The Influence of Regional Knowledge Spillovers on the Innovative Performance of Firms. A Multilevel Approach

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The objective of this paper is to study the effects of regional context and negative regional knowledge spillovers on the innovative performance of industrial firms. The author adopts a multilevel approach to the analysis of these effects, taking into account the hierarchical structure of the data. The innovative performance of a firm depends on its own attributes and on the regional context and the knowledge spillovers between regions. The empirical analysis uncovers evidence relative to the debate about positive and negative innovation spillovers between regions. I estimate a multilevel model of innovation at firm level, where variables of both the firm and regional levels intervene. The conclusion is that both levels have a direct and significant influence on the innovative performance. A database of 6,670 Colombian firms operating in 26 regions is used in the analysis. The main result is that innovation spillovers from neighboring regions have a negative influence over the firm's innovative performance. The relationship is mediated by the number of inhabitants in the region with graduate degrees. These results have implications for regional innovation policies.

Keywords: knowledge spillovers; regional innovation; multilevel analysis.

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Technological progress and the production of new knowledge are considered to be the driving forces of economic development (Schumpeter, 1910; Romer, 1986; 1990). In the regional context this implies that growth depends on the quantity of knowledge generated (Lucas, 1988) and the total innovations that a region is able to develop by exploiting its internal and external capabilities and resources. Spillovers (the leakage of knowledge across firms) are one of the central constructs in the economics of innovation (Knott, Posen and Wu, 2009, 373). Different authors (Krugman, 1991; Grossman & Helpman, 1991) have emphasized the role of knowledge spillovers in the generation of new knowledge which are translated, eventually, into economic growth. Furthermore, recent studies have identified the existence of spatially-mediated knowledge spillovers (Jaffe, 1989; Jaffe et al., 1993; Acs, Audrestsch, and Feldman,, 1992; 1994; Feldman, 1994). However, it seems that knowledge spillovers to a certain extent remain a black box, whose contents needs to be further investigated in order fully comprehend the localization of innovation process (Breschi, and Lissoni, 2001; Feldman and Kogler, 2010, 398).

As Knott, Posen and Wu (2009, 373-374) argue, despite the fact that spillovers are central to models of innovation and growth in the economics of innovation literature, there is no consensus on their functional form or regarding their impact on the innovative behavior of firms. Although spillovers are a crucial factor in determining the optimal environment for innovation and growth, there is no consensus regarding their impact on firms' innovative behavior. The importance of the effects of regional context on the innovation of firms is subject to debate. Research results are mixed when it comes to analyzing the positive or negative impact of development in a region whose neighbors are highly developed. On the other hand, there is no clarity concerning the factors that determine whether the effects of this are positive or negative.

The idea that regional knowledge spillovers exert a positive influence over economic development originated in the writings of Marshall towards the end of the 19th Century. In the mid-20th Century the approach was developed in the theory of regional development poles. According to this theory, developed by Francois Perroux (1950; 1955; 1964), economic growth does not occur in all places at the same time, but is concentrated and "manifested in growth points or poles of varying intensity"; "it is diffused through different channels, with different final effects on the economy as a whole". Growth poles are "*centers for the generation and spatial dissemination of innovations*". Thus, the positive effects of a pole might create growth for the economy as a whole.

Recent studies have confirmed these ideas. The empirical evidence confirms the existence of knowledge spillovers within regions, though the evidence on inter-regional knowledge spillovers is scarce and mixed (Greunz, 2003; Ponds, Oort and Koen Frenken, 2010). Positive effects of knowledge spillovers have been found within and between regions (Moreno-Serrano, Paci & Usai, 2005). Anselin, Varga and Acs, (1997) and Acs, Anselin and Varga (2002) find evidence of positive knowledge spillovers among neighboring US metropolitan statistical areas. Autant-Bernard (2001a; 2001b) demonstrates the importance of geographical proximity between 94 French Departments, finding that innovative activities in one region are positively influenced by the intensity of research efforts in neighboring regions. Bottazzi and Peri (1999) found evidence of positive R&D spillovers in 86 regions, though the significance of these effects decreased rapidly with distance. In the case of Germany, Bode (2004, 56), found evidence that "the proxy for interregional knowledge (KS) spillovers is estimated to be significantly positive, indicating that regions benefit from being situated in close spatial proximity to other highly innovative regions".

However, several authors have suggested possible negative effects of knowledge spillovers. The effect of knowledge spillovers between firms is asymmetrical (Jovanovic and Rob 1989, Jovanovic and MacDonald 1994, Eeckhout and Jovanovic 2002) and might even generate negative effects (Eeckhout and Jovanovic, 2002). Holod and Reed (2009) find that spillovers within the home country may adversely affect growth in the presence of substantial knowledge flows from the foreign country. Building on these ideas this article challenges the predictions of regional growth pole theory that there will be positive knowledge spillovers between regions. It provides a test that supports the view that innovative performance of firms in one region is negatively affected when they neighbor with highly innovative regions.

The aim of this research is to explore the effects of the contexts of regions and their neighbors on the innovative performance of firms. It provides evidence concerning the negative effects of regional knowledge spillovers by examining the effects of neighboring regions on the innovative performance of firms. The central research questions are: What effects does regional context have on the innovative performance of firms? Does proximity to highly innovative regions have positive or negative effects on the innovative behavior of firms? What role does education play in increasing or moderating the effects of having highly innovative neighbors? An examination of these questions determines the effects of highly innovative neighbors on the innovative performance of firms and the interaction between education and the positive or negative effects of regional knowledge spillovers.

The article argues that the reason most of the existing empirical evidence points to the positive effects of regional knowledge spillovers is the failure to consider the hierarchical structure of the data employed. Research has used data from the level of firms and regions. This has implications for the methodological strategy as the structure of the data is hierarchical (firms nested within regions). The techniques employed to estimate the regression coefficients have been based on the method of Ordinary Least Squares (OLS), whose principal assumption is the independence of the data observations. In a sample with data observations nested within groups this assumption of OLS does not hold, resulting in inefficient and biased estimators that affect the magnitude and sign of the regression coefficients. To counteract this methodological problem regression techniques have been developed that explicitly model the different levels of analysis, recognizing the hierarchical structure of the information. This article develops a Poisson Multilevel Regression Model to test regional knowledge spillovers effects on the innovative performance of firms.

The following section reviews the literature on the relationships between regional context and the innovative performance of firms, the debate on regional growth poles and the empirical evidence concerning the existence and effects of regional knowledge spillovers. The third section presents the multi-level theoretical and methodological approach, the data and the specification of the empirical model. The fourth section presents the results of the estimated model and the final section provides conclusions and indicates the implications for regional innovation policy. The available empirical evidence suggests that the existence of negative effects of inter-regional knowledge spillovers, which has not been examined sufficiently in the literature on knowledge spillovers. Neighboring regions with high levels of innovation affect the innovative performance of firms. The results also suggest that a region may counteract these negative effects by retaining a considerable number of individuals with postgraduate qualifications among the population. Secondary results provide evidence that confirms the importance of regional context for the innovative performance of firms.

2. Literature Review

Is a firm's innovative performance dependent on the economic performance and socioeconomic characteristics of the region in which it operates? Is the amount of knowledge-production and innovation of a regional economy related to the amount of knowledge-production and innovation of neighboring regions? Are firm and regional innovation outputs dependent on what happens in neighboring areas? Simple evidence suggests that the answer to these questions is yes. Economies interact with each other and, in the case of regional economies, linkages are assumed to be stronger than across heterogeneous countries. However, the effects of inter-regional knowledge spillovers and regional context on the innovative performance of firm remain unclear in the literature on knowledge spillovers and regional innovation. The multiple levels involved in addressing these issues make analysis difficult. Empirical testing of hypotheses that seek to approach these problems is only just beginning (Buesa, Heijs and Baumert, 2010; Srholec, 2010; 2011). The aim of this paper is to analyze the influence of regional context and inter-regional knowledge spillovers on the innovative performance of firms.

The analysis of the effects of externalities on the accumulation of factors of production has been one of the most important contributions of modern endogenous growth theory. Although the idea of externalities dates back to Marshall (1920), and has been developed and applied by different authors (Arrow, 1962), and the existence of spatially-mediated knowledge spillovers (Jaffe, 1989; Jaffe et al., 1993; Acs et al., 1992, 1994; Feldman, 1994) has been noted, few attempts have been made to relate inter-regional knowledge spillovers to the innovative performance of firms.

Firms are bounded by distance and time, so externalities in the process of production have a spatial dimension. But there is no a priori reason to constrain spillovers to the physical space within the economy where the firms making the investment are located. For example, Coe and Helpman, (1995, 860) point to the diffusion of technology across countries as a source of productivity: ''In a world with international trade in goods and services, foreign direct investment, and an international exchange of information and dissemination of knowledge, a country's productivity depends on its own R&D as well as on the R&D efforts of its trade partners''. The existence of externalities across economies might have important consequences, where both even and uneven development are possible outcomes i, depending on the relative strength of returns internal to each economy and spillovers across economies (Kubo, 1995).

The dominant vision of inter-regional knowledge spillovers maintains that the creation of agglomeration economies and regional growth poles has positive effects on neighboring regions. This idea was initially developed by Francois Perroux. Recent studies have confirmed the postulate behind the theory of regional growth pole, maintaining that "growth and initial productivity in the set of neighboring regions enhance growth in any region" (López-Bazo, Vayá and Artís, 2004, 69).

Two problems are highlighted in the literature on the regional dimensions of innovation. The first refers to the relationships between regional context and the innovative performance of firms – the debate concerning the importance of regional context for the results of innovation. The second concerns the importance of inter-regional knowledge spillovers in the generation of new knowledge and its impact on regional economic growth.

2.1 Regional context and the Innovative Performance of Firms

Various authors maintain that the geographical dimension is fundamental to understanding the innovation process (Bathelt, 2006). The "context matters" (Gittelman, 2007, 88); if the innovation process is to be understood it is of central importance to analyze spatial proximity and geographical concentration (Desrochers, 2001). Regions are important units in meso-level economic coordination: “the region is increasingly the level at which innovation is produced through regional networks of innovators, local clusters and the cross-fertilizing effects of research institutions” (Lundval and Borrás, 1993, 39). Lam (1998; 2000) argues that the skills and capabilities required for the production and transfer of knowledge are special, and time-specific. This being the case spatial proximity is vital to the effective production and transfer of knowledge through mechanisms such as knowledge spillovers.

Regional context is crucial for the innovative performance of firms (Audretsch and Feldman, 2004; Moreno-Serrano, Paci & Usai, 2005b; Rondé and Hussler, 2005). However, the role of regional context in explaining the innovation outputs of firms has been questioned. Beugelsdijk (2007) discusses the importance of the role of the region in increasing innovation by firms, arguing that if researchers wish to analyze the ways in which a firm’s environment affects its performance it is necessary to include variables at the level of the firm. His results suggest that “firm-specific drivers” of innovation arte more important than the regional environment of the firm. He recommends focusing on the principal actors, firms and their interactions (in particular those involving knowledge Exchange) in order to estimate the degree to which these interactions are extended beyond limited territories.

Beugelsdijk (2007) criticizes the over-emphasis on regional context and the underplaying of the role of the firm, analyzing empirical evidence from 1,466 firms in the 12 Dutch regions. His starting point is that there is little research that has analyzed the innovative performance of firms in relation to regional variables, with the result that there is no clear distinction between the effects attributable to the firm and the region. Rather than being based on micro-level evidence (the firm), the argument that “regions matter” is deduced from the macro phenomenon of clusters of innovative activity. This argument has resulted in an ecological fallacy in which a global phenomenon or aggregation of data representative of low-level phenomena cannot be generalized at these low levels (Beugelsdijk, 2007).

In a similar vein Gordon & McCann (2005, 523) criticize the view that innovation is favored by geographical proximity. They disagree with the hypotheses employed by research focused on the regional dimensions of innovation (Jaffe, Trajtenberg and Henderson, 1993), which argue that agglomeration economies foster learning within the economy. Based on research into firms based in London they maintain that there is no inherent reason why any particular configuration of geography and industrial organization (clusters of firms) should be in general terms superior to others (Gordon & McCann, 2005, 524-529).

Beugelsdijk (2007) notes a range of important theoretical and methodological considerations. Recently, Srholec (2010; 2011) has developed a multi-level analytical model that has provided empirical support to the hypothesis that regional and national context have direct effects on the innovative performance of firms. The internal Las capabilities of firms, alongside the quality of the national and regional innovation systems have direct effects on the innovation outputs of firms (Srholec, 2010, 1218; 2011, 32).

This article contributes to the discussion of the role played by regional context in fostering innovative performance by firms. It asks to what degree the regional context might explain why some firms are more innovative than others and the degree to which inter-regional knowledge spillovers affect the innovation outputs of firms. It starts from the argument of Beugelsdijk (2007) that in order to explain the role if the region in explaining differences in innovation outputs, researchers should include information on the characteristics of the firm. In a similar vein to recent studies (Srholec 2010; 2011) it takes into account variables at firm-level and on regional contexts in order to explain the innovative performance of firms.

2.2 Regional Growth Poles and Inter-Regional Knowledge Spillovers

Innovative activity is neither uniformly nor randomly distributed across geographical space (Asheim, and Gertler, 2006). Recent studies show how the development of innovation processes is geographically concentrated (Scott, 2006). The more intense the knowledge- and innovation-based economic activity the more grouped it tends to be spatially. On the other hand, the tendency towards spatial concentration becomes more marked with time (Asheim, and Gertler, 2006; Moreno, Paci, and Usai, 2005). The development of innovation processes leads to distinctive geographical patterns (Morgan, 2004).

The debate on whether regions have positive or negative effects has its origins in the theory of regional growth poles developed around 1950 by the economists Francois Perroux (1950; 1955; 1964) and Charles Boudeville (1996). It posits that growth does not occur everywhere at the same time but occurs in points or poles of growth with varying intensity; it spreads through different channels and has differing end results on the overall economy.

The theory conceives of the "national economy (…) as a combination of relatively active systems (driving industries, industrial poles and geographically agglomerated activities) and of relatively passive industries (affected industries, regions dependent on geographically agglomerated poles). The former induces phenomena of growth in the latter" (Perroux, 1955).

Perroux's model (1955, 56) defines a growth pole as a group of industries that are strongly inter-related through connections with a lead industry. The high-growth lead industry requires products from other sectors or industries. The industries making up the pole grow more than others because their technical development is greater and they have higher rates of innovation (Perroux, 1955, 57). The industries in the pole generate products that are characterized by high income elasticity (greater dynamism in demand). The lead industry produces for broad markets (different to the local market). A development pole so-constituted i sable to generate growth across the economy as a result of multiplying effects: "in a complex geographically agglomerated industrial pole that is experiencing a period of growth the effects of an intensification of economic activities may be noted as a result of proximity and human contacts" (Perroux, 1955, 62).

Growth poles are conceived of as areas of concentrated and highly interdependent economic activity (Perroux, 1955: 44): "historically speaking, each special system whose economy has reached a certain level of growth has one or more growth poles that may be defined as *areas of concentrated and highly interdependent economic activity that have exerted a decisive influence on the nature and rhythm of economic development of the system or subsystems in question*" (Perroux, 1955, 35). The idea is that primitive or backward areas generally lack growth poles; and that these areas are interstitial to a network of growth poles (Perroux, 1955, 50).

Boudeville enriches this approach by developing a theory of spatial localization (Boudeville, 1996). The industry leader is located in a nearby geographical area. In this way growth is transmitted to the rest of the economy and the other activities carried out in the zone. For Boudeville growth poles are made up of a collection of expanding industries located in an urban area. The functioning of this collection of industries leads to the subsequent development of economic activity in the entire area of influence.

There are two ideas behind the principal research questions and hypotheses that are the subject of this research. The first of these is that, geographically, growth poles are considered to be *centers for the generation and spatial diffusion of innovation.* These innovations might include: a- technical forms (new machinery, products, services to the consumer); b- organizational forms (new organizational structures and administrative practices); c- cultural forms (new values, lifestyles, cultural products); d- socio-political forms (new patterns of social and institutional relationships) (Perroux, 1955, 52). Thus, regional economic growth poles constitute the platform for the generation of innovation processes, and it is in the growth poles that innovation is concentrated.

The second principal idea is that "dominance of an economic system in space appears as a form of interaction in which the activities of the growth pole establish the parameters or conditions for economic expansion in a given area" (Perroux, 1955, 48). Thus, economic growth irradiates from and is irrigated by the growth pole, from the economically most developed areas to the less developed: "…each growth pole will serve as pole for the development of larger areas or economic systems in geographical space" (Perroux, 1955, 49).

The theory of growth poles is based on the existence of driving units that, in agglomeration economies, generate a dynamic of growth that is diffused to the surrounding areas. These triggering units will be predominantly urban and constitute export platforms with high export potential. The theory starts from the search for regional equilibrium, achieved by implementing a polarized development strategy. The central idea is that there is a positive relationship between regional growth poles and innovative performance in the regions neighboring the growth pole.

Recent studies have confirmed these ideas, finding that innovative activities become concentrated over time and space (Asheim, and Gertler, 2006). They show that spatial proximity is important to the understanding of phenomenon of innovation as it generates positive externalities such as the dissemination of knowledge (Jaffe, 1986; Jaffe, 1989; Jaffe, Trajtenberg and Henderson, 1993). In a study of R&D spillover Audretsch & Feldman maintain that the spatial concentration of innovative activities is the result of the geographical concentration of production, but principally of the existence of regional knowledge spillovers (1996, 631). This evidence supports the hypothesis that proximity and location are important in the creation of knowledge spillovers (Karlsson & Manduchi, 2001). This idea was first formulated by Marshall (1920) and taken up again according to the assumption that there are geographical limits to the flow of knowledge[2] between firms in an industry (Krugman, 1991). In a patent citation study Jaffe et al. (1993) found a high concentration of citations within US states. Jaffe and Trajtenberg (1996) found similar results. In the case of Switzerland, Sjoholm (1996) found that patent citations originating in more distant countries were less frequent tan those originating from neighboring countries. Maurseth and Verspagen (1999) found evidence for Europe that there it is possible to identify certain regions or clusters of regions that might be characterized as "high-tech" and others as "low-tech".

Analysis of knowledge spillovers has focused on the geographical dimension, exploring the effects within the regions. However, the literature of economic geography and growth has paid little attention to inter-regional externalities; that is externalities that cross the barriers of regional economies (Simonen, 2006, 422). The empirical evidence demonstrates the existence of knowledge spillovers within regions, but the evidence on inter-regional knowledge spillovers remains scarce and inconsistent (Greunz, 2003; Ponds, Oort and Koen Frenken, 2010). Recent studies have found

[2] Particularly tacit knowledge (Polanyi, 1966).

positive knowledge spillover effects within and between regions (Moreno-Serrano, Paci and Usai, 2005). For example, Greunz (2003) shows that positive knowledge spillovers occur between neighboring regions with similar technological profiles. Andersson and Karlsson (2007) found that knowledge flows between regions had positive effects, affecting the growth in value produced by employees. Anselin et al. (1997) and Acs et al. (2002) found evidence in the field of university research of positive knowledge spillovers among neighboring US metropolitan statistical areas. In the case of France, Autant-Bernard (2002) used a knowledge production function framework to demonstrate the importance of geographical proximity between 94 regions. These results indicate that innovative activity in a region is positively influenced by the intensity of research efforts in neighboring regions. Bottazzi and Peri (1999) carried out an empirical study at European subnational level. They found evidence that R&D spillovers existed in a sample of 86 sub-national regions, though their significance reduces rapidly with distance. For Germany, Bode (2004, 56) found evidence that "the proxy for interregional knowledge (KS) spillovers is estimated to be significantly positive, indicating that regions benefit from being situated in close spatial proximity to other highly innovative regions".

Nevertheless, different authors have indicated the possibility of negative effects of knowledge spillovers. The effect of knowledge spillovers on firms is asymmetric (Jovanovic and Rob 1989, Jovanovic and MacDonald 1994, Eeckhout and Jovanovic 2002); even negative (Eeckhout and Jovanovic, 2002). Analyzing the effects of spillovers Singh (2007) finds that knowledge flows between regions is asymmetric, benefitting only one of the regions. Kub *(*1995*)* and Simonen (2006) have suggested that differing patterns of growth in regions (uneven development, stable or joint development, or a mix of the two) may be explained by regional externalities across the regions. Holod and Reed (2009) find that spillovers within the home country may adversely affect growth in the presence of substantial knowledge flows from the foreign country. These ideas cast doubt on the positive effects of knowledge spillovers and raises questions about the negative effects of inter-regional knowledge spillovers. For example, the recent empirical literature on FDI-related spillover effects shows an increasing identification of mixed results. A few studies, particularly in advanced countries, have found positive effects, though most have shown their results to be insignificant or even negative (Marin & Sasidharan, 2010, 1).

Perroux also indicated possible negative effects, though he did not incorporate them into his theory: "if there is only one growth pole for the whole system negative consequences might be derived. The economy of the system might become colonized, the outward flow of resources from the periphery exceeding the return flow from the pole. This structure tends towards the unstable and is preferable to a multipolar structure" (Perroux, 1955).

Building on these ideas this article challenges the dominant view of regional growth poles and of recent evidence that predicts positive effects of knowledge spillovers between regions. It provides a test that the innovative performance of firms in a given region is negatively affected by their adjacency to highly innovative regions. Thus, the dominant view of the positive effects on firm innovation outputs of knowledge spillovers from neighboring regions is called into question. It advances the hypothesis that regional growth poles can negatively affect surrounding spaces or regions. Thus, the effects of the proximity to a growth pole are such that neighboring regions do not benefit but, rather, is negatively affected as a result of their proximity.

Hypothesis 1: there is a negative relationships between innovative performance in neighboring regions and the innovative performance of firms, such that the higher *the level of innovative performance in neighboring regions, the lower the level of innovative performance of firms.*

2.3 Absorptive Capacity and Knowledge Spillovers

The mixed evidence related in the knowledge spillovers literature suggests the hypothesis that not all firms would be expected to benefit equally from knowledge spillovers. One possible explanation is whether a firm benefits maybe depends on its relative backwardness and its capacity for assimilating knowledge—its absorptive capacity. For example, Liao et al. (2003) find that firms with higher levels of absorptive capacity tend to be more proactive in seeking external knowledge whilst those with more modest absorptive capacity will tend to be more reactive. Veugelers and Cassiman (1999) in their analysis of Belgian data, suggest that firms undertaking in-house R&D benefited more from external information sources than companies which had no in-house R&D activity. Kinoshita (2001) using firm-level panel data for the Czech Republic, finds no evidence of spillovers on average but finds positive spillovers for local firms that are research and development (R&D) intensive. She interprets this as evidence that absorptive capacity is important. Thus, only firms (or regions, how forward argument) with some minimum level of absorptive capacity maybe benefit from knowledge spillovers.

Fagerberg, Srholec, Knell (2007, 1596) asumme, following Dosi (1988) and others, that innovation is cumulative and context dependent in ways that prevent the economic benefits of innovation to spread more or less automatically. Accept the widely held view that access to knowledge is a necessary but not sufficient condition for growth. Knowledge needs to be combined with a sufficiently developed ‘‘absorptive capacity’’ (Cohen & Levinthal, 1990; Kim, 1997) or ‘‘social capability’’ (Abramovitz, 1986) in order to deliver the desired economic results.

It is important to point out the multilevelness characteristic of absorptive capacity (Van den Bosch, Van Wijk and Volberda, 2003) and that, like Cohen and Levinthal (1990, 128) do “Outside sources of knowledge are often critical to the innovation process, whatever the organizational level at which the innovating unit is defined”. Absorptive capacity has been associated with international technology transfers (Keller 2004), while national or regional absorptive capacity has been linked both to the capabilities of individual enterprises as well as that of other knowledge creating or mediating organizations in the region (Roper and Love 2006), and the extent of association between organizations (Cooke and Morgan 1998; Narula 2004). Dahlman and Nelson (1995), for example, defined national absorptive capacity like ‘the ability to learn and implement the technologies and associated practices of already developed countries’.

Capabilities are important for the capacity to exploit knowledge available, for example, knowledge spillovers from neighboring regions. Abramovitz (1986, 1994a, 1994b), used the term ‘‘social capability’’ emphasized three general factors as being particularly relevant for knowledge absorption: (1) technical/organizational competence (level of education), (2) availability/quality of financial institutions/markets, and (3) quality/efficiency of governance. In the economics and strategic management literature the notion of absorptive capacity has been widely used to capture ‘the ability of an enterprise to value, assimilate and apply new knowledge’ (Cohen and Levinthal 1989, 1990).

At the firm level, Cohen and Levinthal (1989, 1990) develops the notion of absorptive capacity, defined as the ability to recognize the value of new external knowledge, assimilate it, and apply it to commercial ends (Cohen and Levinthal, 1990).

Key antecedents discerned influencing absorptive capacity are both prior related knowledge (including basic skills and learning experience, and like is take it her, individuals with high level of education and knowledge spillovers) and organizational factors, such as the structure of communication and distribution of knowledge (Van den Bosch, Van Wijk and Volberda, 2003, 2). Cohen and Levinthal also (1990) related absorptive capacity to organizational outcomes such as innovative capabilities and innovative performance. For example, suggest that the higher the level of absorptive capacity, the more likely a firm will be proactive in "... exploiting opportunities present in the environment, independent of current performance…" (Cohen and Levinthal, 1990, 137).

Increments to knowledge available (increasing knowledge spillovers from innovative neighboring regions, for example) can influence the level of innovation in a firm o region. But in absence of necessary capabilities to evaluate knowledge, to assimilate that knowledge and then apply that knowledge commercially the effect can be negative.

Thus, the ability of a firm to evaluate knowledge, to assimilate that knowledge through knowledge spillovers, and then apply that knowledge commercially is crucial. However, the complexity of this process of knowledge acquisition, assimilation and commercialization emphasizes both the multidimensional and multilevel nature of absorptive capacity (Van den Bosch et al. 2003), and its dependence on: (a) individual capabilities, (b) the capabilities of individual enterprises; and, (c) organisations and wider systemic capabilities (like regional systems of innovation context). As Narula (2004) emphasises, national or regional absorptive capacity is influenced by more than the absorptive capacity of individual enterprises, reflecting also the capability of other knowledge creating or mediating organisations in the region, and the extent of association between organizations (e.g., Cooke and Morgan 1998).

For example, Roper and Love (2006) explore the determinants of regional innovation, focussing on the impact of the labour market on regions' capacity to absorb external knowledge. Explore the determinants of regional innovation, focussing on the impact of the labour market on regions' capacity to absorb external knowledge. They argued that indicators of human capital have played an important role in most discussions of absorptive capacity, at regional level (Roper and Love 2006). Their analysis suggests that individual capabilities (labor force skills) are a more important determinant of regional absorptive capacity than organisational effects related to industrial structure. Developments in the supply side of the labour market seem to have the potential to play a significant role in shaping regions' ability to harness external knowledge.

Roper and Love hint at a contingent relationship between the supply side of the regions' labour market and their ability to absorb external knowledge for innovation. Find that the main benefit for innovation of increasing high education, particularly in more prosperous regions, is its increment to absorptive capacity. Roper and Love argued that the significance of this effect, however, will clearly depend on the availability of external knowledge and, hence, on the wider knowledge environment within which the region is located.

Another issue is related to the rising importance in ongoing research efforts to recognize the mediating role of absorptive capacity models (Van den Bosch et al. 2003, 27). These arguments lead to ask ¿What role does level of education region's play in amplifying or reducing the effect of having highly innovative neighboring regions? The idea is that increasing high education (number of inhabitants in the region with graduate degrees), particularly in lagged regions with high innovative neighboring regions, is its increment to absorptive capacity. This increasing regional absorptive capacity can neutralize the negative effects of knowledge spillovers. Thus,

Hypothesis two: The negative relationship between innovative performance in neighboring regions and the innovative performance of firms is mediated by number of inhabitants in the region with graduate degrees; so, that the higher is the number of inhabitants in the region with graduate degrees less is the effect of the negative relationship between innovative performance in neighboring regions and the innovative performance of firms.

3. Multilevel Models: Theory, Multilevel Models and Innovation

Innovation processes do not occur in a vacuum. Innovation is a multilevel phenomenon that involves actors (individuals, teams, units, organizations) and contexts within which actors are immersed (Gupta, Tesluk, & Taylor, 2007). Organizational theory adopts an open systems perspective to emphasize (Scott, 2003) that as entities organizations enjoy an interdependent relationship with the environment (Lawrence and Lorsch, 1967; Powel and DiMaggio, 2001).

Nevertheless, research has tended to concentrate on just one level of analysis[3] (the individual, teams, and firms). Empirical research that deals with and explicitly combines different levels of analysis are scarce[4]. Studies of innovation processes have provided little information on the ways the variables for one level affect innovation at other levels. Research aimed at clarifying the ways in which variables interact at different levels and the ways in which they determine innovation outputs are also infrequent (Gupta, Tesluk, and Taylor, 2007, 885).

With multilevel theory it is possible to understand how phenomena and processes at one level of analysis are related to or nested with those of other levels (Klein, Dansereau and Hall, 1994; Rousseau 1985). It offers a potentially richer perspective on innovation processes, more complete and complex.

New methods for modeling different levels of analysis are promising when compared old and new thinking in the economics of innovation literature. The new economic geography has placed agglomeration economies, knowledge spillovers and spatial context at the center of its analysis (Feldman, 2000, 373). As Feldman indicates, "the concept of location is defined as a geographical unit that facilitates interaction and communication, the search for knowledge, and coordination tasks" (2000, 373).

Earlier research (Jaffe, 1989; Jaffe et al., 1993; Acs et al., 1992, 1994; Feldman, 1994; Audretsch & Feldman, 1996; Greunz, 2003) into the effects of regional context and knowledge spillovers on the innovative performance of firms confirms their hypotheses using Ordinary Least Squares (OLS) regression. These estimate the effects of regional context and firm characteristics using a dependent variable measured at individual or regional level and establish relationships between variables belonging to different levels of aggregation.

However, the OLS regression supposes that the data observations – in this case the firms – are independent (Snijders & Bosker, 1999, 6; Austin et al., 2001, 150) ignoring the dependence that exists between firms that belong to the same region. OLS regression models are not appropriate for approaching hypotheses that link variables measured at different levels (Snijders & Bosker, 1999, 9-13). They treat regional

[3] For an overview on multilevel research in innovation studies, see the "Special Issue on Innovation At and Across Multiple Levels of Analysis", *Organization Science, 18* (6) ,2007.

[4] "… only 10% of all articles on innovation published during 1990–2006 in five key management journals conducted any type of multilevel empirical analysis" (Gupta, Tesluk, and Taylor, 2007, 885).

variables as if they were firm-level variables in a single line of regression. This results in a correlated error term (Austin et al., 2001, 151) for the firms that operate in the same region. Consequently, the dependency between the data observations (firms) of a group (region) produces inefficient regression coefficients and biased standard errors (Bryk and Raudenbush, 1992, 98-102).

Techniques such as hierarchical linear modeling exist to overcome these difficulties (Snijders & Bosker, 1999, 2-3); this is a statistical model that separates the individual-level- from aggregate level effects, according to the assumption that the data are structured hierarchically. This study employs a multilevel regression model to differentiate the role of the regional context variables and those of the firm in explaining the innovation outputs of the firms.

The multilevel model extends traditional statistical techniques by explicitly modeling the regional context. This introduces a degree of realism frequently absent from single-level models (Austin et al., 2001, 151), such as OLS regression. Multilevel regression offers unbiased standard errors (Austin et al., 2001, 151), minimizing the probability of committing the error of rejecting the null hypothesis when it is correct (Type I Error), at the same time as estimating the contextual variability (between regions) of the regression coefficients (Austin et al., 2001, 151-152).

Multilevel models offer advantages compared to traditional regression models when it comes to proving hypotheses concerning relationships between variables of different levels (Snijders & Bosker, 1999; Austin et al., 2001; Rabe-Hesketh & Skrondal, 2008). One advantage is that it reduces conceptual problems related to the level of analysis at which the results and conclusions are deduced. Among the best known of these (Snijders & Bosker, 1999, 13) are the problem of the ecological fallacy (Robinson, 1950; Alker, 1969), which consists of deducing at the individual level using aggregate data derived from a general level. Research into the relation between regional contexts, knowledge spillovers and firm innovation outputs suggests that this is one of the commonest errors (Gordon & McCann, 2005; Beugelsdijk, 2007) if the multilevel nature is not taken into account and the methods employed are not adequate to the nature of the available data.

Multilevel regression is capable of incorporating variables that are measured at different levels and to examine cross-level interactions between them (Austin et al., 2001; Rabe-Hesketh & Skrondal, 2008). It permits an examination of how the intercepts of the regression lines vary within regions and to estimate the causes of this variation (Rabe-Hesketh & Skrondal, 2008, 91). Furthermore, employment of a random coefficient model (Rabe-Hesketh & Skrondal, 2008, 141), permits a separate model to be adjusted for the firms of each region, relating the number of firm- and region-level innovations, permitting the slope coefficients of the regression to be varied within the regions. This in turn permits the differential effects of the firm variables according to the region they belong to. Although not all the advantages compared with traditional statistical techniques are explored in this article, the multilevel regression technique is used to analyze the effects of regional context and neighboring regions on the performance of firms.

3.1 The Data

II *Encuesta de Desarrollo e Innovation Tecnológica* (Survey on Technological Development and Innovation, EDIT II) was used to test the proposed hypotheses for Colombian industry between 2003 and 2004. The sample was made up of 6,670 firms, including 5,252 SMEs and large enterprises operating in 26 regions of the country. Two vectors of variables were constructed: one at the first level, designed to include the characteristics of the firms, and one second level vector which took into account the characteristics of the regional context.

3.1.1 Dependent Variable

Given the nature of innovation in developing countries, the number of patents or R and D indicators was not chosen as the variable to measure firm innovation outputs, because of the limitations of such measurements (Feldman, 2000, 375; Geroski, 1994) and the disadvantages they when it comes to capturing the innovation outputs of firms in developing countries.

The section of EDIT II asks firms about the number of innovations, adjusted by innovation objective, obtained between 2003 and 2004, according to the Schumpeter’s classification (1910). Direct measurements were made of the innovation outputs as measured by new products. This variable involved counting the number of innovations made during the period of reference. Based on this section of EDIT II an indicator was constructed to measure the innovation outputs of the firms: the *Number of Product Innovations Adjusted by Objective.* This variable included innovation based both on invention and imitation.

3.1.2 Independent Variables

The independent variables were classified in two vectors: firm level- and region-level variables. The firm-level vector captured certain characteristics of Colombian firms in relation to their innovative performance. The selection of the variables was based on previous research by Corredor, Forero-Pineda and Forero (2009). The vector included external links the firms considered to be sources of innovative ideas, internal coordination capacity, staff educational levels, patents obtained, spending on I+D and size. A second vector involved variables for measuring the regional context, supported in the literature on regional effects on innovative performance (Srholec, 2010; 2011) and the literature on knowledge spillovers (Jaffe, 1989; Jaffe et al., 1993; Acs et al., 1992, 1994; Feldman, 1994; Audretsch & Feldman, 1996). The vector included characteristics of the regions such as volume of exports, GDP per capita, educational levels and knowledge spillovers.

3.1.2.1 Firm-level Variables

Based on the research of Forero (Forero-Pineda, Corredor and Forero, 2009), five firm-level variables and one control were constructed. The first variable consisted of the total number of links mediated by money that the firm possesses with different actors (government agencies, private banks, overseas organizations, clients, suppliers, universities or firms in the same group). This variable was called *Sum of Money-mediated Types of links* (Forero-Pineda, Corredor and Forero, 2009). The second variable was called *Sum of Informal Types of Links*, and measured the total number of links that the firm recognizes as sources of ideas for innovation that were not necessarily mediated by money (Forero-Pineda, Corredor and Forero, 2009). This variable includes links with clients, suppliers, competitors, universities and research centers, producers’ and commercial associations and firms from the same group. Additionally, this variable includes links with sources of tacit knowledge, such as attendance of trade fairs, events, seminars and lectures (Forero-Pineda, Corredor and Forero, 2009).

The third firm-level variable was called *Sum of Internal Sources of Ideas*. It consists of the total number of links involving internal networks or sources of information for innovation within the firm (Forero-Pineda, Corredor and Forero, 2009). This variable is interpreted as the firm's ability to coordinate its internal networks and resources during an innovation process (Forero-Pineda, Corredor and Forero, 2009). The other variables corresponded to the classic determinants of innovation identified in the literature: *R&D Investment*, which measures investment in the firm's R&D activities; *Patents*, which measures the existence of patents and contracts for the acquisition of licenses; the percentage of total employees holding a *Professional* degree; the percentage of total employees holding a *Technical* degree; and size of the firm, measured the *Total Number of Employees* in each firm. This information represented the size proxy available to the survey. The information corresponding to these variables was constructed using the EDIT II Survey.

3.1.2.2 Region-level Variables

This vector of variables captures the characteristics of the regional context and the influence of neighboring regions. The variable *Exports* was constructed by extracting the average level of regional exports for the years 2002-2003-2004-2005 measured in thousands of dollars. The variable was developed using data on Colombia's regional exports from the Ministry of Commerce, Industry and Tourism. The variable *GDPpc* was constructed by extracting averages for regional GDP per capita for the same period. This variable was compiled using statistical information from the National Accounts Data Base compiled by the Dane. The variable *Inhabitants Postgraduate Degrees* was constructed using information on the number of inhabitants of the region with postgraduate degrees. The information used to compile this variable was taken from the 2005 General Census compiled by the Dane.

The *Interest* variable*: Spillovers Neighboring Regions* was constructed using the total number of innovations weighted by the objectives of the firm as recorded in Edit II (see Annex). This information was used to construct a regional innovation measure, by adding together for each region the total number of innovations made by each firm. The variable used to the measure spillover effects of neighboring regions was calculated in two stages: (1) analyzing all 22 regions included in the study, the regions of greatest geographical and economic proximity were determined, taking into account communications networks and travel times; (2) innovation spillovers were estimated by assigning to each firm the total number of two most innovative neighboring regions.

3.2 The Poisson Multilevel Regression Model

The dependent variable used in this study is a count variable with non-negative integers. Checking the validity of the assumptions possesses a poisson distribution. Generally, count variables are treated as if they were continuous. Applying a linear regression to count variables as if they were continuous can generate problems in the estimation of parameters and give unfortunate results in the efficiency, consistency and bias of the estimators (Scott, 1997, 217). Poisson models were designed to be applied to count variables.

The Poisson model is the most basic of the models applied to these characteristics. It proves a useful way to respond to the structure of the dependent variable. The number of product innovations weighted by the objectives in EDIT II is a count variable; it is discrete and possesses non-negative values. Consequently, it is possible to postulate that its distribution adjust to the characteristics of a Poisson process. According to Winkelmann (2008, 8), Poisson models are characterized as equi-dispersed, that is, its measure and variance are equal and, since the probability of a count is determined by a poisson distribution where the measure of distribution is a function of the independent variables (Scott, 1997, 217).

Given that the information used to construct the variables pertains to different levels the nested nature of the data was taken into account. These two characteristics (poisson distribution of the dependent variable and two levels of aggregation of the independent variables) make it necessary to use a special regression technique, namely the Poisson Multilevel Regression Models (Snijders & Bosker, 1999; Rabe-Hesketh & Skrondal, 2008). This model takes into account the poisson distribution of the dependent variable and the different levels to which the regression coefficients are gathered and estimated.

4. Analysis and Results

This section presents the descriptive statistics (Table 1) for the first and second level variables. Ether is a high concentration of innovation in four regions (Figure 1). It may be observed that there are some regions with high innovative performance; all are surrounded by regions with lower innovative performance.

There is a correlation between variables *GDPpc* and *Inhabitants Postgraduate Degrees*. Therefore it is necessary to test for multicollinearity, because multicollinearity inflates the variance of the parameter estimates. Although multicollinearity does not generally induce bias in regression parameter estimates (Hamilton, 1992), it can affect parameter estimates in a mixed-effect model when other predictors are included (Bonate, 1999; Kreft & De Leeuw, 1998; Kubitschek & Hallinan, 1999). Kreft & De Leeuw (1998) and Kubitschek & Hallinan (1999) have given examples where standard errors of the regression coefficients are affected.

Therefore, there will be a correspondingly large standard error for the regression coefficient for the predictor variable in the original model. Large standard errors tend to result in difficulties achieving a large *t* ratio in the significance test on the parameter estimate and a wide confidence interval around the parameter estimate. As a result, statistical power is reduced and there is less probability of reaching statistical significance (Shieh and Fouladi, 2003, 954). Because of these potentials problems, it is necessary to address the issue of multicollinearity in the developed model here.

As Hamilton (1992) has pointed out, multicollinearity can occur even without strong correlation between variables. First, it is important to note that highly correlated variables are also extremely common in multilevel models (Shieh and Fouladi, 2003). The high correlation between two independent variables can be an indicator of multicollinearity. However, conclusions about the presence or absence of multicollinearity that are based only on these correlations must be drawn carefully. It is possible that in some data sets, such as those involving time series and nested data structure, the correlation between pairs of variables are high, but the data mean it is possible to separate the effects of individual explanatory variables on the dependent variable.

To address this issue, multicollinearity diagnostic statistics produced by linear regression analysis were used. As proposed by Belsley and Oldford (1986) tolerance or variance inflation factor VIF statistics can help to determine how multicollinearity can affect the resulting parameter estimates. The Variance Inflation Factor (VIF) is 1/Tolerance; it is always >= 1 and represents the number of times the variance of the corresponding parameter estimate is increased due to multicollinearity as compared to what the situation would have been in the absence of multicollinearity. There is no formal cutoff value to use with VIF for determining the presence of multicollinearity. However, values of VIF below 10 are often regarded as indicating no multicollinearity problems. The results for the VIF statistics (Tables 2 and 3) for the firm-level and region-level explanatory variables gives values lower than 2. These values are indicative of the absence of problems of multicollinearity in the model proposed. On the other hand, the results of research by Shieh and Fouladi (2003) into the problem of multicollinearity in multilevel models indicate that the level 2 coefficients, that is, the fixed-effect parameters, are not biased under various magnitudes of correlation between predictor variables. These authors argue that their findings are consistent with the literature showing lack of bias in fixed-effect parameter estimates (cf. Bryk & Raudenbush, 1992; Hamilton, 1992).

Another important issue in the multilevel regression model is the considerations of sample size (Snijders & Bosker, 1999; Shieh and Fouladi, 2003, 959). The number of firms reported in the EDIT II survey is 6,670, located in 26 regions. Four regions and the firms operating in them - which had zero results in innovation - were removed from this sample were removed, giving a final total of 6,662 firms located in 22 regions. The number of groups (22 regions) ensured sufficient variation between groups, and the number of firms within each group exceeded 50, thus fulfilling the requirements of the multilevel regression[5]. In multilevel regression models, these considerations concerning the size of the sample are especially important, because, as Shieh and Fouladi (2003, 983) state, larger group sizes and larger number of groups can reduce the effects of high correlation between two independent variables. In the same way, when the number of groups and the number of cases per group increased, the bias of standard errors of fixed-effect parameter estimates decreased (Shieh and Fouladi, 2003, 961). With respect to the relative bias of variance-covariance component estimates, when the number of groups and the number of cases per group increased, the bias of parameter estimates decreased. While for the standard errors of variance-covariance component estimates, when the number of groups and the number of cases per group increased, the bias of the standard errors decreased (Shieh and Fouladi, 2003, 962). These considerations allowed us to continue with the poisson multilevel regression analysis.

4.1 The Effects of Firm- and Regional Context Characteristics on the Innovative Performance of Firms

The first model (Table 4) shows that the firm-level variables *Sum of Money-mediated links, Sum of Informal Links, Sum of Internal sources of ideas, R&D Investment Patents, Technical, Professional and Total Number of Employees* are related directly and significantly to innovation. All the co-efficients have positive signs, a finding consistent with the results obtained in other research into the Colombian case (Forero-Pineda, Corredor and Forero, 2009).

In relation to the region-level variables the results of recent studies (Srholec 2010; 2011) that have found that the characteristics of the regional context exercise a direct effect on firm innovation outputs are confirmed. The variables *Exports* and *GDPpc* have a significant effect on the number of product innovations, weighted by objectives. *Exports* presents a significant coefficient, indicating that the export vocation of a region exerts a positive influence on the on the innovative performance of its firms. This result is in line with the strategic literature, which argues that businesses that operate in more competitive environments (the international market) acquire organizational capabilities that have repercussions for their innovative performance (Zahra, Ireland & Hitt, 2000). Firms that operate in regions with low levels of export activity show lower levels of innovative performance since they are not confronted with competitive pressures that push them to innovate (Geroski, 1994). The *Exports* variable had no effect on the relation between *Spillovers Neighboring Regions*, *GDPpc* and *Number of Product Innovations Adjusted by Objective*.

[5] The number of groups required for multilevel analysis is > 10 and the number of data observations required in each group > 2 (Snijders & Bosker, 1999, 96).

GDPpc, by contrast, had a negative coefficient. A possible explanation for this finding may be found in the argument according to which firms operating in contexts that provide them with sufficient resources show lower levels of innovative performance than those operating in resource-scarce environments (Geroski, 1994). The negative relation between *GDPpc* and the number of a firm's product innovations weighted by objective contradicts the positive relation found with their innovation and financial performance (Teece, 1986); these are innovations that also impact on the productivity of firms and economic growth within a given region (Solow, 1957). A possible explanation of these contradictory results could be the different levels at which the analysis was carried out (regional and firm). The analysis carried out here does not permit conclusions to be drawn that go beyond these results. Additional research is required to determine the causal relationships between innovative performance and financial performance, both at firm-level and regionally. A limitation of this research is the absence of a longitudinal study that would have permitted inferences to be made about causality.

4.2 The Effects Proximity to Highly Innovative Regions on the Innovative Performance of Firms

As may be observed in Table 4 (note a), the coefficient of the variable *Spillovers Neighboring Regions* is significant, and negative. This confirms the proposed hypothesis that proximity of firms to neighbors with highly innovative performance results in low levels of innovation. It contradicts the hypothesis according to which high levels of innovation in a region will exercise a positive effect on neighboring regions, at least in the case of developing countries. The implications of this result are important, as it argues against the likely benefits for neighboring regions of developing regional growth poles. The configuration of innovation processes illustrates a tendency towards concentration, expressed in the configuration of regions with high levels of innovative performance and a concentration of innovative activities, as predicted by the theory of growth poles. But, counter to this theory, the prediction that high levels of innovation would be transferred from regions of high innovative performance to low-performing regions has proved unfounded.

4.3 The Mediating Effect of Inhabitants Postgraduate Degrees

In Table 4 (specification b) the variable *Inhabitants Postgraduate Degrees* is proved, when added to the preceding model, to have had significant and positive effects on a firm's *Number of Product Innovations Adjusted by Objective*. This is an important result as it demonstrates that government policy should prioritize increasing and retaining the percentage of the population with postgraduate qualifications as the percentage of the population thus qualified has a positive effect on innovation in a region. More interesting is the result of the regression analysis of the effect of *Inhabitants Postgraduate Degrees* on the negative relation negative between *Spillovers Neighboring Regions and the Number of Product Innovations Adjusted by Objective*. When *Inhabitants Postgraduate Degrees* is introduced the negative relation between *Spillovers Neighboring Regions* and *Number of Product Innovations Adjusted by Objective* ceases to be significant.

This means that the negative effects on the innovation outputs of a firm having an innovative neighboring region are mediated by the level of higher education in the region. In terms of government policy this is an important finding as it indicates the direction that government policy intended to encourage regional innovation could pursue in regions with low levels of innovative performance that are close to regions with high levels of innovative performance: increasing the proportion of students studying in higher education institutions. The regions with low levels of innovative performance could counteract the negative effects of *Spillovers Neighboring Regions* adopting policies to encourage higher education.

In order to test the mediating effects of the number of *Inhabitants Postgraduate Degrees* a procedure has already been suggested by Baron and Kenny (1986). First, regressing the mediator on the independent variable; second, regressing the dependent variable on the independent variable; and third, regressing the dependent variable on both the independent variable and on the mediator (Baron and Kenny, 1986, 1177). Baron and Kenny maintain that there exists a "perfect mediation effect" if the independent variable -*Spillovers Neighboring Regions*- has no effect on the dependent variable when the mediator is controlled (Baron and Kenny, 1986, 1177). As may be seen in Table 4 (specification b), this is the case with the measuring variable proposed in this article. It only remains to demonstrate that the independent variable (*Spillovers Neighboring Regions*) is a significant determinant of the measuring variable (*Inhabitants Postgraduate Degrees*). Table 5 presents these regression coefficients. The variable *Inhabitants Postgraduate Degrees* has a significant effect on *Spillovers Neighboring Regions*, and the relation is negative.

5. Conclusions

The results provide a range of evidence that constitute advances in our ability to understand the multiple levels of innovation. They confirm that regional contexts are important in explaining the innovative performance of firms. A firm's ability to innovate depends on its own efforts but also on the regional context and on the knowledge spillovers that occur between regions. The analysis provides evidence that contributes to the debate on the positive and negative effects of inter-regional knowledge spillovers. In order to analyze these effects it recognized the hierarchical structure of the data and adopted a multilevel approach. As such it made empirical and methodological contributions to research into the relationships between different levels and innovation.

The literature on regional knowledge spillovers generally agrees on the existence of spatially-mediated knowledge spillovers. Empirical evidence has shown significant and positive effects of knowledge spillovers within regions. However, little work has been done on the relation between inter-regional knowledge spillovers and firm innovation outputs. The results of research into inter-regional knowledge spillovers have mixed results. Non-significant, positive and significant effects have been found, and positive and significant effects have been seen to diminish with distance. This article, which has employed a multilevel model, offers new evidence concerning the negative effects of inter-regional knowledge spillovers. It argues that that, in order to study the influence of regional contexts on the innovation outputs of firms it is important to bear in mind the multiple levels inherent in the structure of the data.

The results are important because they cast new light on the effects of regional knowledge spillovers and the ways in which firms and regions might neutralize the negative effects that have been mentioned. The article confirms the importance of the development of absorptive capabilities at the regional and firm level (Roper and Love, 2006) by increasing the number of inhabitants of a region who have postgraduate qualifications. Such a policy would permit not only increased probability of obtaining innovation outputs but would also moderate the negative effects of proximity with neighboring regions with high levels of innovative performance. Thus, the article offers evidence that the absorptive capabilities of firms and regions serves not only to increase the ability to appropriate knowledge from external sources but also to counteract the negative effects of the concentration of innovation outputs in a few regions with high levels of innovative performance.

These ideas are relevant to policy design aimed at increasing regional innovation. The results of the research will inform managers and entrepreneurs concerning decisions about where to establish businesses in cases where they are interested in a growth model based on innovation. It is important they understand the negative effects of knowledge spillovers if they establish businesses close to regions with high levels of innovative performance. It is not the same to establish a business close to a region with high levels of innovative performance where the spillover effects might be negative as to locate in a region with positive spillovers effects. Furthermore, understanding the effects of the regional context on the innovative performance of firms is a determing factor in decisions about where to establish a firm.

The research provides evidence on the role played by human resources in regional development that will be useful for regional authorities. By demonstrating that the negative effects of knowledge spillovers from neighboring regions are moderated by levels of postgraduate education, arguments are provided to foment regional programs to strengthen education that will contribute to increasing innovation outputs of firms and regions alike.

Furthermore, the results may be extended to improve proposals for the creation of regional cities, contributing to the strengthening of policies to policies to encourage the articulation of innovation processes between center and periphery. The research has also offered inputs that will help design improved programs for regional subsidies designed to attract and promote industry, clusters and to create regional centers for innovation and technological development. Continuing to explore the negative effects of inter-regional knowledge spillovers might cast light on the best way to design incentives linked to regional development based on innovation.

Table 1. Descriptive statistics					
Variable	Obs	Mean	Std. Dev.	Min	Max
Total Number of Employees	6222	9.147.268	2.556.719	0	6902
Sum of Informal Types of Links	4831	123.225	1.497.508	0	5
Sum of Money-mediated Types of links	6211	.4058928	.6600815	0	4
Sum of Internal sourses of ideas	4831	2.227.696	1.654.127	0	7
R&D Invesment	6221	926135.7	1.28e+07	0	8.95e+08
Technical	6212	.1644923	.1838817	0	1
Profesional	6209	.1381745	.1344375	0	1
Patents	6199	.0383933	.3517491	0	5
Spillovers Neighboring Regions	6662	5.382.144	5.893.519	1068	34612
Exports	6662	1.307.357	1.156.212	7.549.609	1.435.142
GDPpc	6621	8620441	2593918	2838856	1.17e+07
Inhabitants Postgraduate Degrees	6662	88308.9	71898.84	2445	179776

Figure 1. Number of innovations by region.

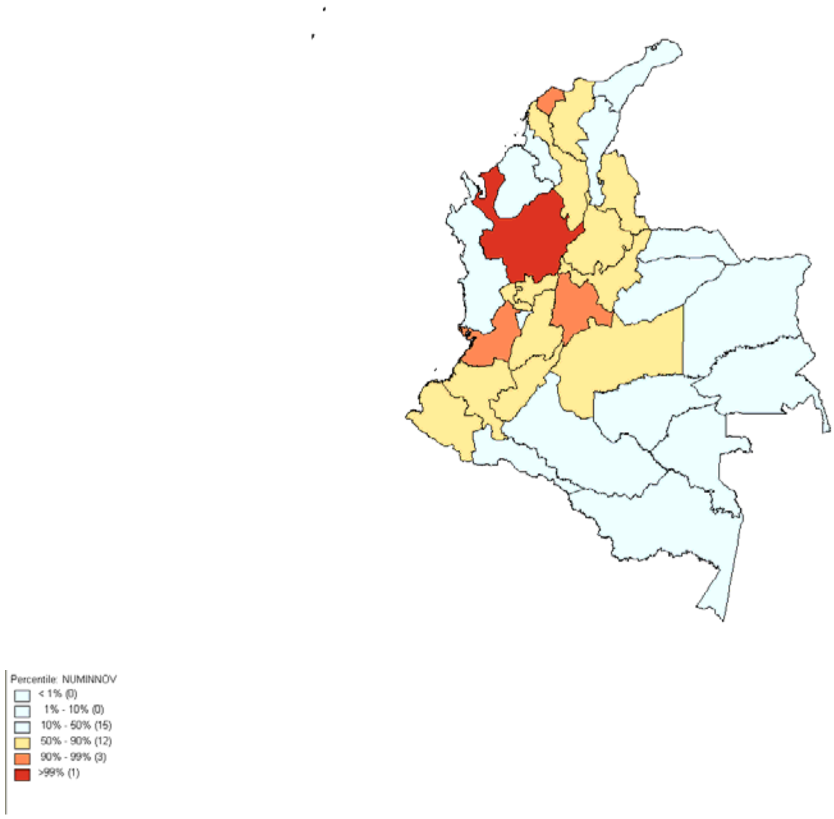

Table 2. VIF Firm Level Variables		
Variable	VIF	1/VIF
Sum of Internal sourses of ideas	1.56	0.641659
Sum of Informal Types of Links	1.48	0.675565
Sum of Money-mediated Types of links	1.04	0.957341
Total Number of Employees	1.32	0.759041
R&D Invesment	1.28	0.780556
Profesional	1.04	0.961662
Technical	1.02	0.984406
Patents	1.01	0.993288
Mean VIF |	1.22	

Table 3. VIF Region Level Variables		
Variable	VIF	1/VIF
GDPpc	2.54	0.394466
Inhabitants Postgraduate Degrees	2.48	0.403835
Exports	1.22	0.820849
Spillovers Neighboring Regions	1.13	0.886882
Mean VIF	1.84	

Table 4. Multilevel Poisson Model								
	1		2		3			
	OLS (a)	OLS (b)	Pisson (a)	Pisson (b)	Multilevel Poisson (a)		Multilevel Poisson (b)	
Variables	Product innovation Outcomes	Product innovation Outcomes	Product innovation Outcomes	Product innovation Outcomes	eq1	Intercep sd	eq1	Intercep sd
Level One Variables								
Total Number of Employees	1.232***	1.147***	0.187***	0.181***	0.179***		0.179***	
	(0.202)	(0.201)	(0.0261)	(0.0260)	(0.00644)		(0.00644)	
Sum of Money-mediated Types of links	0.830***	0.854***	0.0947***	0.0941***	0.0950***		0.0951***	
	(0.153)	(0.153)	(0.0166)	(0.0166)	(0.00395)		(0.00395)	
Sum of Informal Types of Links	2.019***	1.943***	0.233***	0.229***	0.226***		0.226***	
	(0.291)	(0.290)	(0.0280)	(0.0278)	(0.00665)		(0.00665)	
Sum of Internal sourses of ideas	1.453***	1.414***	0.146***	0.142***	0.144***		0.144***	
	(0.168)	(0.168)	(0.0165)	(0.0164)	(0.00355)		(0.00355)	
R&D Invesment	1.61e-07***	1.64e-07***	4.16e-09***	4.66e-09***	4.16e-09***		4.16e-09***	
	(5.58e-08)	(5.66e-08)	(1.05e-09)	(1.11e-09)	(3.51e-10)		(3.51e-10)	
Technical	1.791*	1.504	0.288**	0.250**	0.213***		0.213***	
	(0.939)	(0.930)	(0.126)	(0.126)	(0.0306)		(0.0306)	
Profesional	5.039***	4.414***	0.607***	0.512***	0.469***		0.469***	
	(1.420)	(1.417)	(0.165)	(0.162)	(0.0386)		(0.0386)	
Patents	0.576	0.535	0.0699	0.0668	0.0665***		0.0664***	
	(0.555)	(0.550)	(0.0491)	(0.0495)	(0.0113)		(0.0113)	
Level Two Variables								
Spillovers Neighboring Regions	-2.56e-05	-1.56e-05	-2.89e-06	-1.60e-07	-2.32e-05**		-1.60e-05	
	(3.18e-05)	(3.16e-05)	(3.80e-06)	(4.25e-06)	(1.16e-05)		(1.11e-05)	
Exports	0.374**	0.359**	0.0520**	0.0864***	0.184***		0.167***	
	(0.149)	(0.146)	(0.0223)	(0.0243)	(0.0577)		(0.0529)	
GDPpc	-1.79e-07**	-1.24e-06***	-2.24e-08**	-2.55e-07***	-1.57e-07***		-2.75e-07***	
	(7.85e-08)	(1.10e-07)	(1.04e-08)	(2.05e-08)	(5.32e-08)		(7.47e-08)	
Inhabitants Postgraduate Degrees		4.20e-05***		8.73e-06***			8.43e-06**	
		(3.98e-06)		(7.68e-07)			(4.09e-06)	
Constant	-5.346***	0.785	0.219	1.023***	-0.366	-0.746***	0.269	-0.851***

	(1.790)	(2.074)	(0.271)	(0.311)	(0.701)	(0.165)	(0.704)	(0.169)
R-squared/McFadden's R2 (Poisson)	0.140	0.149	0.148	0.165				
Adj R-squared/McFadden's Adj R2 (Poisson)	0.138	0.147	0.148	0.165	0,20027119		0,20031761	
Log likelihood Null mode					-41.080		-41.080	
Log Likelihodd Full mode					-32.852		-32.851	
Observations	4,793	4,793	4,793	4,793	4,819	4,819	4,819	4,819
Number of groups					22	22	22	22
Robust standard errors in parentheses								
*** p<0.01, ** p<0.05, * p<0.1								

Table 5. Regression Mediating Effect	
VARIABLES	Inhabitants Postgraduate Degrees
Spillovers Neighboring Regions	-1.798***
	(0.0745)
Constant	97,986***
	(1,017)
Observations	6,662
R-squared	0.022
Number of obs	6662
F(1, 6660) =	582.00
Prob > F =	0.0000
R-squared =	0.0217
Adjusted R2	0.022
Root MSE =	71119
Robust standard errors in parentheses	
*** p<0.01, ** p<0.05, * p<0.1	

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