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Innovation and Knowledge Spillovers in Developing Countries

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Innovation and Knowledge Spillovers in Developing Countries

Elif Bascavusoglu[*][†]

Abstract

The purpose of this paper is to evaluate empirically the determinants of innovative activities in emerging countries, with particular attention to national, international and intersectoral knowledge spillovers. Our study concerns 16 emerging and 10 technology source countries, for the period 1980–1999 when the majority of the countries studied undertook institutional reforms with the aim of increasing their technological capacity. We introduce foreign knowledge stocks, constructed according to the trade-growth approach, into a knowledge production framework, by means of patent citations. We expand on previous studies by taking into account the role of institutions and various measures of proximity between technology source and recipient countries. Our findings show that emerging countries, although they rely on foreign technology, also benefit from their own R&D efforts. Our results also indicate that the timing of IPR reforms and financing issues are the greatest problems in the innovation process, and highlight the positive role played by international trade in the technology transfer process.

Keywords : innovation, knowledge spillovers, technology transfer, patent citations.

JEL Classification : F1, F2, O3

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1 Introduction

In the evolutionary framework, innovation is considered to be an accumulation of past competencies (Winter, 1971), and cognitive, organizational and productive learning (Pavitt, 1984). In addition, technology transfer is considered from a new point of view: as well as a transfer of material, it is also a process of transferring concepts and capacities (Dosi, 1993). The notion of technology transfer is not limited to the acquisition of a new technology, but also refers to the acquisition of a new technical capacity, allowing for a new technological trajectory[1]. Thus, the process of technology diffusion presents strong similarities with the process of innovation.

As suggested by Hall (2004), without diffusion, innovation would have little social or economic impact: "Understanding the diffusion process is the key to understanding how conscious innovative activities conducted by firms and government institutions, activities such as funding research and development, transferring new technology, launching new products or creating new processes, produce the improvements in economic and social welfare which are usually the end goal of these activities"[2]. Consequently, for developing economies, which are in large part 'followers' in terms of new technology, diffusion is the most important part of the innovation process. Therefore, the externalities of existing knowledge – that is, technological spillovers – are as important as innovations in analysing the world's growth performance and innovation patterns. Meanwhile, a certain number of developing economies have recently attained the status of 'technology creators' (Mani and Romijn, 2005) as a result of a long process of training and incremental innovation. Nevertheless, apart from some studies on South East Asia (Krugman, 1994; Kim and Nelson, 2000; Hu and Jaffe, 2003), the empirical literature seems to have underestimated this technological dynamism of emerging countries.

This paper aims to fill this gap, by presenting a panel data analysis of innovation activities in emerging countries. We consider these countries to be technology producers, which is rare in the literature, and seek to evaluate the determinants of their innovative capacities. However, knowing that these countries also rely on foreign technology, our principal objective is to highlight the role of technology transfer in the innovation process.

The particularity of our study is that we combine several methods in order to demonstrate the determinants of innovation in emerging countries. We introduce foreign knowledge stocks, constructed according to the trade-growth approach, into a knowledge production framework by the use of patent citations. We expand on previous studies by taking into account the role of institutions, following national innovation systems theory. In addition to international spillover variables, we also consider national spillovers, using self-citations (Mancusi, 2004).

We propose an empirical exploration of the innovation activities of 16 emerging countries at the sectoral level, during the period 1980–1999. The use of disaggregated sectoral level data allows us to

[1] For a discussion of definitions and various typologies of the technical capacity concept, see Reddy and Zhao (1990).
[2] Hall (2004) p.3.

evaluate different patterns of innovation according to the technological specialization of industries. We also seek to analyse the impact of different social or cultural links on the technology transfer process by taking into account cultural and historical proximity variables between industrialized and emerging countries (Lundvall, 1992; Keller, 2002; Hussler, 2004).

Our choice of countries may need some explanation. The subjects of our study are 'emerging' rather than developing countries. Although there is no clear-cut definition of these terms, we consider that emerging countries constitute the more developed part of developing countries. All the countries in our sample are above a certain level of technical ability and development, and are therefore more likely to absorb and adopt foreign technology. Given the otherwise relatively high level of development and innovative capacity of some of the countries in our sample, referring to these as 'emerging' countries may seem open to question. However, taking into account the period of analysis, we believe that this study highlights the learning process of these countries. By carrying out a cross-country time-series analysis, our particular concern is to indicate what distinguishes these countries from those that had not reached the same technological and development level. Finally, we argue that, if we had not included the more successful countries in our sample, we would have risked underestimating the learning process of emerging and/or developing countries as a whole.

The remainder of the paper is organized as follows: a brief survey of the innovation process in emerging countries is presented in Section 2. The following two sections describe the database, variables, empirical specification, and estimation method used. Section 5 presents and discusses our results, and the conclusion is given in Section 6.

2 Innovation in Emerging Countries: State of the Art

A key characteristic of developing countries is the fragile link between the production of knowledge and their economic systems (Nelson, 1993). In this context, the analysis of national systems of innovation, considered as an essential base for economic development in the long run, is crucial for developing countries (Lundvall, 1992; Nelson, 1993; Furman et al., 2002). Within this framework, the ability to use a technology effectively depends on the formation and versatility of the labour force, the quality of relations between the public sector and institutions, and the nature of the system of intellectual property rights (IPR), as well as on public programmes (Amable et al., 1997).

However, the greater part of the literature on national systems of innovation concentrates on developed countries. Among the few exceptions are studies that focus on South East Asia (Kim and Nelson, 2000). The success of these countries is related mainly to industrial policies and positive interaction between the public and private sectors (Chang, 1997). Nevertheless, in most developing countries industrial innovation is largely informal, and the dominant cultural models underestimate scientific knowledge and technological innovation (Arocena and Sutz, 2005). Firms in these countries prefer to invest in machinery and equipment rather than in research and development (R&D). They seem to grow without deepening their technological capacities, and technological training is both slow and passive (Intarakumnerd et al., 2002). Moreover, there is an absence of links between the various actors (government, university, industry) necessary to stimulate a culture of innovation.

A number of differences exist between the innovation paths of leaders and those of technological followers (Forbes and Wield, 2000). For example, Porter and Stern (2001) find substantial differences in the innovative environment of countries of the Organization for Economic Cooperation and Development (OECD), on the one hand, and developing countries, on the other. Yet their index of national innovating capacity shows countries such as Taiwan, Singapore and Israel appearing alongside OECD countries. China and India, although still at a relatively low level of innovation, are progressing rather quickly. In fact, the absolute gap, in terms of innovativeness, between more industrialized and less industrialized countries is decreasing. Several countries, such as Ireland, Israel, Singapore, South Korea and Taiwan, which were initially imitators and consumers of innovation, have increased their innovating activities considerably (Furman and Hayes, 2004). Analysis of the degree of specialization in developing countries shows that exports in high technology are concentrated in certain countries, such as South Korea, Singapore, Malaysia, Thailand and the Philippines, but the rate of catching-up with industrialized countries is rapidly increasing (Mani, 2000). Velho (2004), in a study on science and technology in Latin America, notes that considerable differences exist not only between this region and more advanced countries, but also within Latin America itself. Although not as high as those of Asian countries, the innovation performances of Argentina, Brazil, Chile, Costa Rica and Mexico stand out from other Latin American countries as a result of their levels of investment in R&D and innovating activities. In this context, analysing the determinants of the innovative activities of emerging countries is even more pertinent, given the increasing technological capacities and improving institutional environments of these countries.

This paper aims to contribute to this literature by presenting a cross-country study at an industrial level. Our sample comprises emerging countries from different geographical regions and with different levels of innovation performance, allowing us a much more detailed comparative analysis than the studies described above.

3 Description of Data and Variables

3.1 Data

Our study concerns 16 emerging countries and 10 technology source countries during the period 1980–1999 when most of the countries involved undertook institutional reforms in order to increase their innovative capacities[3]. Data on patent applications and citations are from the NBER Patent and Citation Dataset, described in Hall, Jaffe and Trajtenberg (2001). This dataset contains all the patents granted by the U.S. Patent Office (USPTO) from 1963, and all the citations made by each patent,

[3]Emerging countries are Argentina, Brazil, China, Czech Republic, Hong Kong, Hungary, Israel, India, South Korea, Mexico, New Zealand, Russia, Singapore, Taiwan, Venezuela and South Africa; technology source countries are the United States, Japan, Germany, Canada, France, Switzerland, Sweden, the Netherlands and Italy.

from 1975[4]. We chose to evaluate the sample of patents granted between 1980 and 1999 in order to have a series long enough to avoid potential truncation problems and to minimize the effects of missing initial conditions. The data on market size and labour costs are from the Trade and Production Database (UNIDO), which contains data on trade, production and tariffs for 67 developed and developing countries[5]. Northern countries' R&D and bilateral foreign direct investments (FDI) are from the OECD, bilateral export and import flows are from the NBER World Trade Database, and emerging countries' R&D are from UNESCO[6]. Sectors correspond to the technological fields defined and constructed by Hall et al. (2001), where the 400 USPTO patent classes have been aggregated into 6 fields and 36 technological sub-fields[7].

3.2 Endogenous Variable

Our dependant variable is the count of patent applications made by emerging countries to the USPTO. According to the USPTO, a patent should fulfil the requirements of originality, non-obviousness and economically profitable use, and this definition corresponds to that of a 'new idea' (Peri, 2005). Patent applications are used as an indicator of new technology, given that they contain information on a new technology in which the patentee has an economic interest (Ramani et al., 2004).

Recently, traditional patent counts and related statistics have been increasingly complemented by the use of patent citations in estimating knowledge flows. In fact, patent citations can be interpreted as a 'paper trail' left by the accumulated knowledge. As Jaffe, Trajtenberg and Henderson (1993), pioneers of this method, put it: 'The granting of a patent is a legal statement that the idea embodied in the patent represents a novel and useful contribution over and above the previous state of knowledge, as represented by the citations. Thus, in principle, a citation of Patent X by Patent Y means that X represents a piece of previously existing knowledge upon which Y builds'[8]. In this paper, we consider that patents are good proxies for innovation activities, and patent citations for knowledge flows[9].

Statistics show that the number of patents increased for the whole sample between 1980 and 2000, but not in a homogeneous way[10]. Figure 1 gives a detailed picture in which the numbers of patents per million people are presented on the same scale. South Korea and Taiwan are set apart

[4] The original database described in Hall et al. (2001) concerns only the period 1975–1999. We completed this database by using the data available on Bronwyn Hall's personal homepage (http://emlab.berkeley.edu/users/bhhall/bhdata.html).

[5] Several correspondence tables have been used in order to construct the final database. See the Appendix (7.1) for more detail.

[6] The description of the variables and their sources is given in the Appendix (7.3).

[7] The final dataset is an unbalanced panel with 50 336 observations, instead of [16 x 10 x 18 x 20 =] 57 600. In this paper, we do not take into account the sectors, countries or years for which there is no patent application, given that we are interested in the impact of technological spillovers on the innovative activities of emerging countries.

[8] Jaffe, Trajtenberg and Henderson (1993) p.580.

[9] Using patent citation data, Jaffe et al.(1993) and Jaffe and Trajtenberg (1996) evaluate empirically the spillovers from academic research to firms, focusing on the geographical localization of knowledge flows. Similarly, Sjöholm (1996) concludes that distance matters for technological spillovers in Sweden. Maruseth and Verspagen (2002) and Peri (2003) find evidence of technological spillovers across, respectively, European regions and European and North American regions.

[10] Our endogenous variable is the number of granted patents, which may underestimate the final number of patents, but meanwhile allows us to avoid biases due to the application–grant lags.

from the rest of the sample, followed by Singapore and, to a lesser extent, Israel, New Zealand and Hong Kong. The case of South East Asian countries has been analysed extensively in the literature (see Vogel (1991), Krugman (1994), Kim and Nelson (2000), among others). In particular, Taiwan and South Korea have been designated as two recently industrialized economies, passing from the status of imitator to that of innovator. Foreign knowledge flows from industrialized countries played a crucial role in the recent success of these two countries (Hu and Jaffe, 2003). Israel has also been highlighted as a centre of technology, attracting R&D operations from multinational firms (Trajtenberg, 2001), whereas recent studies have shown that the relative productivity performance of New Zealand has declined despite the economic and institutional reforms of 1984 (Johnson et al., 2005). Figure 2 also presents the number of patents per country, but on individual scales. From this, it can be seen that, in spite of the difference stressed above, each country shows an upward trend.

Figure 1: Number of Patents Adjusted by Population Per Million (Same Scale)

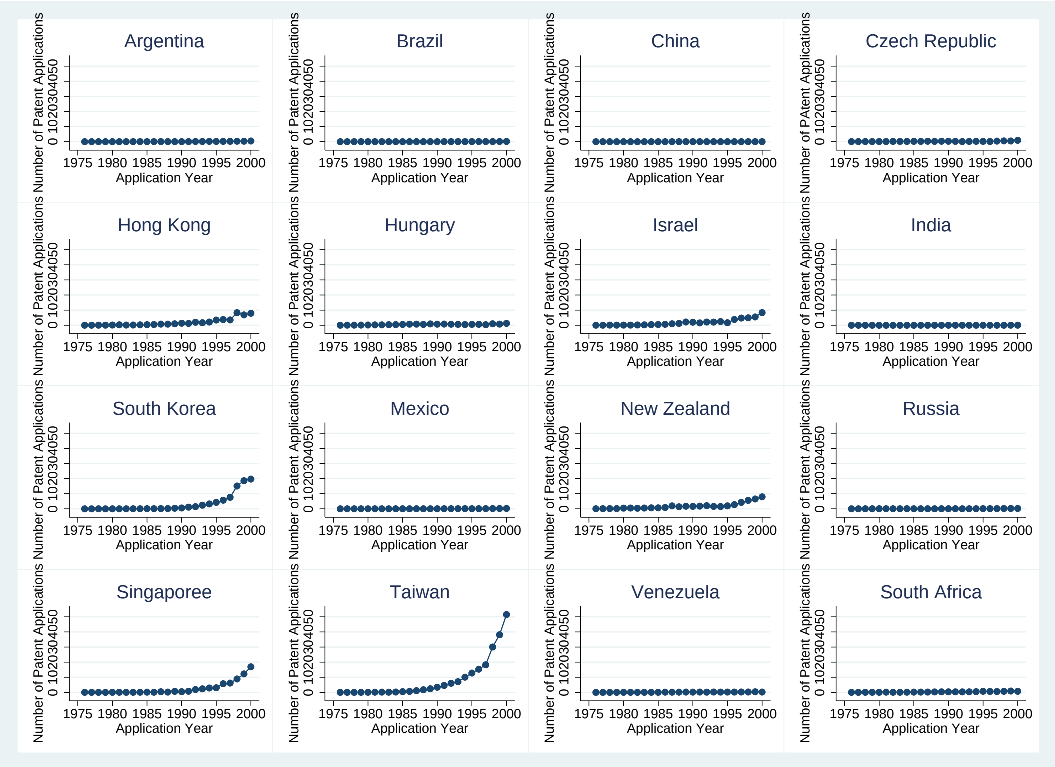


Table 1 presents several indicators on the patent applications in order to show whether there is any qualitative difference in terms of innovation between countries. The number of citations and claims received has been used in the literature to take account of the different quality levels of patents (Lanjouw and Schankerman, 2004). In this study, changes in patent numbers capture the qualitative differences in the patenting behaviour of different countries, which allows us to minimize potential truncation problems associated with citation data. Although we can observe a quantitative difference in the number of patent applications and citations, Table 1 shows that there is no qualitative

Figure 2: Number of Patents Adjusted by Population (Different Scale)

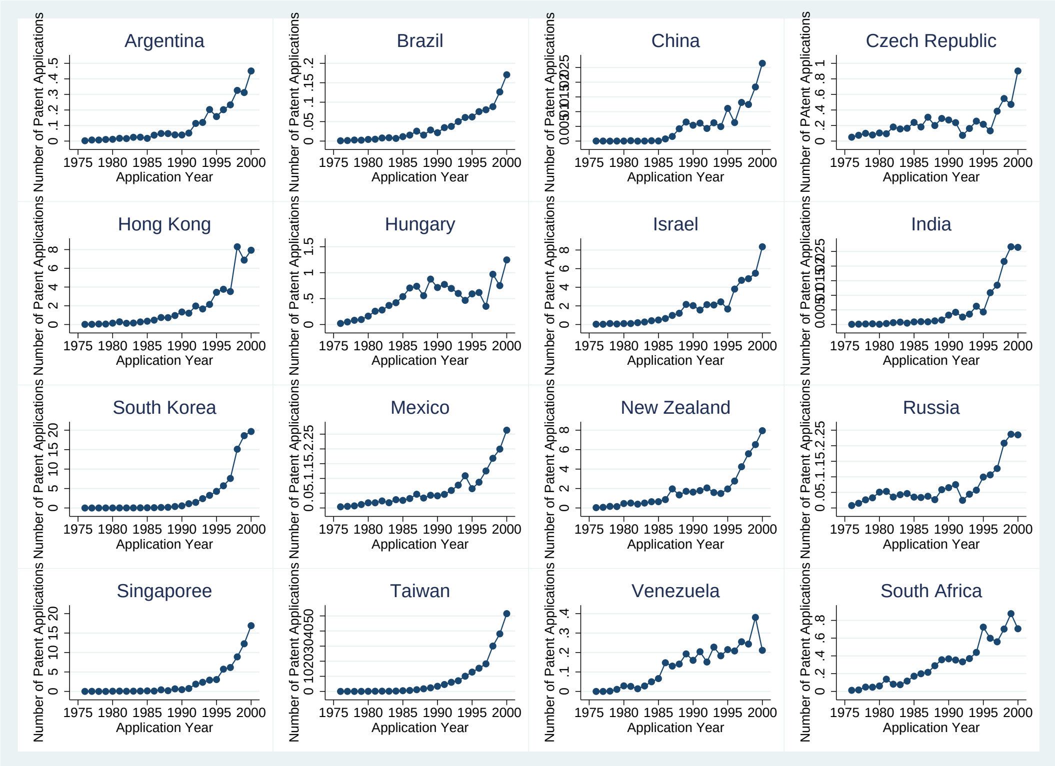


Table 1: Quality Indicators for Patents

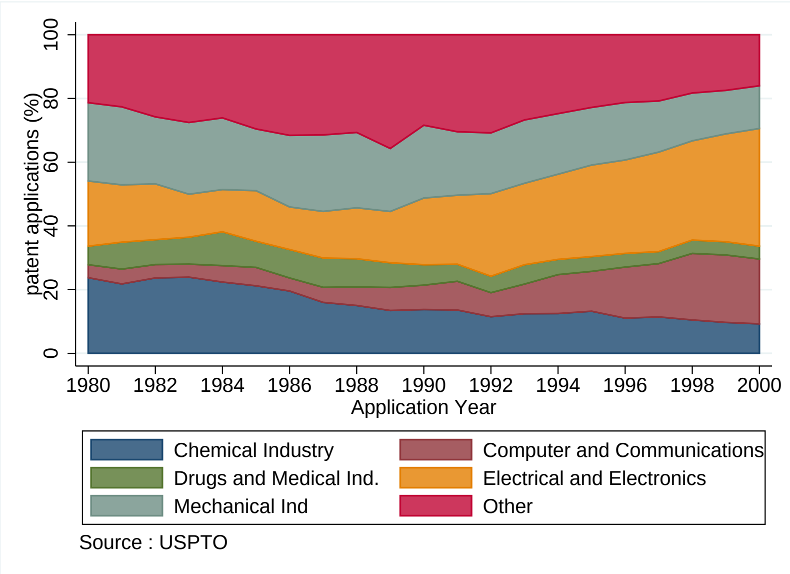
Country	Number of Patent Applications (1963–2002)	Mean of Received Citations (1963–2002)	Total Number of Citations Received (1975–2002)	Number of Claims
Venezuela	613	4.19	2267	5138
Argentina	1009	4.05	4886	5008
India	1328	3.85	2931	5600
Brazil	1469	4.02	4746	8329
China	1490	3.03	3654	7055
Israel	1568	4.61	8117	12643
Singapore	1670	3.64	6092	7821
New Zealand	1842	4.02	6851	13875
Hong Kong	1914	4.06	7520	12329
Mexico	2083	3.58	7162	10187
Czech Rep.	2265	4.08	9463	7448
Hungary	2543	3.49	8894	14893
South Africa	3395	3.82	15664	24363
Russia	8347	4.09	30348	36043
South Korea	25489	4.21	67329	108017
Taiwan	35435	3.44	109507	105859

Source : USPTO (2001)

difference in the innovative activities of our sample, thus allowing us to use non-weighted patent numbers.

When we look at the distribution of innovations according to six principal technological fields, as illustrated in Figure 3, we note a diversification of innovating activities from the 1990s, to the benefit of the high technological sectors such as electric-electronics and computers. Nevertheless, the pharmaceutical industry remains stable in time and its share is relatively weak. If we look at the distribution of patents according to the technological intensity of the sectors, medium technologically intensive sectors take the lead with 43%. In the emerging countries, 33% of innovations are in the sectors with low technological intensity, and 23% in the high-tech sectors[11].

Figure 3: Sectoral Distribution of Patent Applications According to the Principal Technological Fields



When we look at the distribution of citation types, international citations constitute almost 90% of total citations, and 70% occur in the same technological field[12]. This preponderance of international citations confirms our assumption concerning the importance of foreign technology in the innovation process of emerging countries[13]. The Czech Republic, Hungary and South Korea cite their national patents most often, whereas Singapore and China seem to depend to a greater extent on foreign patents. We note that the majority of international citations relate to the pharmaceutical industry, even if the differences between the sectors are very small. Emerging countries seem to cite their national patents for the most part in the sector of electric-electronics (11%). This finding confirms that our sample countries are specialized in the medium to high technology sectors.

[11] The definition and classification of the sectors according to their technology level are from Hatzichronoglou (1997).

[12] Table 12 in the Appendix presents the distribution of citations according to technological sector and cited country.

[13] In developed countries, the distribution of these two types of citation is 50%, of which 20% corresponds to the citations of patents held by the innovating firm itself (Mancusi, 2004).

3.3 Independent Variables

Our principal independent variable is international and intersectoral spillovers. The first stage of the construction of the spillover variable consists of building foreign research and development stocks. We built the stock of knowledge for our 10 technology source countries using the perpetual inventory method on the basis of industrial expenditure in R&D[14]. The second stage involves taking into account the intensity and direction of foreign knowledge, since the diffusion of the latter is neither immediate nor complete (Jaffe et al., 1993; Peri, 2002; Mancusi, 2004). We employed patent citations for this purpose, assuming that the frequency with which an inventor from a given country/sector cites the patents of another country/sector is an approximation of the intensity of the knowledge flows from the cited country/sector to the citing one.

One of the problems to be overcome when using patent citations relates to the identification and measurement of changes in the intensity of citations that are associated with other effects. As explained largely by Hall, Jaffe and Trajtenberg (2005; 2001), patent citations could be a noisy measure of technological spillovers, since the number of citations received for a particular patent can vary substantially according to technological classes or time[15]. In order to prevent any potential bias in our estimates, we use the so-called 'Fixed Effect Approach' developed by Hall et al. (2001). This approach consists of removing any source of systematic variation of citation intensities in time. This is done by deflating the number of citations by the average number of citations received by patents that belong to the same sector and year group [16]. Hence, we remove any variation due to time or technological class, or both[17]. For each country c, we initially calculate all the patent citations in each sector i, and identify the sector and country to which the cited patent belongs. We also distinguish citations that are directed towards the patents in the same sector and country. Finally, we calculate the relative number of citations, and consider that this represents the intensity of knowledge flows. Our international spillovers (R^f_{cit}) variable is thus measured as follows:

$$R^f_{cit} = \prod_{c \neq h} (RD_{hit})^{RC_{cit}} \tag{1}$$

where RC_{cit} is the relative number of citations in sector i and country c, at time t, to the patents held by country h in the same sector i. RD_{hit} represents the accumulated R&D stock of the country h, in the sector i, at time t.

The innovativeness of developing countries depends to a great extent on their capacity for absorption, assimilation and use of foreign technology. In the empirical literature, this capacity to

[14]The accumulation of the R_{cit} is described by the following relation: $\delta R_{cit} = RD_{cit} - \delta R_{cit}$, where δ is the rate of depreciation. In accordance with Crépon and Duguet, we took an annual depreciation rate of 15%, and a pre-sample annual growth rate of 5%. See the Appendix (7.2) for details of the calculation according to the perpetual inventory method.

[15]An average patent applied in 1999 gives rise to double the number of citations of an average patent applied in 1975 (Hall et al., 2001).

[16]See Hall et al. (2001) for a more detailed explanation.

[17]The main advantage of this approach is that it does not imply any assumptions about the causes of the differences in citation intensities. However, there is also a risk of losing any 'real' effect. Given our use of patent citation in this paper, this last point is not an issue for us.

benefit from foreign knowledge is often approximated by R&D expenditure. However, these statistics are rather scarce and not always highly reliable with regard to developing countries. In this paper, we propose an alternative indicator of technological or absorptive capacity. Following Mancusi (2004), we build an indicator of 'self-citations', which takes into account the citations of other patents held by the same firms, sectors and country. We use this to weight the R&D stocks of the emerging countries, as a measurement of the domestic firms' absorptive capacity, since it indicates the number of times a firm produces a new idea based on activities of research in the same sector (intrasectoral self-citations) or in another sector (intersectoral self-citations)[18]. This new measure of technological capacity also enables us to disaggregate the stock of R&D which is available only at the macroeconomic level.

Our variable of the technological capacity or national spillovers is thus measured in a similar way to the international spillovers variable:

$$R_{cit} = \prod (RD_{ct})^{RC_{cit}} \tag{2}$$

where RC_{cit} is the relative number of citations in the sector i and country c, to the patents in the same sector/country, and RD_{ct} represents the accumulated R&D stock of the country c.

As well as the spillover variables, we also take into account: market size as a push factor for the innovation (Hall and Mairesse, 1995; Crepon et al., 1998; Blundell et al., 1999); labour costs, which reflect the structure of employment[19]; trade openness, either as a vehicle of technology flows (Coe and Helpman, 1995; MacGarvie, 2005b) or as an incentive to innovate by the induced competition (Grossman and Helpman, 1991); and the stock of foreign direct investment as a major vector of technology transfer (Borensztein et al., 1998; Blomström and Kokko, 1999; van Pottelsberghe and Lichtenberg, 2001).

While evaluating the impact of foreign technology on the innovative activities of emerging countries, we also assess the role of geographical, technological, cultural and historical proximities[20]. Are there more spillovers between two relatively close countries? We expect more knowledge flows between two countries that use similar technologies (Jaffe and Trajtenberg, 1998; Orlando, 2000; Peri, 2002; Hu and Jaffe, 2003) and are geographically close (Jaffe et al., 1993; Audretsch and Feldman, 1996). On the role of cultural and historical proximities, less has been written in the previous literature. Apart from the seminal work of Hussler (2004) on European regions, there has been no study analysing the impact of these proximities in a North–South framework.

[18] Given the construction of this variable, and its similarity with the international spillovers variable, we refer to this variable as 'national spillovers'.

[19] In the technology transfer literature, it is largely shown that technological spillovers and the factor demands are substitutable; technological spillovers could reduce the need for domestic labour through the introduction of a new, less intensive technology (Blomström and Kokko, 1999). Within this framework, we expect a negative impact of this variable, and interpret this sign as a decrease in the effective labour force. Nevertheless, variation in labour cost can also reflect the structure of employment in the host country; a rise in the number of qualified employees leads to a rise in wages per capita, thus reflecting a higher capacity of absorption in the country and/or sector. From this perspective, a rise in production costs could stimulate innovating activities. The sign of the coefficient on labour cost and its interpretation is thus ambiguous.

[20] See the Appendix, Table 7.3 for the definition and sources of these variables.

Finally, the innovation capacity of a country depends not only on its innovating productivity and R&D resources, but also on its legal framework and political choices (Furman et al., 2002). We therefore include in our estimation several institutional indicators – these are five sub-indicators of the economic freedom index constructed by the Fraser Institute. The first of these concerns size of government, which takes into account the general consumption of a government, tax rate, State-owned companies and their investment share in gross domestic product (GDP). This index, highlighting the degree of government intervention, can be used as an approximation of the role of government in encouraging R&D. Countries can choose among tax incentives, subsidies, patent rights or direct incentives to increase research investments, but the expected outcome will depend closely on the type of support programme (Guellec and Pottelsbergue, 2003, 2001).

The second sub-indicator relates to the legal structure and protection of ownership rights (IPR). It is concerned with legal independence, intellectual property protection, military interference in legal and political payments, and the integrity of the legal system. Maskus (2000) and Smarzynska (2004), among others, have shown the positive effect of intellectual property rights on licence agreements and/or foreign direct investments. In addition, an adequate legal system decreases the risks associated with technological contracts (Yang and Maskus, 2003). However, the negative impact of the reinforcement of IPR, especially in developing countries, has also been emphasized (Deardorff, 1992; Correa, 2000; Chen and Puttitanun, 2005). The expected impact of this variable is therefore ambiguous.

The third sub-indicator introduced into our specification is the freedom to trade. This indicator combines measurements of taxes on international trade, tariffs and non-tariff barriers, trade sector size and access to international capital markets. Given the relationship between trade openness and innovation, this variable is expected to have a positive effect.

The fourth sub-indicator measures labour market regulation. The relationship between innovation and the protection of employment depends heavily on the system of regulation and on the characteristics of each industry (Bassanini and Ernst, 2002). The final indicator refers to the regulation of credit and business markets and to financial freedom. Previous literature indicates a positive effect for the latter[21].

4 Empirical Specification and Estimation

4.1 Empirical Specification and Measurement Issues

Our empirical specification is based on the knowledge production function (KPF) approach, initiated by Griliches (1979; 1986). As stated by Acs et al. (2002), this models the 'functional relationship between the inputs of the knowledge production and its output that is economically useful

[21] See Hall (2002) for an overview of the literature concerning research and development investment finance.

new technological knowledge'[22]. This approach focuses on knowledge spillovers in a technological space. Since the production is that of innovation, this framework has the advantage of minimizing the effect of rent spillovers[23].

Several specifications have been investigated in the empirical literature in order to study the relationship between the patents and the determinants of technological activity, in the knowledge production function context (see, among others, Pakes and Griliches (1984), Haussman et al. (1984), Montalvo (1993), Blundell, Griffith and Windmeijer (1995)). Some studies have also introduced technological spillovers as a determinant of the innovation process[24].

We use the concept of knowledge production function for measuring the contribution of R&D and knowledge spillovers to the innovation. The basic assumption states that the output of the innovation process (Q) is a result of the resources invested in inventive activity (R), usually R&D capital or investment, and that the patents (P) are a good measure of this economically valuable knowledge. The patents do not play any explicit economic role in Griliches's model. They are just an indicator of innovative activity, based on the assumption that some random fraction of Q gets patented. Following Griliches, we assume that Q_{cit} is an index of innovative output of country c, sector i and time t, and the stock of R&D is the main input in the innovative activity. The production of Q_{cit} can then be expressed by a knowledge production function:

$$Q_{cit} = f(X_{cit}, R_{cit}, R^f_{cit}, R_{cjt}, R^f_{cjt}, \upsilon_{cit}) \tag{3}$$

where X_{cit} are the country, sector and time-specific effects that may affect the innovative activity, and R and R^f stand for, respectively, domestic and foreign R&D stock accumulated from past and current investment, while j denotes sectors different from i. We assume that the above function is Cobb-Douglas, the knowledge production function can be expressed then by the log-linear form:

$$Q_{cit} = X_{cit}.[(R_{cit})^\alpha, (R^f_{cit})^\beta, (R_{cjt})^\gamma, (R^f_{cjt})^\delta, e^\upsilon_{cit}] \tag{4}$$

As stressed earlier, the technological capacity of the emerging countries – that is, the national spillovers – are proxied by the domestic R&D investments weighted by self-citations. By substituting, respec-

[22] Acs et al. (2002) p.1074

[23] In his pioneer work, Griliches (1979) distinguishes between two kinds of knowledge externalities: pure knowledge spillovers and rent spillovers. Rent spillovers occur mainly because of imperfect and asymmetric information, whereas pure knowledge spillovers appear when the knowledge generated by a firm contributes directly to the innovation process of others; it is due to the imperfect appropriability of knowledge associated with the innovations.

[24] Jaffe (1986) performs a particular specification of knowledge production function by introducing technological dummies and a pool of international spillovers. Crépon and Duguet (1993) also evaluate technological spillovers, but consider dummy variables and current stocks of R&D capital, instead of R&D expenditures. However, these two studies, among the first to analyse spillover effects in a KPF framework, led to contradictory results. Whereas Jaffe finds evidence of geographically bounded technological spillovers, the results of the study by Crépon and Duguet show a negative impact of foreign R&D on domestic patenting. Nevertheless, differences in samples analysed, specification of spillover variables and the econometric methods conducted in both papers can explain these divergent findings. Los and Verspagen (1996) compare different technology flow matrices and conclude a positive impact of R&D spillovers, this result being robust to the weighting scheme. In line with Jaffe, Brendstetter (2001) assesses the impact of domestic and foreign R&D spillovers in American and Japanese firms, and finds that the spillover effects are more national than international in scope.

tively, (1) and (2) in (4), we obtain the specification of the knowledge production function:

$$Q_{cit} \quad = \quad X_{cit} {R_{ct}}^{\alpha RC_{cit}} \prod_{c \neq h} (RD_{hit})^{\beta RC_{chit}} e^{v}_{cit} \tag{5}$$

Equation (5) stresses the role of international spillovers in the innovation process of emerging countries [25]. It indicates that innovation in each country c and sector i is the result of the characteristics and endowments of each country c, and the R&D investments of other countries h and sectors j. The elasticity of innovation to the foreign R&D is hence proportional to the intensity of the knowledge flows, measured here by the patent citations. We assume therefore that the number of new patents generated in a country c, and sector i, P_{cit}, is an exponential function of its new knowledge. Because of the discrete nature of patent data, P_{cit} are assumed to be independent and have Poisson distribution with parameters λ_{cit}[26]. The parameters λ_{cit} depend on a set of explanatory variables, which in this case are the determinants of the knowledge production function :

$$\lambda_{cit} = e^{Q_{cit}} e^{\sum_c \vartheta_c D_{ci} + \sum_s \vartheta_s D_{si}} \tag{6}$$

Equation (6) allows controlling for country (c) and industry (i) specific effects, by a set of dummies (D), and also includes individual effects. By substituting (5) in (6) and taking logs, we obtain our basic specification for international spillovers:

$$P_{cit} = \ln X_{cit} + \alpha R_{ct} + \beta RD_{hit} + \sum_c \vartheta_c D_{ci} + \sum_s \vartheta_s D_{si} + \epsilon_{cit} \tag{7}$$

where X_{cit} represents variables specific to the countries and sectors, such as market size, labour costs, trade openness or institutional framework. Finally, as we did not find any difference in the quality of the patents held by our sample (see Table 1), we will use the number of raw patent applications instead of the numbers weighted by the citations or claims[27].

4.2 Estimation Method

Patent data include numerous zero counts and integer values. This implies some distributional assumptions and specific econometric methods when estimating the knowledge production function. Therefore, the usual linear estimates are no longer consistent, since some basic assumptions, such as normality of residuals or the linear adjustment of data, are no longer respected. Moreover, non-observable heterogeneity is likely to occur, given the complex structure of the individual effect

[25] The number of intersectoral citations being relatively weak compared with the number of international citations (Table 12 in the Appendix), we chose to conduct our empirical analysis at two separate levels. The corresponding knowledge production function specification is thus: $Q_{cit} = X_{cit} {R_{ct}}^{\alpha RC_{cjt}} . \prod_{i \neq j} (RD_{hjt})^{\gamma RC_{chijt}} e^{v}_{cit}$. The results of these estimations can be found in the Appendix (7.5).

[26] See the next section for a discussion of count data models.

[27] Peri (2005) did not find any significant difference, on the impact of technological spillovers, between the use of weighted and raw patents for the USPTO data. Mancusi (2004), on the data of the EPO, also uses the count of the unweighted patents.

in Equation (7). The units of panel (pairs of country/sector) are correlated and, consequently, the residual variance–covariance matrix is no longer diagonal. In this case, random effect models are not consistent[28]. It is thus preferable to use a fixed effect model where intra-individual variability is taken into account. In addition, the fixed effect model also makes it possible to correct for the correlation between the specific effects and the explanatory variables. Allison and Waterman (2002) propose the use of a Non Conditional Negative Binomial (NCNB) estimator[29]. In their model, P_{cit} follows a negative binomial distribution, with an expectation of μ_{it} and a parameter of dispersion, λ, and dummy variables are introduced for the fixed effects[30].

Finally, the consistency of conditional maximum likelihood models is based on the strict exogeneity of the independent variables (Blundell et al., 1995). It is difficult to respect this assumption in the patent–R&D relationship, where the patent application for an innovation is likely to stimulate R&D investments (Cincera, 1997). But, as in this present paper, we tend to evaluate in particular the impact of foreign R&D on the innovation process of emerging countries, we believe to meet the condition of exogeneity of the explanatory variables. In our case, there is no reason for the patent application of an emerging country to stimulate the R&D investments of industrialized countries. Furthermore, the domestic R&D is introduced into our estimation weighted by the self-citations.

5 Estimation Results

5.1 Basic Specification

We begin our analysis by evaluating the possible specifications for both national and international spillover variables. In the first place, we test two alternative weighting schemes for the foreign knowledge stock. The first is the variable presented in Section 3.3, constructed by the relative number of citations from the emerging countries to industrialized countries' patents (CIT_{DC}). This is our principal variable. The second is an alternative measure constructed by taking into account all the citations at the sectoral level, including the developed countries (CIT_{IC})[31].

The second specification relates to our variable of technological capacity; that is, the stock of domestic R&D weighted by self-citations. This specification enables us to introduce R&D expenditure at the sectoral level. Furthermore, at the same time we avoid the risk of correlation among the units of panel (here, countries) due to the inclusion of an aggregated variable in the estimations (Moulton, 1986).

[28] The standard deviation will be downward biased.

[29] Haussmann, Hall and Griliches (1984) developed a Fixed Effect Negative Binomial Regression (NBR) Model, based on the approach of conditional maximum likelihood from Anderson (1970). However, Allison and Waterman (2002) show that the NBR model is not a true fixed effect model, because it does not control for all the stable co-variables.

[30] The only disadvantage of this model is the underestimation of the standard deviations. But this skew can be corrected by a correction factor, based on the statistics of deviance, D, defined by: $D = \Sigma\Sigma(y_{it}\ln(y_{it}/\mu_{it})) - (y_{it}+\lambda)\ln((y_{it}+\lambda)/(\mu_{it}+\lambda))$.

[31] This second variable is constructed following the approach of Verspagen (1997) and aims to avoid potential bias due to the small number of citations. Compared with industrialized countries, the majority of the countries that constitute our sample do not produce many patents and, consequently, even fewer citations.

Table 2: Alternative Weighting Schemes for the Spillover Variables

	(1)	(2)	(3)	(4)	(5)
Market Size	0.053***	0.055***	0.056***	0.048***	0.057***
	[0.004]	[0.008]	[0.008]	[0.004]	[0.008]
Labour Costs	0.225***	-0.198***	-0.136***	-0.114***	-0.107***
	[0.005]	[0.009]	[0.009]	[0.005]	[0.007]
Domestic R&D	0.085***	0.092***	0.093***		
	[0.002]	[0.003]	[0.003]		
Trade Openness	0.091***	0.025***	0.033***	0.045***	0.027***
	[0.004]	[0.008]	[0.008]	[0.005]	[0.008]
Foreign Direct Investment	0.000***	-0.000	0.000***	0.000***	0.000
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
Foreign R&D*CIT_DC		0.324***			0.331***
		[0.005]			[0.005]
Foreign R&D*CIT_IC			0.683***		
			[0.055]		
Domestic R&D * Self-citations				0.125***	0.121***
				[0.017]	[0.013]
Constant	-6.687***	-3.321***	-2.673***	-4.191***	-2.555***
	[0.111]	[0.245]	[0.484]	[0.112]	[0.254]
Observations	52256	55356	49356	49356	49356
Log-likelihood	-13569.17	-12235.13	-13560.14	-14231.67	13246.02
Likelihood-ratio test ($\alpha = 0$)	6.35	7.47	6.74	6.32	6.54
Prob>chibar2	0.000	0.000	0.000	0.000	0.000

*Significant at 10%; ** significant at 5%; *** significant at 1%. Standard errors in brackets.
All variables are in logarithms, except the dependent variable.

Table 2 summarizes the results for the basic specification and the impact of the various spillover variables. At first sight, we note that all the variables have the expected signs. The market size variable is significant and positive, as is trade openness. The market demand thus constitutes one of the principal determinants of the innovation (Geroski and Walters, 1995). The FDI variable also seems significant, but its impact is negligible[32].

The labour costs variable, which was positive in the basic specification (1), becomes negative with the introduction of the spillover variable, in the subsequent specifications ((2) to (5)). Specification (1) indicates a positive impact of the quality of labour force on innovating activities, while the change of sign, which appears thereafter, reflects a relation of substitution between domestic labour and foreign technology (de Mello, 1997). The emerging countries thus depend more on foreign technology than on their own human capital. On the other hand, an increase in labour cost also corresponds to an increase in the cost of R&D, if one assumes that the average wage also reflects researchers' wages. From this point of view, a negative coefficient would quite simply show a decline in innovative activities following a rise in costs.

The introduction of the international spillover variables does not significantly affect the impact of other variables. However, we can note a slight increase in the impact of domestic investments

[32]The correlation matrix indicates a correlation of 0.4 between trade openness and FDI, enabling us to include them both in our specification.

in R&D (where the effect passes from 1.08 to 1.96). Foreign technology will not only stimulate the innovating activities of emerging countries, but will also increase the possibility of these countries gaining greater benefit from their own efforts in R&D (Cohen and Levin, 1989). In addition, the impact of the openness variable declines in the following specifications, indicating that its high value included of some technological spillovers effect, illustrating the role of trade flows in international technology transfer (Coe and Helpman, 1995; Coe et al., 1997).

Concerning the impact of the alternative spillover variables, a strong contrast between the two methods of weighting appears (Column (2) vs. (3) for international spillovers, and (1) vs. (4) for national spillovers.). In fact, foreign knowledge, weighted by the sectoral citations without consideration of either the source or the direction, overestimates the impact of international spillovers. Given the difference with the first specification (2), we conclude that this measurement of weighting presents an upward bias for our sample. Although the citations of the developing countries are largely lower than those of the countries known as developed, we maintain that our results are not skewed, since we remain within a North–South framework. Column (4) shows the impact of the national spillovers. Weighting the expenditure of domestic R&D by the self-citations increases the innovation by 1.38, instead of 1.08 (in the first column). As the self-citations are considered to be an indicator of accumulated knowledge at the firm level (Mancusi, 2004), we can interpret them as a measure of absorption capacity at the sectoral level.

Finally, the last column presents our preferred specification, where we consider both the international and the national spillovers[33]. These first observations confirm the use of the relative number of patent citations between the emerging and the industrialized countries as a foreign knowledge transmission vector. We conclude that international spillovers have a positive and significant impact on the innovating activities of the sample countries. We can count market size, technological capacity and the openness among the other determinants of the innovation. We will now look further into our analysis by introducing the variables of technological and geographical proximity, before testing more specifically the characteristics of the host countries with regard to technological capacity and institutional framework.

5.2 Does Distances Limit the Scope of the Spillovers?

In this section, we seek to evaluate the limits, if any, of technological spillovers. Our purpose here is to see whether the technological transfer is robust to the different concepts of distance, namely the geographical, technological, cultural and historical distance between the emerging countries and the technological leaders.

For this purpose, we modify our specification slightly, by duplicating our spillover variables using a dummy, which takes the value of 1 if the two countries are relatively 'close'; and 0 otherwise.

[33]Hence, in the remainder of this paper, as international spillovers, we refer to the stock of knowledge weighted by the number of citations from emerging to developed countries. In the same way, national spillovers correspond to the stock of domestic R&D weighted by self-citations.

Thus, in the first specification, where we seek to analyse the role of geographical proximity, the dummy variable is equal to 1 if the two countries are contiguous. We try to see whether countries profit more from their frontier neighbours than from others. With regard to technological distance, we use the technological proximity index developed by Jaffe (1986)[34]. We consider that two countries are technologically 'close' if $\omega_{ij} = 0.7$[35]. Cultural distance is approximated by the use of the same official language between two countries, and the historical proximity by past colonial presence of an industrialized country in an emerging one.

Table 3: Spillovers and Proximities

	Geographical Distance	Technological Distance	Cultural Distance	Historical Distance
Market Size	0.058***	0.051***	0.004	0.010
	[0.007]	[0.008]	[0.008]	[0.008]
Labour Costs	-0.213***	-0.204***	-0.265***	-0.265***
	[0.009]	[0.009]	[0.009]	[0.009]
D1*International Spillovers	0.431***	0.390***	0.327***	0.326***
	[0.005]	[0.005]	[0.005]	[0.005]
D0*International Spillovers	0.265***	0.075***	0.235***	0.318***
	[0.026]	[0.026]	[0.026]	[0.025]
National Spillovers	0.385***	0.396***	0.355***	0.345***
	[0.008]	[0.008]	[0.008]	[0.008]
Trade Openness	0.028***	0.021***	0.025***	0.040***
	[0.008]	[0.008]	[0.008]	[0.009]
Foreign Direct Investments	0.000	0.000	0.000***	0.000***
	[0.000]	[0.000]	[0.000]	[0.000]
Constant	-16.555***	-15.615***	-16.745***	-15.369***
	[0.254]	[0.326]	[0.253]	[0.265]
Observations	49356	49356	49356	49356
Log-likelihood	-25460.367	-27657.493	-28647.14	-24941.09
Likelihood-ratio test ($\alpha = 0$)	15135	15074	14967	16323
Prob>chibar2	0.000	0.000	0.000	0.000

*Significant at 10%; ** significant at 5%; *** significant at 1%. Standard errors in brackets.
D1(D0) equals 1 for 'closer' ('far'). All variables are in logarithms, except the dependent variable.

Table 3 summarizes the empirical results. The first specification relates to geographical distance. The geographical borders of knowledge flows have been discussed considerably in the literature[36]. Although the spillovers that originated from frontier countries are higher than those from non-frontier countries (with an impact of 1.5 against 1.3), the latters are significant and positive and the difference between the two sub-samples is not significantly important. With regard to the intrasec-

[34]The technological similarity between two countries I and i is given by the following equation:

$$\omega_{Ii} = \frac{\sum_{k=1}^{K} N_{Ik} N_{ik}}{\sqrt{\sum_{k=1}^{K} N_{Ik}^2 \sum_{k=1}^{K} N_{ik}^2}}$$

where $k = 1, 2, ..., K$ indicates sectors and N stands for the number of patents. The more similar the technological fields of countries I and i, the closer ω_{Ii} would be to 1. If the two countries have no patent in the same sector, ω_{Ii} would be nil.

[35]The choice of the value of 0.7 is arbitrary, but alternative estimates with the values of 0.6 and 0.8 did not give significantly different results, while the use of 0.5 led to the same results for the two sub-groups.

[36]See Acs and Audretsch (1991), Jaffe and Henderson (1993), Audretsch and Feldman (1994; 1996), among others.

toral spillovers, the national borders are not an obstacle in the diffusion of technology. These results do not confirm previous studies on the transmission of knowledge at the regional level (Maurseth and Verspagen, 2002; Verspagen and Schoenmakers, 2004; Peri, 2005)[37]. Nevertheless, analysed at the regional level, geographical borders could be more important than at the sectoral level. Moreover, none of these studies takes into account the case of emerging countries where the extent and the impact of foreign technology are much more important than in developed countries.

The technological distance between emerging countries and technological leaders arises as one of the principal determinants of the extent of international spillovers. This result confirms those obtained by Jaffe et al. (1993), Caballero and Jaffe (1993), Adam and Jaffe (1996), and Orlando (2000), but partially contradicts those of Peri (2005)[38]. Our results indicate that the R&D undertaken in Northern countries increases the number of the patents by 1.47 in the emerging countries using similar technologies. For countries that do not have the same technological specialization, this impact is 1.01. This result highlights the importance of the technological capability of the emerging countries in the absorption of foreign technology (Cohen and Levin, 1989; Blomstrom et al., 1994).

With regard to the last two specifications, neither the cultural nor the historical proximities have a strong impact on the international spillovers. Alhough these kinds of proximity seem to foster international technology diffusion (Keller, 1996; Hussler, 2004; MacGarvie, 2005a), they do not influence the innovation process in the emerging countries, which profits from foreign technology regardless of its source.

5.3 Impact of the Institutional Framework

In this section, we focus on the role of institutions in the innovation process. Even if the emerging countries seem to depend strongly on foreign technology, in the long term they have to build their own innovation dynamics in order to catch up with the technological frontier. The purpose of this section is to analyse to what extent this institutional framework is already present in our sample countries, and its efficiency[39].

[37] By analysing flows of knowledge between 147 European and North American regions, Peri (2005) indicates that at least 15% of original knowledge is lost by crossing borders, while in Europe, Maurseth and Verspagen (2002) find an impact of 50% of geographical borders on spillovers.

[38] Peri (2005) reports that technological specialization in similar fields stimulates flows of knowledge at the regional level, while the degree of geographical distance increases flows coming from more advanced areas.

[39] In order to make our data compatible with these institutional indicators, available on the basis of a five-year period, we conduct our analysis on a five-year mean, from 1980 to 2000. We thus include the years 1999 and 2000, but since we reason on the means, it is not very probable that our results include a truncation bias.

Table 4: Innovation, R&D Spillovers and Institutional Framework

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Market Size	0.062	0.123***	0.066*	0.074*	0.064*	0.026	0.068*
	[0.039]	[0.039]	[0.038]	[0.039]	[0.038]	[0.041]	[0.039]
Labour Costs	-0.054*	-0.042*	-0.027*	-0.047**	-0.039*	-0.056*	-0.034
	[0.076]	[0.073]	[0.077]	[0.077]	[0.073]	[0.085]	[0.075]
International Spillovers	0.049*	0.052*	0.048*	0.050*	0.056*	0.057*	0.047*
	[0.049]	[0.049]	[0.048]	[0.048]	[0.046]	[0.047]	[0.047]
National Spillovers	0.163***	0.158***	0.146**	0.145**	0.159***	0.208***	0.160***
	[0.059]	[0.046]	[0.057]	[0.057]	[0.059]	[0.067]	[0.052]
Trade Openness	-0.039	-0.041	-0.032	-0.029	-0.026		-0.008
	[0.038]	[0.037]	[0.038]	[0.039]	[0.037]		[0.039]
FDI	0.000***	0.000***	0.000***	0.000***	0.000**	0.000**	0.000**
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
Government Size		-0.485***					
		[0.076]					
IPR			-0.265***	0.690*			
			[0.103]	[0.379]			
(IPR^2)				-0.070***			
				[0.026]			
Regulation					-0.171***		
					[0.029]		
Freedom to Trade						0.290***	
						[0.072]	
Access to Fin. Markets							0.522***
							[0.049]
Constant	-3.469	0.289	-1.135	-4.668*	-2.753	-1.751	0.509
	[2.367]	[2.316]	[2.474]	[2.718]	[2.299]	[2.489]	[2.328]
Observations	13900	13900	13900	13900	13900	13900	13900
Log-likelihood	-13568.54	-13551.17	-13563.79	-13559.35	-13548.73	13552.24	-13558.67
Likelihood-ratio test ($\alpha = 0$)	9913.44	9695.98	9393.70	8902.28	9027.34	9009.97	16003.45
Prob>chibar2	0.000	0.000	0.000	0.000	0.000	0.000	0.000

*Significant at 10%; ** significant at 5%; *** significant at 1%. Standard errors in brackets.
All variables are in logarithms, except the dependent variable.

Table 4 presents, separately for each indicator, the results for the impact of the institutional framework on the innovating activities of emerging countries. The first evaluates the impact of government size on the economy. Unexpectedly, a rise of 1% in the government size leads to a 1.62% decrease in innovating activities[40] (column 2). This result can however be explained by the small number of patents assigned by government agencies[41]. But it draws nevertheless attention to the structure of government intervention in stimulating the innovative activities of developing countries. Previous studies have found that the type of government support influences considerably the effectiveness of such policies (Guellec and Pottelsberghe, 2004). The rate of return on private R&D has been shown to exceed that of public R&D – and even a negative effect of government funding on private research has been found (Lichtenberg, 1993). The design of public science and technology (S&T) policies is hence even more crucial for emerging economies.

The next two columns in Table 4 take into account the impact of the legal system and intellectual property rights protection on innovation activities. The reinforcement of the patent system seems to decrease the propensity to innovate in the emerging countries (Column 3). However, a number of studies have highlighted the non-linear impact of IPR protection (Maskus and Penubarti, 1995; Thompson and Rushing, 1996, 1999; Chen and Puttitanun, 2005). Hence, when we include the square of the IPR protection, we find an inverted U-shaped relationship between IPR and innovation (Column 4). Contrary to earlier studies, this result indicates a positive effect until the emerging countries reach a certain threshold of protection, when the reinforcement of the IPR seems to lead to a deterioration in innovative activities[42]. This negative effect of the IPR is also shown in a recent study by Schneider (2005), who finds that, by comparing the determinants of innovation between the two (industrialized and developing) groups, the impact of the IPR is negative or nil for the developing countries. In the same way, Lerner (2002) and Branstetter (2005) show that the reinforcement of the patent system stimulates domestic patent applications very little, or not at all. Tight intellectual property protection can curtail innovation opportunities because it becomes more difficult to develop new technologies while at the same time respecting the rights of patent holders (Cohen and Levin, 1989). Moreover, the criteria of novelty in patent grants are not very likely to support the incremental innovations that constitute the majority of innovations in developing countries (Braga et al., 2000).

Freedom to trade has a positive impact, with a coefficient of 1.33 (Column 5). In order to avoid collinearity, the variables of trade openness and foreign direct investments were omitted in this specification. International trade, incorporating knowledge flows, transmits foreign technology to the emerging countries and contributes to their innovating activities (Geroski and Walters, 1995; Blundell et al., 1999).

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[40] It should be borne in mind that this indicator does not take into account the government regulatory role, and measures only government's direct use of resources for its own purposes and its control over resources through ownership.

[41] When we look at patent distribution by assignee type, we note that only in Israel, and to a lesser extent Russia, are the majority of patents assigned to government agencies.

[42] The estimated quadratic function reveals that the turning point in the patent index is 4.9.

Finally, access to financial markets has the most important impact relative to other institutional indicators. The importance of financial markets has already been stressed in the literature within the framework of the financing of R&D investments (Hao and Jaffe, 1993; Hall, 2002). The differences in terms of financial markets, legal regulation of bankruptcy, and credit and currency policies seem to determine the majority of the cross-country differences in the propensity to innovate (Canepa and Stoneman, 2002). The decline in the market size coefficient in the specifications (2) to (5) can also be noted: we deduce that, while reflecting the structure of the market, this coefficient has also so far included the effects of the institutional framework.

Table 5: Innovation, R&D Spillovers and Institutional Framework

	(1)	(2)
Market size	0.023**	0.014
	[0.012]	[0.011]
Labour Costs	0.039	-0.183***
	[0.056]	[0.039]
International Spillovers	0.088***	0.072***
	[0.024]	[0.023]
National Spillovers	0.299***	0.304***
	[0.023]	[0.023]
Trade Openness		0.077***
		[0.024]
Size of Government	-0.178***	
	[0.024]	
IPR	1.073***	0.749***
	[0.172]	[0.179]
$(IPR)^2$	-0.088***	-0.017
	[0.013]	[0.014]
Access to Financial Markets	0.164***	
	[0.015]	
Freedom to Trade	0.341***	0.297
	[0.060]	[0.061]
Regulation		-0.940***
		[0.072]
Constant	-4.343***	0.479
	[1.496]	[1.448]
Observations	13900	13900
Log-likelihood	-13728.93	-13770.58
Likelihood-ratio test ($\alpha = 0$)	16536.46	19593.70
Prob>chibar2	0.000	0.000

*Significant at 10%; ** significant at 5%; *** significant at 1%. Standard errors in brackets.
All variables are in logarithms, except the dependent variable.

Table 5 presents the overall impact of the institutional framework on innovative activities. Because of the strong correlation between the indicators of access to financial markets, commercial freedom and market regulation, we introduce these variables separately into our estimations. We note a decline in the traditional determinants of innovating activities, such as market size and labour cost, as well as in the international spillovers. The results confirm the assumption that the legal and institutional framework plays a dominant part in the capacity of emerging countries to innovate (Porter and Stern, 2001; Furman et al., 2002). This conclusion is reinforced by the coefficient of the national spillover variable; that is, the investments in R&D undertaken in the emerging country, weighted by the self-citations. The impact of the IPR protection varies according to the specification. In the second column, the positive impact of the degree of protection seems more important and long lasting. This highly strong influence of the patent system can be due to the poor explanatory power of the regulation index, which does not manage to capture all the potential influence of the institutional framework[43]. We also note that the constant term is positive, although insignificant in Column (2), indicating a potential omitted variable bias[44]. We therefore conclude that the first specification has more robust results. Both financial and commercial freedom have positive and significant effects on the innovation process of emerging countries, corroborating preceding studies. Commercial openness increases the propensity of host countries to innovate, by means of increasing competition (Grossman and Helpman, 1991) and technology transfer (Coe et al., 1997), or by reinforcing the impact of property rights (Gould and Gruben, 1994; Maskus and Penubarti, 1995). Access to financial markets encourages the financing of domestic R&D investments, as well as facilitating access to and exploitation of foreign technologies.

5.4 Innovation and Industrial Specialization

In the preceding estimates, dummy variables relating to industries have proved to be significant (not reported). This gives an initial indication of the industrial differences in the innovating activities of emerging countries. The purpose of this section is to highlight these differences by providing an analysis at the industrial level.

Tables 6 to 10 present the estimation results for the five principal industries according to Hall et al.'s classification. There are considerable differences in the role of the spillovers among industries[45]. The results show that the emerging countries depend heavily on foreign technology in the pharmaceutical industry (Table 6). The variable of the international spillovers has the most important coefficient, and the domestic R&D weighted by self-citations is not significant. Although recent studies find an upward trend in the pharmaceutical innovations of emerging countries since the late 1990s (Lanjouw and MacLeod, 2005), the period analysed in this paper does not enable us to take this recent development into account. The chemical industry constitutes the second sector where the coefficient of the international spillovers is high. A rise of 1% in investments in the R&D of industrialized countries increases about by 17% the patents deposited in the chemical industry in emerging countries. However, we note a decline of this coefficient when institutional variables are taken into account (Column (4) in Table 7). Technological capacity also seems important in explaining inno-

[43] The coefficients of the IPR variables indicate that the negative effect emerges at an index level of 22, which is above the maximum value.

[44] Fritsch et al. (2004) stress that a positive constant within the KPF framework indicates the share of innovation that comes from nowhere, since it is not explained by the investments in R&D. This situation can be explained in two ways: either the innovation results from the international spillovers and not from the R&D of the innovating country/sector, or the estimate suffers from a bias due to omitted variable (Fritsch and Franke, 2004). Since, in our estimate, we take into account the international spillovers, as well as the effort of domestic R&D, this can be due only to the omitted variables.

[45] Given the previous results and correlation matrice, we no longer include the labour market regulation variable in our estimation.

Table 6: Drugs and Medical Industry

	(1)	(2)	(3)	(4)
Market Size	0.359*	0.312*	-0.513	-0.592*
	[0.202]	[0.182]	[0.335]	[0.323]
Labour Costs	-0.106	0.052	0.780**	0.555*
	[0.198]	[0.244]	[0.367]	[0.299]
International Spillovers	0.901**	0.926***	0.929**	0.966*
	[0.423]	[0.354]	[0.369]	[0.500]
National Spillovers	0.042	0.039	0.007	0.163
	[0.127]	[0.134]	[0.114]	[0.101]
Trade Openness	0.227*	0.214*	0.293**	
	[0.143]	[0.138]	[0.149]	
IPR		0.130	3.219***	3.732***
		[0.155]	[0.824]	[0.913]
IPR^2			-0.225***	-0.280***
			[0.062]	[0.070]
Size of Government				-0.037
				[0.064]
Freedom to Trade				0.027
				[0.039]
Access to Financial Markets				0.415***
				[0.134]
Constant	7.993	3.618	-4.733	-5.676
	[12.260]	[12.636]	[13.143]	[11.582]
Observations	11128	3023	3023	2987
Log-likelihood	-216.3218	-215.8963	-209.56349	-202.14979
Likelihood-ratio test ($\alpha = 0$)	301.55	301.78	198.51	105.73
Prob>chibar2	0.000	0.000	0.000	0.000

*Significant at 10%; ** significant at 5%; *** significant at 1%. Standard errors in brackets. All variables are in logarithms, except the dependent variable.

Table 7: Chemical Industry

	(1)	(2)	(3)	(4)
Market Size	-0.125**	-0.123**	-0.152***	-0.066***
	[0.050]	[0.050]	[0.054]	[0.019]
Labour Costs	-0.179***	-0.191***	-0.184***	-0.034
	[0.048]	[0.074]	[0.070]	[0.068]
International Spillovers	0.928***	0.936***	0.943***	0.441
	[0.347]	[0.354]	[0.348]	[0.313]
National Spillovers	0.155***	0.155***	0.160***	0.160***
	[0.036]	[0.036]	[0.035]	[0.031]
Trade Openness	-0.126***	-0.124**	-0.149***	
	[0.049]	[0.049]	[0.053]	
IPR		-0.015	0.371	0.462
		[0.076]	[0.379]	[0.310]
(IPR^2)			-0.030	-0.042*
			[0.030]	[0.023]
Size of Government				-0.294***
				[0.040]
Access to Financial Markets				0.062**
				[0.031]
Freedom to Trade				0.280***
				[0.079]
Constant	8.548	8.945	8.289	5.526
	[7.367]	[7.655]	[7.493]	[6.183]
Observations	5110	1287	1287	1143
Log-likelihood	-515.4317	-515.4088	-514.77686	-497.65154
Likelihood-ratio test ($\alpha = 0$)	843.75	843.28	800.75	692.11
Prob>chibar2	0.000	0.000	0.000	0.000

*Significant at 10%; ** significant at 5%; *** significant at 1%. Standard errors in brackets. All variables are in logarithms, except the dependent variable.

Table 8: Electrical and Electronics Industry

	(1)	(2)	(3)	(4)
Market Size	0.057	0.059	-0.151**	-0.074**
	[0.058]	[0.058]	[0.064]	[0.031]
Labour Costs	-0.180***	-0.194**	-0.038	0.176
	[0.051]	[0.098]	[0.072]	[0.109]
International Spillovers	0.007*	0.009*	0.054*	0.076*
	[0.109]	[0.109]	[0.098]	[0.103]
National Spillovers	0.311***	0.310***	0.277***	0.345***
	[0.048]	[0.050]	[0.045]	[0.043]
Trade Openness	0.065	0.066	-0.148**	
	[0.059]	[0.059]	[0.065]	
IPR		-0.018	2.469***	2.369***
		[0.117]	[0.420]	[0.420]
(IPR^2)			-0.185***	-0.181***
			[0.031]	[0.033]
Size of Government				-0.225***
				[0.058]
Access to Financial Markets				0.080**
				[0.035]
Freedom to Trade				0.357***
				[0.124]
Constant	-3.259	-2.926	-12.330***	-19.264***
	[3.157]	[3.798]	[3.481]	[3.129]
Observations	15312	4021	4021	3850
Log-likelihood	-1055.2727	-1055.2523	-1039.1776	61031.5283
Likelihood-ratio test ($\alpha = 0$)	6210.92	6210.26	5536.16	4958.12
Prob>chibar2	0.000	0.00	0.000	0.000

*Significant at 10%; ** significant at 5%; *** significant at 1%. Standard errors in brackets.
All variables are in logarithms, except the dependent variable.

Table 9: Mechanical Industry

	(1)	(2)	(3)	(4)
Market Size	-0.007	0.011	-0.021	-0.029
	[0.057]	[0.057]	[0.053]	[0.027]
Labour Costs	-0.349***	-0.510***	-0.446***	-0.211
	[0.057]	[0.083]	[0.089]	[0.178]
International Spillovers	0.144*	0.139*	0.146*	0.174**
	[0.076]	[0.075]	[0.074]	[0.085]
National Spillovers	0.561***	0.572***	0.528***	0.475***
	[0.047]	[0.046]	[0.047]	[0.081]
Trade Openness	0.051	0.074	0.040	
	[0.055]	[0.056]	[0.053]	
IPR		-0.170**	0.814**	1.538***
		[0.076]	[0.339]	[0.568]
(IPR^2)			-0.077***	-0.124***
			[0.026]	[0.042]
Size of Government				-0.097
				[0.061]
Access to Financial Markets				-0.004
				[0.095]
Freedom to Trade				0.042
				[0.137]
Constant	-0.727	2.632	-0.288	-5.601
	[3.289]	[3.692]	[3.725]	[4.957]
Observations	7262	1931	1931	1763
Log-likelihood	-1033.9861	-1031.1389	-1025.8821	-1036.3138
Likelihood-ratio test ($\alpha = 0$)	5510.42	5473.12	5191.58	5519.54
Prob>chibar2	0.000	0.000	0.000	0.000

*Significant at 10%; ** significant at 5%; *** significant at 1%. Standard errors in brackets.
All variables are in logarithms, except the dependent variable.

Table 10: Computers and Communication Industry

	(1)	(2)	(3)	(4)
Market Size	0.316***	0.322***	0.239***	-0.034
	[0.039]	[0.042]	[0.047]	[0.043]
Labour Cost	-0.356***	-0.394***	-0.337***	-0.138
	[0.042]	[0.092]	[0.076]	[0.090]
International Spillovers	0.101**	0.099*	0.088*	0.006*
	[0.085]	[0.084]	[0.081]	[0.106]
National Spillovers	0.413***	0.412***	0.397***	
	[0.047]	[0.047]	[0.045]	[0.056]
Trade Openness	0.306***	0.314***	0.243***	
	[0.039]	[0.044]	[0.048]	
IPR		-0.043	1.248***	1.902***
		[0.085]	[0.360]	[0.397]
(IPR^2)			-0.094***	-0.154***
			[0.025]	[0.032]
Size of Government				-0.120***
				[0.041]
Access to Financial Markets				0.167***
				[0.030]
Freedom to Trade				0.265**
				[0.127]
Constant	-15.628**	-13.653*	-15.477**	-10.385
	[6.149]	[7.419]	[6.666]	[7.186]
Observations	9055	2405	2405	2397
Log-likelihood	-872.50532	-872.33135	-865.39289	-852.42196
Likelihood-ratio test ($\alpha = 0$)	2103.16	2099.27	1909.13	1441.46
Prob>chibar2	0.000	0.000	0.000 0.000	0.000

*Significant at 10%; ** significant at 5%; *** significant at 1%. Standard errors in brackets.
All variables are in logarithms, except the dependent variable.

vating activities. On the other hand, the mechanical, computer and communication, and electronics industries of emerging countries do not seem to depend heavily on foreign technology. Indeed, as shown in Tables 8, 9 and 10, domestic R&D plays a much more important role than international spillovers.

The impact of the institutional variables does not seem to vary according to the industry. Government size reduces the propensity of emerging countries to innovate, highlighting once again the importance of the type of government support in stimulating innovation. Commercial freedom always has a positive impact, even though the commercial openness variable is not always significant. Surprisingly, access to financial markets, which has the highest coefficient in previous estimates, is not significant for the mechanical industry. The impact of the IPR is rather similar through different industries. With the exception of the pharmaceutical industry, the reinforcement of the patent system has an initial negative impact, corroborating the preceding results, when we do not take into account the non-linearity[46]. Thereafter, IPR protection seems first to stimulate emerging countries' innovating activities, and then to reduce them[47].

[46] In respect of the pharmaceutical industry, the impact IPR is instantaneously positive.

[47] According to the estimated quadratic functions, the turning point stands at around 6.5, except for the mechanical engineering industry, where the perverse effect of the IPR appears as soon as the protection index reaches 5.2; and the pharmaceutical industry, where, on the other hand, it is necessary to reach an index of 7.1.

Table 11: R&D Spillovers and Innovative Capacity

	Countries with High Innovative Capacity			Countries with Low Innovative Capacity		
	(1)	(2)	(3)	(1)	(2)	(3)
Market Size	-0.024	-0.261***	0.172**	0.020*	0.024*	0.454***
	[0.097]	[0.086]	[0.077]	[0.077]	[0.074]	[0.080]
Labour Costs	0.301*	0.405**	0.050	-0.246***	-0.248***	-0.101**
	[0.169]	[0.163]	[0.094]	[0.063]	[0.061]	[0.051]
International Spillovers	0.032**	0.032**		0.966**	0.914**	
	[0.020]	[0.020]		[0.411]	[0.407]	
National Spillovers	0.477***	0.341***		0.188***	0.180***	
	[0.054]	[0.099]		[0.037]	[0.033]	
Intersectorial International Spillovers			0.021*			0.088*
			[0.411]			[0.043]
Intersectorial National Spillovers			0.304*			0.962***
			[0.315]			[0.232]
Size of Government	-0.143	-0.189**		-0.391***	-0.404***	
	[0.191]	[0.175]		[0.042]	[0.039]	
IPR	-4.751***	-8.069***		-1.113***	-0.830**	
	[1.023]	[1.126]		[0.346]	[0.368]	
(IPR^2)	-0.340***	-0.555***		0.086***	0.062*	
	[0.066]	[0.074]		[0.032]	[0.033]	
Access to Financial Markets	0.516**			0.418		
	[0.278]			[0.118]		
Freedom to Trade		0.507***			0.088*	
		[0.129]			[0.079]	
Trade Openness			0.155***			0.037*
			[0.056]			[0.040]
Constant	-13.076***	-13.039***	-9.744***	-8.260***	-7.265***	10.515***
	[5.635]	[5.858]	[1.426]	[1.494]	[1.906]	[2.015]
Observations	19824	19356	19356	29532	29532	29532
Log-likelihood	-1848.190	-1848.109	-1734.7867	-1781.2939	-1733.0048	1732.759
Likelihood-ratio test ($\alpha = 0$)	2997.34	2953.29	2945.53	3442.79	3749.57	3813.10
Prob>chibar2	0.000	0.000	0.000	0.000	0.000	0.000

*Significant at 10%; ** significant at 5%; *** significant at 1%. Standard errors in brackets.
All variables are in logarithms, except the dependent variable.

5.5 Distinction According to the Innovative Capacity of Emerging Countries

The descriptive statistics given in the preceding sections have shown us that there were considerable differences in terms of innovation in our sample (See Figures 1 and 2). Our final specification consists of analysing the impact that these differences can induce in technological spillovers. For this purpose, we divide our sample into two sub-samples, according to the number of the patents applied by the emerging countries (See Table 11). We consider South Korea, Hong Kong, Israel, New Zealand, Taiwan and Singapore to be relatively innovative countries, and the remainder of our sample as relatively less innovative.

The impact of international and national technological spillovers differs considerably according to the innovating experience of the sample under consideration. Countries that have a certain capacity for or experience in innovating activities seem to rely much less on foreign technology. A rise of one unit of the R&D expenditure in the industrialized countries increases by 1.33 the propensity to patent in more innovative countries, and by 2.66 in the others. This result can seem to contradict the literature on the importance of the absorption capacity of host countries in the process of technology transfer. Countries with a certain level of innovating capacity should profit more from foreign technology (Blomstrom et al., 1994; Sjoholm, 1999; Kumar and Persaud, 1999; Blomström et al., 2000). However, this conclusion is moderated by the coefficient of the domestic R&D variable. Indeed, countries with strong innovating capacity depend rather on their own efforts in research. A rise of 1% in investments in R&D in highly innovative countries increases by 40% the number of patent applications, in contrast to 20% for less innovative countries. Finally, it can be noted that the whole sample we analyse consists of countries beyond a certain level of technological capacity and human capital. Consequently, the subset with high innovating capacity corresponds mainly to newly industrialized countries, which have almost caught up with the technology source countries.

The two sub-samples do not react in the same way to the institutional variables. The coefficient of the government size variable, although significant and negative in both cases, is relatively more important for the less innovating countries. The commercial freedom variable has almost the same effects on the two groups. On the other hand, the impact of financial freedom is higher for the group with high innovative capacity. This result is not surprising as the need for finance is more important for these countries, given their technological level. So far, we have not affirmed the insignificance of the financial framework for less innovative countries, but we can nevertheless claim that it does not constitute the principal obstacle for the majority of emerging countries.

With respect to the impact of patent protection, we also find two different cases. For the first group of countries, we do not find a non-linear relationship between the IPR index and the innovative activities, since the sign both of the IPR index and of its squared term is significant and negative. A reinforcement of IPR protection reduces the propensity to innovate in the more innovative countries. This result contradicts previous literature, which expects a stronger impact of IPR protection in countries with a certain level of development and technological capacity (Maskus, 2000). It also attenuates our conclusions concerning the technological level of countries with strong innovating capacity. Indeed, with imitation becoming more expensive, technological externalities can also be reduced, which would explain the low value of the coefficient of the technological spillovers. It therefore proves that a flexible mode of IPR protection is more suitable for stimulating the innovation process in emerging countries (Lanjouw, 1998).

On the other hand, for relatively less innovative countries, we find a reversed U-shaped relation, as was predicted by the preceding studies. However, the positive effect of IPR protection intervenes at an index of 6.38, which is well above the level of protection in force in developing countries. This result shows once again the importance of accompanying policy with additional measures when developing countries strengthen their patent system, since the expected positive effects can take time to occur.

Finally, the last columns (3) in Table 11 show the results for technological spillovers at the intersectoral level. Once again, the countries with a high capacity seem to profit more from their own R&D efforts, although the intersectoral spillover variable is now significant. But this time, the innovating activities of the countries with low technological capacity also depend heavily on national spillovers. We thus confirm the results presented in Table 2, concerning the sensitivity of the intersectoral spillovers to geographical distance. Knowledge flows are less likely to occur between countries with different technological specialization and different levels of development (Bernstein and Nadiri, 1988).

6 Conclusion

The objective of this paper has been to evaluate the determinants of innovative activities in emerging countries, with a particular interest in the role of foreign technology. Combining several approaches in a cross-country time-series analysis, we have sought to identify the characteristics common to 'successful' countries, which benefit more from technological spillovers.

In a broad sense, our results show that technological spillovers exist, at national, international and intersectoral levels. However, their intensity and impact vary according to the countries and/or industries considered, as well as the relative distance of technology source countries from emerging countries. It should be noted that the share of the intersectoral spillovers remains rather weak, indicating the industry-specific nature of R&D.

Although market size figures as a push factor, among the traditional determinants of innovation activities trade openness emerges as the most important. This result, along with the high positive impact of the institutional variable of commercial freedom, points to trade as a vehicle for knowledge spillovers, confirming previous studies. However, no evidence has been found for the role of foreign direct investments. Finally, labour costs seem to reduce innovative activities. This last finding can be interpreted either as a substitution relationship between foreign technology and local labour force, or as a cost, depending on the nature of the innovative activities of emerging countries.

It appears that emerging countries, although they rely on foreign technology, benefit more from their own R&D efforts in particular instances. This is the case in medium and low technological industries, in which the majority of our sample countries are specialized. Furthermore, when we distinguish between countries' innovative capacity, our findings show that the relatively more innovative countries benefit more from national than international spillovers. Without neglecting the role of foreign technology, the governments of emerging countries had to stimulate technological capacity building. This conclusion is reinforced by the high coefficient found for the technological proximity variable, indicating once again the importance of local technological capacity level.

This study has given rise to some interesting results concerning policy implications. Access to financial markets is found to be a determinant in the intensity of innovative activities. The greatest problem for emerging countries seems to be the financing of their own R&D. On the other hand, government size sub-index has unexpected negative impact, even if this result may be due to the small number of patents assigned by the government agencies in our sample countries. Nevertheless, a discussion about the role of government and the right incentives to set up would be very useful. The main concern of the governments of emerging countries should be to promote technological capacity in the more effective way.

The final issue to emerge from this study concerns the protection of intellectual property rights. Although the majority of emerging countries are strengthening or have strengthened their IPR systems since the mid-1990s within the TRIPS (Trade-related aspects of intellectual property rights) agreement, the impact of patent protection on global innovation and welfare continues to be a subject of debate. Our results show that the reinforcement of patent protection has a negative impact in the first stages of development, where the innovative capacities rely mostly on imitation of foreign technologies. It is only when an emerging country has developed its own innovative capacities that IPR protection becomes relatively more important. However, our findings do not allow us to conclude that a strengthened patent protection has a positive impact on the innovative activities of emerging countries.

This paper contributes to the earlier literature in several ways. First, we have considered emerging countries as technology producers, an approach relatively rare in the literature (except for South East Asia). However, while trying to highlight the determinants of innovation in these countries, particular attention has been paid to the role played by foreign technology. Both international and national spillovers have been considered, in order to evaluate the extent to which emerging countries rely on technologies developed elsewhere.

Secondly, the cross-country panel analysis undertaken in this paper provides a full picture of the innovation process of emerging countries, enabling us to highlight the common characteristics of more successful countries and/or industries. Considering different countries from different regions, and with different endowments and specialization, enables us to undertake a more detailed analysis than would be possible with case studies.

Finally, combining several approaches in our analysis allow us to consider the innovation process as a whole. The present study evaluates technological spillovers in a knowledge production framework, and takes into account institutional aspects of innovation. We can therefore deduce some political implications. However, we believe that the most important question raised by this paper concerns the role of governments in stimulating and building the technological and absorptive capabilities of emerging countries. The greatest deficiency of these countries resides in the financing of local R&D investments and the timing of IPR reforms. In this context, our results draw attention to the type of government support that may be required to stimulate the propensity to innovate.

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7 Appendix

7.1 Data Construction

Our primary source of data comes from NBER Patent and Citation Dataset[48] and UNIDO Trade and Production Database[49]. NBER data contain all the patents granted by the U.S. Patent Office (USPTO) and all citations made by each patent to others, since 1975. The USPTO assigns each patent to an original patent class. This United States Patent Classification (USPC) System consists of about 400 main patent classes and 120 000 patent sub-classes. In order to match patent citations over sectors and countries with UNIDO data presented in the International Standard Industrial Classification (ISIC. Rev2), we needed to use several correspondence tables.

The first correspondence table was between the USPC System and the International Patent Classification (IPC). We would like the thank Professor Brian Silverman for providing these data. Once we had the IPC number for each patent on our database, we used a concordance that links the IPC system to the U.S. Standard Industrial Classification (SIC) system at the four-digit SIC level, in order to have an SIC number for each citing and cited patent. This concordance table also come from Professor Silverman[50]. The next step was to link these SIC numbers to ISIC Rev.2 Classification in order to match the two databases.

Using Jon Haveman's industrial concordance tables[51], we connected our four-digit SIC numbers to the three-digit ISIC Rev.3 Classification System. The final step consisted of linking the ISIC Rev.3 Classification system to ISIC Rev.2, based on the United Nations' correspondence tables.

7.2 Perpetual Inventory Method

The formulation of stocks used in this paper to evaluate R&D (R) and patent stocks could be represented as follows. The stock at time t is equal to the new investment at time t plus the stock at time $t-1$ less the retirements which depend on the depreciation rate:

$R_t = I_t + (1-\delta)R_{t-1}$ $R_t = I_t + [(1-\delta)I_{t-1} + (1-\delta)^2 I_{t-2} + (1-\delta)^3 I_{t-3} + ... + (1-\delta)^n I_{t-n}]$

Then, if we assume a constant annual rate of growth of the past investments: $R_t = I_t + (1-\delta)\lambda I_{t-1} + (1-\delta)^2\lambda^2 I_{t-2} + (1-\delta)^3\lambda^3 I_{t-3} + ... + (1-\delta)^n\lambda^n I_{t-n}$

$R_t = \frac{I_t}{1-\lambda(1-\delta)}$

where:

R_t = fixed research and development capital stock at time t

I_t = new investment at time t

δ = depreciation rate (constant over time)

[48]See Hall et al. (2001) for details.

[49]See Nicita and Olarreaga (2001) for details.

[50]See Professor Silverman's homepage ($http://www.rotman.utoronto.ca/\ silverman/ipcsic/documentation\_IPC-SIC\_concordance.htm$) for details.

[51]$http://www.macalester.edu/research/economics/page/haveman/Trade.Resources/tradeconcordances.html$

$\lambda = \frac{1}{1-\mu}$

μ = the mean annual rate of growth of I_t

We use a depreciation rate of 15% and a pre-sample annual growth rate of 5%. In order to test the sensitivity of our results, several depreciation rates have been used in the construction of stocks. However, we found that the precise depreciation rate makes no significant difference to the results.

7.3 Description of Variables and Sources

International Spillovers	Northern countries' R&D(1) expenditures weighted by patent citations
National Spillovers	Host countries' R&D(2) expenditures weighted by self-citations
R&D(1)	Northern countries' R&D expenditures* ANBERD Database – OECD ISIC Rev2, 1973–1999
R&D(2)	Emerging countries' R&D Science and Technology Indicators – UNESCO, 1960–1999
Patent Citations	Number of citations per country and sector NBER Patent Citation Database – NBER 1963–1999
Market Size	Sectoral Production* Trade and Production Database – UNIDO ISIC Rev 2, 1976–1999
Labour Cost	Mean salary* Trade and Production Database – UNIDO ISIC Rev 2, 1976–1999
Technological Proximity	Jaffe et al. (1986)' technological proximity between i and j $\omega_{ij} = \frac{\sum_{k=1}^{F} f_{ik} f_{jk}}{\sqrt{\sum_{k=1}^{F} f_{ik}^2 \sum_{k=1}^{F} f_{jk}^2}}$ NBER Patent Citation Database – NBER 1963–1999
Trade Openness	Sum of imports and exports on sectoral value added NBER World Trade Database – NBER SITC Rev3, 1960–2000
Geographical Distance	Geodesic distance between the capitals Distance Database – CEPII
Language	The use (or not) the same language (official, national or language spoken by at least 20% of the country) Distance Database – CEPII
Colonial Presence	Colonial presence (or not) of the northern country in the emerging country for a long time and with a substantial participation in the local government Distance Database – CEPII
Institutional Indicators	Sub-indicators of the economic freedom indicator Economic Freedom Indicators – Institute Fraser, 1970–2003

*All variables in current values have been converted to constant U.S. 1995 dollars.

7.4 Additional Tables

Table 12: Citation Distribution by Type/Country/Sector

	National		International	
Country/Sector	Intra-branch	Inter-branch	Intra-branch	Inter-branch
Total	8.33	2.31	61.37	27.99
Chemicals	4.28	2.01	59.34	34.37
Computers and Communication	4.62	2.46	60.17	32.76
Drugs and Medical	4.67	1.84	64.96	28.53
Electrical and Electronic	11.22	1.92	63.33	23.52
Mechanical	8.86	2.71	60.06	28.37
Others	9.35	2.78	60.46	27.40
Argentina	3.25	1.22	70.18	25.36
Chemicals	0.86	1.44	58.79	38.90
Computers and Communication	2.27	0.00	55.11	42.61
Drugs and Medical	4.75	1.39	78.80	15.06
Electrical and Electronic	0.80	3.19	70.52	25.50
Mechanical	1.92	0.52	76.61	20.94
Others	3.55	1.03	61.81	33.61
Brazil	2.04	0.81	68.51	28.63
Chemicals	1.42	0.42	66.83	31.33
Computers and Communication	1.01	0.00	58.39	40.60
Drugs and Medical	1.24	0.00	79.40	19.36
Electrical and Electronic	1.30	0.33	64.39	33.98
Mechanical	2.80	1.21	65.65	30.34
Others	2.51	1.32	69.18	27.00
China	1.89	0.41	71.09	26.61
Chemicals	2.38	0.39	74.51	22.72
Computers and Communication	3.31	0.37	53.78	42.54
Drugs and Medical	2.58	0.82	62.49	34.11
Electrical and Electronic	2.31	0.16	76.92	20.61
Mechanical	0.55	0.70	72.56	26.19
Others	0.95	0.32	69.02	29.71
Czech Republic	9.01	2.12	62.36	26.50
Chemicals	11.53	2.23	58.80	27.44
Computers and Communication	0.00	0.00	48.10	51.90
Drugs and Medical	2.01	8.02	58.15	31.83
Electrical and Electronic	0.88	0.44	68.79	29.89
Mechanical	3.30	1.65	69.63	25.41
Others	15.94	1.15	61.38	21.53
Hong Kong	3.21	0.44	66.85	29.50
Chemicals	1.03	0.69	49.14	49.14
Computers and Communication	1.26	0.56	64.63	33.54
Drugs and Medical	1.45	0.96	48.92	48.67
Electrical and Electronic	4.37	0.57	65.26	29.81
Mechanical	5.17	0.46	69.17	25.20
Others	2.83	0.25	71.97	24.95
Hungary	5.57	3.77	61.16	29.50
Chemicals	6.06	3.77	65.82	24.34
Computers and Communication	0.83	0.83	56.51	41.83
Drugs and Medical	9.21	8.30	47.51	34.98
Electrical and Electronic	3.08	0.49	70.48	25.95
Mechanical	3.88	1.33	65.01	29.79
Others	2.90	1.14	67.74	28.23
Israel	2.11	1.21	59.89	36.79
Chemicals	4.53	4.46	50.57	40.44
Computers and Communication	1.12	0.56	56.66	41.65
Drugs and Medical	2.90	0.21	77.99	18.89
Electrical and Electronic	1.48	0.90	55.82	41.80
Mechanical	0.68	0.93	53.44	44.95
Others	2.25	1.05	61.32	35.38

Source : USPTO.

Country/Sector	National Intra-branch	National Inter-branch	International Intra-branch	International Inter-branch
India	2.34	0.73	64.51	32.41
Chemicals	2.42	0.88	67.53	29.16
Computers and Communication	0.15	0.15	50.15	49.54
Drugs and Medical	4.75	0.99	68.98	25.28
Electrical and Electronic	0.88	0.59	67.39	31.14
Mechanical	0.85	0.56	56.34	42.25
Others	1.19	0.30	52.84	45.67
South Korea	6.13	2.28	61.91	29.68
Chemicals	4.13	1.98	56.41	37.48
Computers and Communication	5.50	3.08	60.59	30.82
Drugs and Medical	3.10	1.38	61.44	34.08
Electrical and Electronic	7.66	2.13	64.34	25.87
Mechanical	4.87	1.29	63.19	30.65
Others	6.31	1.89	60.32	31.48
Mexico	4.28	0.76	63.39	31.57
Chemicals	3.22	0.60	60.90	35.28
Computers and Communication	0.00	1.08	64.62	34.30
Drugs and Medical	3.95	1.13	59.80	35.12
Electrical and Electronic	2.74	0.39	62.43	34.44
Mechanical	7.30	0.96	65.39	26.36
Others	3.08	0.60	64.25	32.08
New Zealand	3.18	1.07	63.16	32.59
Chemicals	2.66	1.18	53.11	43.05
Computers and Communication	1.96	0.65	66.62	30.77
Drugs and Medical	4.57	2.09	58.65	34.69
Electrical and Electronic	3.32	2.13	56.90	37.65
Mechanical	3.89	0.37	61.79	33.95
Others	2.76	0.72	69.03	27.49
Russia	5.05	1.26	63.46	30.23
Chemicals	3.91	1.05	64.69	30.35
Computers and Communication	1.62	0.60	68.11	29.67
Drugs and Medical	5.71	1.21	59.86	33.22
Electrical and Electronic	4.72	0.85	66.58	27.85
Mechanical	7.19	1.99	60.00	30.83
Others	5.97	1.65	61.46	30.92
Singapore	1.87	0.42	62.61	35.10
Chemicals	0.62	0.72	36.77	61.89
Computers and Communication	1.20	0.45	59.49	38.86
Drugs and Medical	0.66	0.33	68.52	30.49
Electrical and Electronic	2.54	0.35	66.94	30.17
Mechanical	0.72	0.56	58.11	40.61
Others	1.35	0.45	64.66	33.54
Venezuela	3.97	0.76	68.23	27.04
Chemicals	5.70	0.67	72.61	21.03
Computers and Communication	2.00	0.67	62.00	35.33
Drugs and Medical	1.12	1.12	55.62	42.13
Electrical and Electronic	1.42	0.95	56.40	41.23
Mechanical	4.44	0.44	73.11	22.00
Others	1.36	1.06	62.58	35.00
South Africa	5.46	1.47	62.72	30.35
Chemicals	4.13	1.25	64.93	29.69
Computers and Communication	4.56	2.23	56.19	37.02
Drugs and Medical	2.82	0.82	70.40	25.96
Electrical and Electronic	9.43	1.11	63.92	25.54
Mechanical	4.73	2.13	58.67	34.46
Others	6.49	1.17	63.80	28.54

Source : USPTO.

Table 13: Sectoral Distribution of Innovation

Sector	Number of Patents	Percentage
Chemicals, exc. Drugs	19748	17.34
Computers and Communication	26489	23.26
Drugs and Medical	6617	5.81
Scientific Instruments	10641	9.34
Electrical and Semiconductor Devices	16081	14.12
Materials Processing and Handling	4378	3.84
Motors, Engines and Parts	6537	5.74
Transportation	5052	4.43
Food and al.	4766	4.18
Apparel and Textiles	4501	3.95
Furniture, House Fixtures	9038	7.93
Paper and Paper Apparels	5138	4.51
Others nce.	28367	24.91
Total	113848	100

Source: USPTO and UNIDO.

7.5 Intersectoral Technological Spillovers

Table 14: Innovation and Intersectoral R&D Spillovers

	Basic Specification	Geographical Distance	Cultural Distance	Historical Distance
Market Size	0.369***	0.382***	0.372***	0.383***
	[0.070]	[0.120]	[0.070]	[0.120]
Labour Costs	-0.379*	-1.024***	-0.395*	-1.032***
	[0.217]	[0.165]	[0.217]	[0.166]
International Spillovers	0.025***			
	[0.003]			
D1*International Spillovers		0.054**	0.022***	0.045**
		[0.417]	[0.001]	[0.018]
D0*International Spillovers		0.048	0.021***	0.031*
		[0.421]	[0.000]	[0.011]
National Spillovers	0.115***	0.171***	0.118***	0.167***
	[0.027]	[0.052]	[0.027]	[0.052]
Trade Openness	0.551***	0.084	0.554***	0.085
	[0.047]	[0.086]	[0.047]	[0.086]
Constant	0.771***	0.662***	0.772***	6.165***
	[0.042]	[0.074]	[0.042]	[1.892]
Observations	49356	49356	49356	49356
Log-likelihood	-25460.36	-27657.49	-28647.14	-24941.09
Likelihood-ratio test ($\alpha = 0$)	6.35	7.47	6.74	6.32
Prob>chibar2	0.000	0.000	0.000	0.000

D1(D0) equals to 1 for 'closer' ('far') countries. All variables are in logarithms, except the dependent variable.
*Significant at 10%; ** significant at 5%; *** significant at 1%. Standard errors in brackets.

Table 15: Intersectoral Spillovers by Industry

	Drugs and Medical Ind.	Chemicals Industry	Electrical and Elec. Ind.	Mechanical Industry	Computers and Comm. Ind
Market Size	-1.876***	0.112*	-0.031	-0.042**	-0.023
	[0.430]	[0.215]	[0.025]	[0.020]	[0.016]
Labour Costs	0.780*	-0.022**	0.188	0.788***	0.233**
	[0.470]	[0.017]	[0.128]	[0.161]	[0.117]
International Intersectoral Spillovers	-0.337	0.106	1.452**	-0.055	0.186*
	[1.051]	[0.303]	[0.654]	[0.496]	[0.423]
National Intersectoral Spillovers	-0.116	0.094	-0.384	0.426***	0.467*
	[0.357]	[0.084]	[0.377]	[0.084]	[0.277]
Constant	13.785	0.542	-6.662*	-10.621**	-16.519**
	[12.616]	[6.900]	[3.561]	[4.457]	[7.117]
Observations	9036	4526	13758	6843	8324
Log-likelihood	192.07934	-487.83987	955.41122	- 948.11794	-879.30495
Likelihood-ratio test ($\alpha = 0$)	230.46	454.90	1833.94	1880.21	1875.45
Prob>chibar2	0.000	0.000	0.000	0.00	0.00

*Significant at 10%; ** significant at 5%; *** significant at 1%. Standard errors in brackets.
All variables are in logarithms, except the dependent variable.

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