.788**	-0.028**	-1.498**	-0.019**	-1.050**	-0.024**	-2.506**	-0.091**	-5.669**	-0.521**	-3.436**	-0.091**	-2.248**	-0.078**	-17.831**	-0.928**	-3.252**	-0.086**	-2.293**	-0.080**	-5.543**	-0.485**	-3.255**	-0.086**	-3.795**	-0.146**	-5.683**	-0.515**	-5.198**	-0.171**
	[0.095]	[0.003]	[0.146]	[0.002]	[0.115]	[0.003]	[0.241]	[0.011]	[0.009]	[0.018]	[0.386]	[0.015]	[0.251]	[0.010]	[0.075]	[0.007]	[0.393]	[0.013]	[0.234]	[0.009]	[0.015]	[0.015]	[0.387]	[0.013]	[0.505]	[0.026]	[0.016]	[0.015]	[1.004]	[0.056]
After_2005	-2.863**	-0.328**	-3.417**	-0.234**	-3.088**	-0.283**	-3.123**	-0.392**	-1.956**	-0.345**	-3.374**	-0.354**	-3.509**	-0.473**	-4.235**	-0.359**	-3.796**	-0.452**	-3.437**	-0.456**	-2.199**	-0.417**	-3.780**	-0.449**	-3.535**	-0.476**	-2.199**	-0.424**	-3.840**	-0.460**
	[0.060]	[0.010]	[0.090]	[0.013]	[0.072]	[0.012]	[0.076]	[0.013]	[0.045]	[0.013]	[0.093]	[0.015]	[0.097]	[0.015]	[0.153]	[0.021]	[0.117]	[0.018]	[0.100]	[0.016]	[0.064]	[0.016]	[0.126]	[0.020]	[0.108]	[0.018]	[0.064]	[0.016]	[0.132]	[0.021]
BIO	-0.814**	-0.027**	-1.635**	-0.019**	-1.285**	-0.027**	-0.673**	-0.024**	-0.561**	-0.018**	-1.159**	-0.026**	-2.138**	-0.066**	-4.326**	-0.047**	-3.147**	-0.069**	-2.158**	-0.067**	-2.224**	-0.071**	-3.149**	-0.069**	-2.579**	-0.079**	-2.225**	-0.074**	-3.619**	-0.080**
	[0.105]	[0.003]	[0.152]	[0.002]	[0.130]	[0.002]	[0.110]	[0.003]	[0.081]	[0.002]	[0.135]	[0.002]	[0.178]	[0.006]	[0.453]	[0.008]	[0.288]	[0.007]	[0.172]	[0.006]	[0.174]	[0.009]	[0.285]	[0.007]	[0.205]	[0.007]	[0.174]	[0.009]	[0.321]	[0.009]
Foreign*After2005							2.445**	0.148**	5.546**	0.912**	3.310**	0.173**	2.273**	0.128**	17.664**	0.999**	3.225**	0.167**	2.143**	0.117**	5.501**	0.900**	3.191**	0.164**	3.878**	0.308**	5.641**	0.918**	5.274**	0.432**
(DD)							[0.259]	[0.025]	[0.069]	[0.010]	[0.401]	[0.039]	[0.269]	[0.023]	[0.183]	[0.000]	[0.407]	[0.037]	[0.299]	[0.024]	[0.080]	[0.010]	[0.466]	[0.042]	[0.522]	[0.072]	[0.080]	[0.009]	[1.017]	[0.157]
After2005*BIO													2.629**	0.188**	4.820**	0.265**	3.520**	0.241**	2.484**	0.171**	2.442**	0.317**	3.485**	0.237**	3.125**	0.252**	2.442**	0.324**	4.093**	0.325**
(DD)													[0.206]	[0.024]	[0.491]	[0.066]	[0.313]	[0.040]	[0.241]	[0.027]	[0.196]	[0.048]	[0.368]	[0.047]	[0.245]	[0.034]	[0.196]	[0.049]	[0.360]	[0.056]
Foreign*BIO																			0.423+	0.018	-0.062	-0.002	0.099	0.003	4.320**	0.627**	2.225**	0.412**	5.773**	0.809**
(DD)																			[0.242]	[0.012]	[0.130]	[0.004]	[0.307]	[0.009]	[0.603]	[0.122]	[0.176]	[0.061]	[1.104]	[0.143]
After2005*Foreign*BIO																									-4.468**	-0.058**	-2.286**	-0.025**	-6.053**	-0.047**
(DDD)																									[0.641]	[0.005]	[0.220]	[0.002]	[1.127]	[0.006]
N	12,553	12,553	12,553	12,553	12,553	12,553	12,553	12,553	12,553	12,553	12,553	12,553	12,553	12,553	12,553	12,553	12,553	12,553	12,553	12,553	12,553	12,553	12,553	12,553	12,553	12,553	12,553	12,553	12,553	12,553
Log-likelihood	-2348	-2348	-1406	-1406	-1860	-1860	-2283	-2283	-1387	-1387	-1791	-1791	-2167	-2167	-1208	-1208	-1667	-1667	-2165	-2165	-1208	-1208	-1667	-1667	-2136	-2136	-1208	-1208	-1647	-1647

Robust standard errors in brackets

Significance levels: ** p<0.01, * p<0.05, + p<0.1

++ Results from probit estimation

Table 14. OLS results for *Moved_1year*

(testing for multicollinearity issues)

	Moved_1year	
Foreign	-0.004**	-0.003
	[0.001]	[0.003]
After_2005	0.014**	0.014**
	[0.002]	[0.002]
BIO	0.009**	0.012*
	[0.003]	[0.005]
Inter_Foreign_2005	0.001	0.002
	[0.003]	[0.003]
Inter_2005_BIO		-0.002
		[0.006]
Inter_Foreign_BIO		-0.005
		[0.005]
Observations	12,553	12,553
R-squared	0.017	0.017

Robust standard errors in brackets
** p<0.01, * p<0.05, + p<0.1

Model with IT as industry

$$Moved = \beta_0 Foreign + \beta_1 After2005 + \beta_2 IT + \beta_3 Foreign * After2005 + \beta_4\, IT * After2005 + \beta_5 Foreign * IT + \beta_6 Foreign * IT * After2005 + \varepsilon$$

Table 15. Variable description

Name	Variable	Description
IT	Independent variable	Dummy with the of 1 if industry is IT
*IT*After2005*	Interaction term (DD)	Counts all the inventions from the IT industry applied for after 2005
*Foreign*IT*	Interaction term (DD)	Counts all the inventions from the IT industry that have at least 1 foreign co-author
*Foreign*IT*After2005*	Interaction term (DDD)	Counts all the inventions from the IT industry applied after 2005 with at least 1 foreign co-author

Table 16. Logit model with IT differentiation

	Moved		Moved 1 year		Moved 2 years		Moved		Moved 1 year+++		Moved 2 years		Moved		Moved 1 year+++		Moved 2 years		Moved		Moved 1 year		Moved 2 years		Moved		Moved 1 year+++		Moved 2 years	
	Coeff	Mfx	Coeff	Mfx	Coeff	Mfx	Coeff	Mfx	Coeff	Mfx	Coeff	Mfx	Coeff	Mfx	Coeff	Mfx	Coeff	Mfx	Coeff	Mfx	Coeff	Mfx	Coeff	Mfx	Coeff	Mfx	Coeff	Mfx	Coeff	Mfx
Foreign	-0.672**	-0.022**	-1.381**	-0.016**	-0.943**	-0.020**	-2.349**	-0.079**	-5.523**	-0.482**	-3.332**	-0.082**	-2.096**	-0.073**	-5.562**	-0.486**	-3.092**	-0.079**	-2.139**	-0.075**	-17.352**	-0.913**	-3.100**	-0.079**	-2.262**	-0.080**	-5.826**	-0.537**	-3.239**	-0.085**
	[0.093]	[0.003]	[0.146]	[0.002]	[0.114]	[0.002]	[0.239]	[0.010]	[0.015]	[0.020]	[0.385]	[0.014]	[0.245]	[0.009]	[0.013]	[0.016]	[0.388]	[0.013]	[0.243]	[0.010]	[0.063]	[0.008]	[0.387]	[0.013]	[0.272]	[0.011]	[0.044]	[0.017]	[0.417]	[0.015]
After2005	-2.564**	-0.253**	-3.065**	-0.164**	-2.778**	-0.215**	-2.823**	-0.311**	-1.816**	-0.285**	-3.078**	-0.280**	-3.097**	-0.380**	-2.014**	-0.349**	-3.465**	-0.372**	-3.015**	-0.361**	-3.723**	-0.256**	-3.372**	-0.352**	-3.029**	-0.366**	-1.985**	-0.348**	-3.381**	-0.358**
	[0.063]	[0.011]	[0.086]	[0.013]	[0.071]	[0.012]	[0.080]	[0.014]	[0.046]	[0.015]	[0.094]	[0.016]	[0.100]	[0.019]	[0.059]	[0.018]	[0.123]	[0.023]	[0.103]	[0.020]	[0.149]	[0.025]	[0.125]	[0.024]	[0.105]	[0.021]	[0.062]	[0.019]	[0.126]	[0.024]
IT	-1.134**	-0.045**	-1.725**	-0.028**	-1.393**	-0.038**	-1.024**	-0.041**	-0.644**	-0.027**	-1.284**	-0.037**	-2.473**	-0.134**	-2.714**	-0.270**	-4.331**	-0.252**	-2.504**	-0.137**	-5.704**	-0.253*	-4.346**	-0.254**	-2.590**	-0.144**	-2.714**	-0.278**	-4.598**	-0.287**
	[0.086]	[0.003]	[0.133]	[0.003]	[0.102]	[0.003]	[0.089]	[0.003]	[0.063]	[0.002]	[0.106]	[0.003]	[0.206]	[0.017]	[0.331]	[0.062]	[0.504]	[0.056]	[0.207]	[0.017]	[1.002]	[0.107]	[0.502]	[0.056]	[0.224]	[0.019]	[0.331]	[0.064]	[0.581]	[0.071]
Foreign*After2005							2.352**	0.131**	5.459**	0.895**	3.299**	0.163**	2.087**	0.114**	5.486**	0.897**	3.041**	0.147**	1.906**	0.100**	16.942**	0.998**	2.781**	0.126**	2.069**	0.113**	5.661**	0.920**	2.949**	0.141**
(DD)							[0.260]	[0.023]	[0.069]	[0.012]	[0.400]	[0.038]	[0.264]	[0.021]	[0.066]	[0.010]	[0.403]	[0.034]	[0.282]	[0.021]	[0.255]	[0.000]	[0.427]	[0.033]	[0.310]	[0.025]	[0.107]	[0.012]	[0.442]	[0.038]
After2005*IT													2.081**	0.081**	2.535**	0.140**	3.997**	0.136**	1.945**	0.075**	5.106**	0.103*	3.823**	0.126**	2.061**	0.080**	2.476**	0.140**	4.096**	0.143**
(DD)													[0.229]	[0.011]	[0.338]	[0.033]	[0.524]	[0.028]	[0.240]	[0.011]	[1.028]	[0.041]	[0.542]	[0.028]	[0.257]	[0.012]	[0.343]	[0.034]	[0.609]	[0.035]
Foreign*IT																			0.426*	0.018+	0.409	0.005	0.495+	0.014+	1.221*	0.064	2.714**	0.452**	2.800*	0.174
(DD)																			[0.210]	[0.010]	[0.320]	[0.005]	[0.263]	[0.009]	[0.616]	[0.044]	[0.332]	[0.099]	[1.233]	[0.148]
Foreig*After2005*IT																									-0.872	-0.027	-2.549**	-0.053**	-2.359+	-0.040*
(DDD)																									[0.644]	[0.017]	[0.355]	[0.009]	[1.253]	[0.017]
N	12,553	12,553	12,553	12,553	12,553	12,553	12,553	12,553	12,553	12,553	12,553	12,553	12,553	12,553	12,553	12,553	12,553	12,553	12,553	12,553	12,553	12,553	12,553	12,553	12,553	12,553	12,553	12,553	12,553	12,553
Log-likelihood	-2293	-2293	-1392	-1392	-1836	-1836	-2234	-2234	-1361	-1361	-1768	-1768	-2179	-2179	-1246	-1246	-1678	-1678	-2177	-2177	-1245	-1245	-1676	-1676	-2176	-2176	-1245	-1245	-1675	-1675

Robust standard errors in brackets

Significance levels: ** $p<0.01$, * $p<0.05$, + $p<0.1$

++ Results from probit estimation