Space, place and innovation: a distance-based approach

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*Innovation is increasingly considered a prerequisite for regional development and it is commonly understood that certain regions are more conducive to innovation than others. Regions that do not possess the required institutional and cultural contexts are often encouraged to work on creating them. However, there is increasing evidence that innovation is also a spatial phenomenon: the propensity of establishments to innovate also varies with their location relative to major and minor metropolitan areas, independent of local context. This article investigates whether the geography of innovation is similar for three different types of manufacturing sectors (*high-tech (HT), medium-tech*, first and second transformation) and across two different types of innovation (product, process). It is shown that, in Québec, to the extent that geography and innovation are connected, it is principally distance from a metropolitan area that plays a role. Our results lend support to McCann's (2007) recent spatial model of innovation and are also compatible with Duranton and Puga's (2003) theory of nursery cities. Our results also show that HT innovators behave differently from other manufacturers, with a tendency to internalize their innovation behaviour (perhaps out of necessity or for reasons of secrecy) in more distant locations.*

Key words: distance, innovation, manufacturing sectors, space, urban areas

L'espace, le lieu et l'innovation: une approche fondée sur la distance

L'innovation apparaît de plus en plus comme un facteur indispensable du développement régional, et il est généralement reconnu que certaines régions offrent un contexte plus propice à l'innovation que d'autres. Dès lors, les régions privées des institutions et des milieux culturels appropriés sont incitées à les développer. Toutefois, l'innovation est aussi un phénomène spatial comme l'indiquent des observations de plus en plus nombreuses: la probabilité qu'un établissement introduise une innovation varie avec sa localisation par rapport aux métropoles, et ce, indépendamment du contexte local. S'inscrivant dans une perspective géographique, cet article présente une étude comparative de l'innovation pour trois secteurs manufacturiers (haute technologie, moyenne technologie, ainsi que première et deuxième transformation) et pour deux types d'innovation (produit, procédé). Les résultats montrent qu'au Québec, dans la mesure où un lien existe entre géographie et innovation, le rôle de la distance aux métropoles est prépondérant. Ces résultats rejoignent ceux de McCann (2007) qui a mis au point un modèle spatial de l'innovation pour l'étude de la distance aux métropoles, et sont compatibles avec la théorie des villes «nourricières» élaborée par Duranton et Puga (2003). Ils montrent aussi que les entreprises innovatrices du secteur de la haute technologie se comportent différemment des

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autres, ayant tendance à internaliser leurs comportements d'innovation dans des régions plus éloignées, peut-être par nécessité ou bien pour en préserver le secret.

Mots clés : développement, distance, fabrication, innovation, métropole, villes nourricières

Introduction

It has become commonplace, indeed almost a truism, to highlight the importance of innovation in the economy. Countries, and by extension regions, are exhorted to ensure that companies remain competitive by continuously innovating (CFI 2009; OECD 2009). The need to focus upon innovation as a prerequisite for economic growth, which was highlighted theoretically in the 1950s by economists such as Solow (1970), has now become a practical necessity. Indeed, whereas post-World War II western economies benefited from expanding internal markets, favourable terms of trade with the rest of the world, and war reconstruction efforts, since the 1980s this has no longer been the case. Emerging economies, such as China, India and South Korea now benefit from their own growing markets and can compete on a cost basis with developed economies. In order to maintain their competitiveness, Western economies have turned towards innovation, attempting now to compete on the terrain of novelty and efficiency (Metcalfe 2006).

Innovation has often been considered a purely technological process (Malecki 1997): engineers and scientists invent a new technique, which is then marketed by their company or by an entrepreneur. Increasingly, however, it has been recognized that innovation is also a social process. Lundvall (1992, 2007) proposed that it is not only establishments, but entire nations that are more or less innovative. He introduced the idea of national systems of innovation. These systems encompass national institutions (e.g., colleges, universities, government departments, business organizations), policies (e.g., support to entrepreneurs, to export), financial systems and culture. According to him, in certain nations these different institutions and processes coalesce into a system that is conducive to innovation, whereas in others there are frictions that prevent innovative processes from occurring.

Similar ideas were being developed contemporaneously at the regional scale: Aydalot (1986), Maillat (1991) and Camagni (1991), for instance, emphasize the connection between innovation and regions. They suggest that the type of system put forward by Lundvall at the national scale may also operate at a regional level. These early regional analysts do not necessarily refer back to Lundvall (1992),[1] and a multiplicity of related concepts have been put forward: local innovative milieu (Maillat 1991), regional clusters (Porter 1990), learning regions (Florida 1995) and so on. Each of these ideas has its specificities (Moulaert and Sekia 2003), but each takes a very similar approach to space: regions or cities are understood to possess institutions, entrepreneurial cultures and collaborative frames of mind more or less conducive to identifying and exploiting new ideas (Cooke *et al.* 2004).

This article seeks to go beyond this regionalist approach and investigate some recent ideas about the geographic connection between proximity and innovation. In particular, following McCann (2007), Gordon and McCann (2005), Andersson and Karlsson (2004) and Shearmur and Doloreux (2009), variations in the propensity to innovate with distance from urban centres are investigated. In other words, the regionalist approach which postulates that innovation is a function of spatially discontinuous local attributes is abandoned, in favour of exploring a spatial approach which postulates that innovation is a function of proximity to certain key sources of ideas, information and markets. Of course, it is not being argued that the spatial approach should supersede the regionalist approach: rather, that it is a useful complement and extension.

The specific questions that are addressed concern the variation across space of innovation in

[1] Lundvall (2007) expresses doubts about the appropriateness of applying the innovation systems idea at a regional scale.

three different manufacturing sectors (high-tech (HT), medium-tech (MT) and first and second transformation (FST)) in Québec. It is hypothesized that innovation will vary with distance from urban areas (McCann 2007), that process innovation will tend to occur further out (and maybe in smaller cities) than product innovation (Duranton and Puga 2003) and that innovation in HT sectors, for reasons associated with secrecy and/or survivor bias (Gordon and McCann 2005), are more probable in remoter regions. These hypotheses will be tested, as will the hypothesis that innovation varies discretely region by region with no structures linked to distance from urban areas.

The first section explores the rationale behind introducing space as a continuous variable (as opposed to a discrete regional classification) into innovation analysis. The second section sketches an interpretative framework and moves towards a tentative theoretical understanding of the connection between continuous space and innovation. Particular attention is paid to possible differences between innovation types (product and process) and industrial sectors. The third section describes the data and the methodology, and the fourth section presents some exploratory empirical results: given the novel type of question being addressed and the limited data access, these results should be seen as a starting point for more thorough investigation. With this in mind, the last section discusses the results and possible future research directions. Also highlighted is the key question of data access, which limits the geographic analysis of public microdata in Canada and circumscribes the possibility for further exploring the type of questions addressed in this article.

Why Would Innovation Vary Continuously Across Space?

It is now well established that innovation depends on information, feedback from clients and competitors, collaborative ventures and the exchange of tacit information (Gertler 2003; Cooke *et al.* 2004; Boschma 2005). It is often argued that this type of information exchange and application of knowledge in response to market opportunities can be facilitated by local context: certain regions are better suited than others to innovation. Their diversity (Jacobs 1969), institutional and cultural capacity to gather and use knowledge (Florida 1995), local culture (Maillat and Kebir 1999) and history (Doloreux and Dionne 2008)—in short their 'buzz' (Bathelt *et al.* 2004; Storper and Venables 2004)—enable and encourage firms to innovate and entrepreneurs to seize new opportunities. It is extremely difficult to pinpoint precisely which ingredients contribute most to buzz—hence the term, which is imprecise yet well understood. Indeed, it is probably not useful to think in terms of 'factors' that contribute to buzz (Lundvall 2007): rather, each region combines elements in different ways, and there are multiple combinations that are conducive to innovation (and also many that are not). Whether or not a particular region's profile will lead to buzz also depends on historical context: as Hall (1999) shows, the economic fortunes of even the most innovative cities throughout history have waxed and waned with wider contextual evolutions and with subtle internal ones. Despite the difficulty in capturing the essence of buzz, one fact repeatedly emerges: the conditions for innovation are usually best in or around large, diverse and cosmopolitan metropolitan areas (Jacobs 1969; Hall 1999; Malecki and Oinas 1999; Crevoisier and Camagni 2001; Florida 2004). This may nevertheless depend upon the type of innovation: cost-reducing process innovation may occur in smaller more specialized cities, whereas it may be the more radical product innovations that are focussed in and around metropolitan areas (Duranton and Puga 2003).

One of the reasons that metropolitan areas are often pointed to as gathering the prerequisites for regional innovativeness is that they enable intensive and diverse exchanges of informal, or tacit, information. According to Storper and Venables (2004), it is particularly face-to-face interaction, both formal (with clients, advisors and competitors) and informal (through social networks and chance encounters), that is a key factor. Such interaction is enabled by proximity, and proximity to a multiplicity of actors is facilitated within dense metropolitan regions. Less radical and process-oriented innovations may occur more frequently in smaller more specialized cities to which producers of mature products move to reduce costs (Duranton and Puga 2003). Because process innovation is often introduced through imitative behaviour (Levin *et al.* 1987), the localization economies that characterize smaller specialized cities may explain the urban (but not necessarily metropolitan) focus of such innovative activity.

The connection between geographic proximity and knowledge exchange (in view of innovation) is, however, problematic. Three recent critiques will be outlined further.

The nature of proximity

Proximity is commonly understood as having geographic connotations. However, as Boschma (2005) points out, there are in fact multiple ways in which economic actors can be close. Furthermore, geographic proximity is maybe the least relevant in terms of information exchange.

Indeed, Boschma (2005) outlines five types of proximity each of which can enhance knowledge exchange: (i) cognitive (sharing a common vocabulary and conceptual framework); (ii) organizational (capacity to coordinate and exchange knowledge); (iii) social (micro-level social ties of friendliness and trust); (iv) institutional proximity (macro-level routines, rules and regulations); and (v) geographic proximity.

It is useful to use an example to illustrate why geographic distance can be largely irrelevant to knowledge exchange and collaboration. As academic researchers, for instance, we are well aware that many collaborations occur over vast distances, not because we are physically close to a colleague but because we share cognitive (we work on similar or complementary topics), social (we are of a similar social class, and presumably get on relatively well) and often institutional (we often collaborate with colleagues from other universities, sharing a similar approach to knowledge and to research) proximities. There is no reason to believe that this is not also the case for entrepreneurs and businesses, though in many cases—especially for small businesses—the geographic range over which collaborations can take place is probably smaller than it is for academics.

Bearing this in mind, actual physical co-location with other economic actors is not as important for information exchange leading to innovation as these other types of proximity. Although geographic proximity *facilitates* some of these other proximities, particularly amongst actors who have limited time or money to travel, it is not a necessary factor.[2] Indeed, Gordon and McCann (2005), who present empirical evidence from London, show that ‘innovative behaviour [there] seems to have rather little to do with strong local inter-business connections highlighted in the co-operative, social network versions of the milieu literature’ (p. 541).

Social processes play out across space, and may develop more easily in certain places than in others, but space itself is secondary: in other words, knowledge exchange leading to innovation *requires* social, institutional, cognitive or organizational proximity, but does not *require* geographic proximity. From this perspective, spatial proximity is of a different nature than Boschma’s four other types of proximity: geographic proximity is neither a necessary nor a sufficient type of proximity to ensure productive exchange of tacit information. Social and cognitive proximities are probably necessary, as are, for larger organizations, institutional and organizational proximities. None are sufficient conditions for productive information exchange.

Proximity and time

Torre (2008) and Torre and Rallet (2005) introduce a key dimension, that of time. They share Boschma’s (2005) concern with the different types of proximity and with the ambiguous status of geographic proximity as it relates to innovation and knowledge exchange. Like Boschma, they also see geography as an ‘enabling’ type of proximity, but one that is by no means always necessary to stimulate tacit knowledge exchange. However, they suggest that geographic proximity is necessary *at some point in any collaborative relationship*: social, cognitive, institutional or organizational proximity is only possible if there has been, at some point in time, some form of geographic proximity.

[2] Iammarino and McCann (2006) conclude that ‘co-location ...*may or may not* offer structures, organizations and institutions which improve the likelihood of local innovation’ (1023). They show that the effect (or not) of co-location on innovation depends on the transactions costs, type of inter-firm relations, technology and types of knowledge that characterize the industry and innovation process being considered.

Here, too, an example from the academic world can be used to illustrate the point. Even if our most fruitful collaboration is with a colleague from the other side of the world, there is an overwhelming likelihood that we have actually met this colleague on a few occasions. Often, the initial contact will have been established at a conference, or, if it was by e-mail, will have rapidly been followed by a face-to-face encounter somewhere in the world. Thus, although it is not necessary to be geographically proximate in a continuous fashion in order to benefit from tacit knowledge exchange and constructive collaboration, *it is necessary to converge in space from time to time*. The necessity stems from the fact that knowledge is embodied and that we are social beings: information is not merely a stream of bits and bytes, but involves sentiments of trust and friendship between individuals that cannot be developed, nor maintained indefinitely, across space. Temporary geographic convergence therefore plays a key role in building trust (a social tie) and in evaluating cognitive and institutional proximity. Once a certain level of confidence is established—and only face-to-face contact, often in informal settings, will enable that—then geographic proximity ceases to play a key role.

Proximity and distance

To the extent that geographic proximity has often been referred to in the context of knowledge exchange and innovation, it may seem obvious that distance has also been integrated into the study of innovation. However, it is only very recently that this has been done in a systematic way. Indeed, most of the (few) empirical studies that integrate distance into their analyses have been studies of patent distribution and use, with emphasis on whether or not knowledge generated in universities is appropriated locally or not (Jaffe 1989; Breschi and Lissoni 2001). The conceptual starting point for these studies has often been knowledge diffusion models. 'Knowledge is . . . regarded as a local public good, to be retained by co-located economic agents, to the exclusion of distant ones' (Breschi and Lissoni 2001, p. 256).

The idea that the innovation activity of firms may be attributable to their geographic location, and not only to the region (or city) within which they are located, has recently been put forward by Andersson and Karlsson (2004). They suggest that for a firm it is not the *local* institutions, culture, information, face-to-face contacts and markets that are conducive to innovative activity, but rather the location of the firm relative to these important factors. They propose that each point in geographic space possesses a certain accessibility 'potential' to these inputs, and that by combining these accessibilities certain locations will emerge as more conducive to innovation than others.

McCann (2007) proposes a very similar, but simplified, model. Rather than assuming that it is access to a wide variety of factors (all located in different places) that determines the innovative potential of a point in space, he takes as a starting point that these factors tend to be concentrated in metropolitan areas. He further simplifies the conceptual approach by summarizing these factors by a key indicator of buzz, the intensity of face-to-face contacts. Given this simplified framework, he demonstrates by way of a theoretical model that different types of innovation will tend to take place at different distances from metropolitan areas: those types of innovation most intensive in face-to-face contacts will occur close to metropolitan areas, and those that require fewer such contacts will tend to occur farther away. He therefore predicts concentric patterns of different types of innovation.

The basic prediction of each model is that innovation will be higher the closer establishments are to factors of innovation. McCann (2007) qualifies this by arguing that even if all firms wish to locate close to metropolitan areas, competition between firms means that some types of innovation (those that are less face-to-face intensive) will be forced farther from the centre: thus, depending on the type of innovation its intensity will either decrease as one moves away from a metropolitan centre, or increase then decrease.

Recent exploratory analysis of the geography of innovative activity in Knowledge Intensive Business Services (KIBS) (Shearmur and Doloreux 2009) and in manufacturing establishments (Shearmur 2008) in Québec tends to corroborate these theories. It reveals that there are indeed concentric patterns of innovation around metropolitan areas in Québec, and these patterns seem to support the theoretical suggestions of

Andersson and Karlsson (2004), and McCann (2007). However, it also reveals an unexpected result: for both services and manufacturers, there are some types of innovation that *increase* with distance from a metropolitan area (without decreasing afterwards). They interpret this by suggesting that, close to the centre of metropolitan areas, firms are involved in more intense webs of collaboration (similar to Marshallian industrial districts). In such places it is not individual firms that innovate, but the network as a whole, with relatively fewer firms recording innovation—innovation can emerge from the recombination of fairly standard products and services. If this is true, firm level data will tend to show lower levels of innovation in and around such districts and, in particular, in and around metropolitan areas. Farther away from metropolitan areas, firms—particularly those in knowledge intensive sectors—will tend to internalize their innovative activities and, given the poorer market conditions, only innovators will survive. This increased internalization of innovation combined with survivor bias would explain the rising levels of innovation as one moves away from factors of innovation. An alternative explanation for these patterns may be that knowledge intensive firms *prefer* remote regions in order to protect the knowledge that they generate (Suarez-Villa and Walrod 1997; Iammarino and McCann 2006); in sectors where knowledge has great value, it may be of strategic importance to *avoid* informal knowledge spillovers and interactions. Firms that are not in knowledge intensive sectors, that is, those that locate in remote areas because of resource availability, low labour costs or to serve local markets, will probably not display higher rates of innovation in remoter locations: the knowledge that they generate may be of less strategic importance, and their innovations more dependent on contacts with clients, suppliers and other agents.

Towards a Synthesis of the Connection Between Geography and Innovation

Proximity and innovation

The various ideas presented earlier about the connection between innovation and space are disparate, but are not contradictory. In this section, I attempt to gather them into a coherent description of the way in which geography and innovation interact.

Geography is not a factor of innovation. It provides a context for firms, and this context can be more or less conducive to innovation. It is the way in which a firm interacts with this context that will possibly lead to innovative activity. One of the important contextual elements greater in some locations than in others is the capacity for firms and individuals to generate and strengthen social, cognitive, organizational and institutional proximity.

It has often been assumed in innovation studies that it is necessary to 'be there' (Gertler 2003): indeed Torre and Rallet (2005) criticize the geographic approach to innovation and knowledge spillovers for too often adopting an 'in or out' approach. However, if one substitutes 'distance to key factors of innovation' for the more commonly used 'region', then it is no longer necessary to assume that an establishment is either in or out of an innovative milieu or learning region. It is no longer necessary to 'be there'—rather, it is only necessary to be reasonably accessible.

If one assumes that most key factors of innovation are strongly present in large metropolitan areas, then the complex and data intensive superposition of potentials suggested by Andersson and Karlsson (2004) can be replaced by a more straightforward measure of distance to a metropolitan area (McCann 2007).

However, one cannot ignore the important body of work that takes a regional approach rather than an accessibility approach. The two approaches can be reconciled if one accepts that certain proximities may act over smaller distances than others. Thus, evidence of successful regional systems of innovation may be interpreted as evidence that, in those regions, there exist factors whose influence only extends to (approximately) the limits of the region. From a spatial analytic perspective a regional approach artificially dichotomizes distance—one is either in or out of the region, whereas a distance based approach does not: distance is introduced as a continuous variable. Thus, one can formally reconcile the approaches by recognizing that the regional approach adopts a dichotomous measure of distance.

Time can also be introduced into this conceptual approach. Proximity to a metropolitan area enables the type of temporary interaction emphasized by Torre (2008). For certain types of innovation, it may only be necessary to have infrequent face-to-face meetings with collaborators, clients and other key actors. Even if these collaborators are located elsewhere in the world, reasonable access to a metropolitan area facilitates temporary interactions by virtue of the convergence of transport and communication networks on these large cities.

Remoteness and innovation

There is a tendency to assume that it is proximity to certain factors of innovation that is conducive to innovation. Although McCann's (2007) model reveals that certain types of innovative activity will tend to occur farther away from a metropolitan area than others, this distance is a consequence of the compromise that innovative firms make between proximity and cost. It is those firms that most need proximity that will bid the highest price for land.

Shearmur and Doloreux's (2009) empirical results show that, in some service sectors, innovation tends to increase with distance from a metropolitan centre. This result is counterintuitive if one assumes that, from a geographic perspective, it is *only* proximity to factors of innovation that may lead to innovation.

In order to reconcile this observation with the general consensus that more innovation occurs in (or close to) key nodes, it is necessary to consider what is being measured and why firms innovate. In their study, and in many others that are based upon surveys that follow the Oslo manual (OECD 2005) format, establishments are asked whether they have introduced a new or improved product or process over the last 'x' years, and if so whether this new product or process is only new to the firm or also new in a wider context. The local propensity to innovate is thus a ratio (an odds ratio) of firms that innovate to firms that do not. It is possible that, even though there are a greater number of innovative firms close to metropolitan areas, the *relative* number of innovative firms is greater in remoter regions. If this is the case, the odds ratio will *decrease* in the very locations where factors of innovation are most strongly present.

To explain why the probability of innovating does not necessarily rise with proximity to factors of innovation (i.e., to metropolitan centres) it is useful to consider the interplay between internalized and externalized innovation. Indeed, close proximity enables firm-level specialization—thus innovation in dense metropolitan areas may occur by recombining the outputs of many noninnovative firms. As one moves farther away, and as the density of firms decreases, innovation may increasingly occur in-house: the ratio of innovative firms to noninnovative firms may thus increase with distance from key factors of innovation. It is also possible that certain firms, particularly those that are producing sensitive knowledge, may avoid central locations in order to minimize the possibility of informal knowledge exchanges (which, in their case, would constitute a loss of valuable property) and to reduce the likelihood of personnel poaching. In this case internalization of the innovation process may be actively chosen as a way of protecting it, and a remote location may be considered more propitious for such internalization.

Another reason why the propensity to innovate may rise as one moves away from metropolitan areas is survivor bias: particularly for firms engaged in knowledge intensive activities (and which therefore would benefit, *ceteris paribus*, from location in metropolitan areas), their very existence in remote, information-poor locations may be a consequence of their capacity to innovate. Whereas firms engaged in routine activities may benefit from the lower cost of remote locations (and hence may be less innovative than competitors in higher cost central locations), firms engaged in more knowledge intensive activities may see innovation as a survival strategy in remote locations which present no obvious advantages for these activities.[3]

[3] Such a process implies that these innovative firms choose to locate (or to remain) in places that are not rational in an economic sense, and that innovation may be a strategy deployed in order to make it possible to remain there. The author has, in the course of his work on peripheral regions, met a number of innovative entrepreneurs who are well aware that profit and growth prospects are better closer to metropolitan regions but who choose to remain in their remote location for personal (often family or quality of life) considerations. Given the small numbers of establishments (particularly HT ones) in these regions, this type of decision may have a noticeable effect on the ratio of innovative to noninnovative establishments.

Finally, process innovations—those aimed at reducing costs for industries that are not competing in the area of product innovation—may more readily occur in smaller cities. Thus, certain types of innovation, particularly those associated with cost reduction, may be more probable in remoter cities than in large metropolitan areas.

Summary and research question

If geographic proximity's principle role in innovation is as an enabler of other types of nonspatial proximity, then there is good reason to believe that the propensity to innovate varies across space with distance from metropolitan regions. Metropolitan regions are highpoints of social interaction, informal information exchange and access to global networks: as distance from these highpoints increases, the most knowledge intensive types of innovation will tend to decrease, whereas other types of innovation may increase—but always occurring as close as possible (given competition with other firms) to metropolitan factors of innovation (McCann 2007).

However, firm-level data may not be good at identifying the most knowledge intensive types of innovation: indeed, if these tend to emanate from collaborative networks, then there is no reason to believe that each individual participant in the network will innovate. Thus it is uncertain whether firms will be (individually) more or less innovative close to metropolitan centres. However, as one moves away from metropolitan centres two types of behaviour are expected: on the one hand knowledge intensive firms (such as HT manufacturers) will be more innovative since they are increasingly called upon to internalize their innovative activities as the possibility of collaboration decreases with distance from metropolitan areas. Innovative firms in HT sectors may also remain in remote locations by choice (in order to protect valuable knowledge), and there may be survivor bias since noninnovative firms of this type probably cannot survive in remote locations. On the other hand, firms that are engaged in more routine lower-tech production, and which benefit from locating in remote areas because of cheaper labour and access resources, will be less innovative in remote areas. In these sectors product innovation will tend to be higher closer to metropolitan areas because only product-innovators will derive benefits from these higher cost environments. Process innovations in more routine manufacturing may occur further out from metropolitan areas or in small more specialized cities (Duranton and Puga 2003; McCann 2007).

By dividing manufacturing establishments into HT, MT and FST sectors, the following hypotheses will therefore be tested:

- HT firms tend to be more innovative in remoter locations.
- MT and FST sectors tend to be more innovative closer to metropolitan areas.
- Process innovation in MT and FST sectors will tend to occur further from metropolitan areas than product innovation, and/or in smaller urban areas.
- Local factors do not account for the observed spatial patterns.

Data and Methodology

Data and data access

One of the reasons why distance has not often been included in studies of innovation is the fact that most innovation surveys rely on relatively small samples of firms, selected to ensure size and sector representativity, but rarely selected on the basis of detailed geographic criteria. The population of firms surveyed in the context of the Canada Innovation Survey of 2005—the Statistics Canada data source that is used in this article—was selected on the basis of this type of criterion except in Québec where a group of government and community actors paid for oversampling[4]: thus, in Québec the survey is in fact a census of manufacturing firms which have over 20 employees. The 3,158 manufacturing observations that are analyzed represent about 70

[4] The organisations that participated in financing the manufacturing census are as follows: Institut de la Statistique du Québec, Ministère du Développement économique, de l' Innovation et de l' Exportation du Québec, Industrie Canada (région du Québec), Conseil National de Recherche du Canada (région du Québec), Ministère des finances du Québec, Conseil de la Science et de la Technologie du Québec and Economic Development Canada. The Innovation Studies Research Network and INRS research funds financed access to these data.

percent of all manufacturing firms of over 20 employees in Québec. Weights are provided by Statistics Canada to correct for underrepresentation of certain sectors.

Each firm is geocoded to its six digit postal code, of which there are 50,000 in Québec. Thus the postal code is an (almost) unique spatial identifier, with very few postal codes containing more than one firm.

In order to test whether regional characteristics (as opposed to distance from urban areas) are explanatory factors, the 3,158 observations are grouped within MRC (Municipalités régionaux de compté) of which there are 99 in Québec. These have been combined (using rules of contiguity and our knowledge of the local economies to ensure consistency) into 50 spatial units which each contain at least 20 observations (see Figure 1).

For each observation two distances are calculated: distance to the closest large metropolitan area (Montréal, 3.5 million people; Ottawa-Gatineau, one-million people; Québec city, 600,000 people) and distance to the closest medium-sized urban agglomeration (Saguenay, 144,000 people; Sherbrooke, 146,000 people; Trois-Rivières, 126,000; Rimouski, 50,000), defined as cities of over 50,000 people located

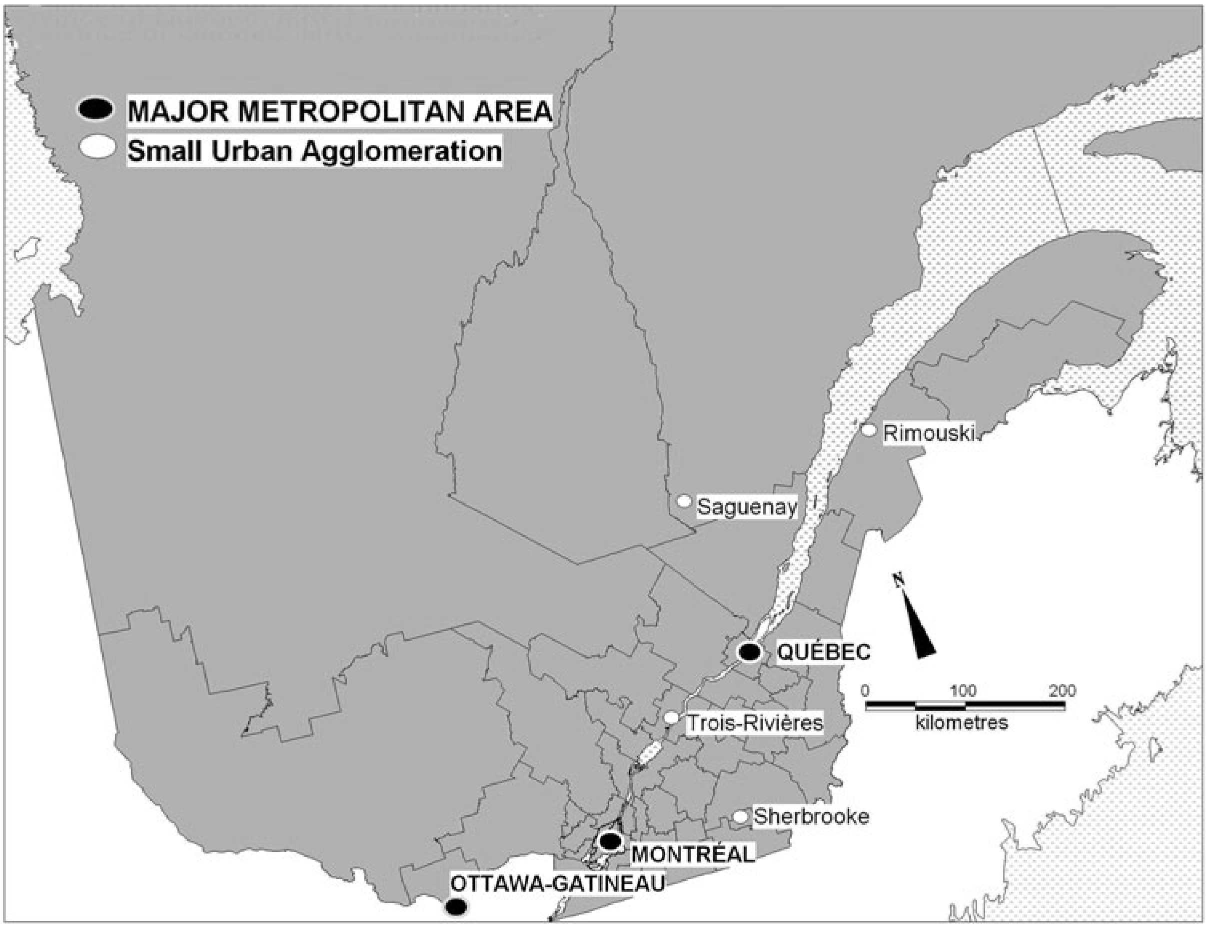

Figure 1
Québec with regional subdivisions and urban areas

Table 1
Classification of three-digit industries by reliance on internal R and D staff

Type	Sectors	Percent of total weights*
High-tech (high R&D)	Petroleum and coal products (324), plastics and rubber (326), computers and electronics (334), electrical equipment and components (335), machinery (333)	19.8% (approximately 626 observations)
Medium-tech (medium R&D)	Textiles (313 and 314), primary metals (331), food and beverages (311 and 312), nonmetallic minerals (327), transportation equipment (336), chemicals (325), miscellaneous (339)	33.3% (approximately 1,053 observations)
First and second transformation (low R&D)	Wood products (321), clothing and leather (315 and 316), paper (322), printing (323), fabricated metals (332), furniture (337)	46.8% (approximately 1,479 observations)

*Approximate numbers based upon the weights are provided.

over 100 km away from a major metropolitan area.

The data at our disposal provide four different measures of innovation (Appendix A): the introduction, between 2002 and 2004, of a product or process new to the establishment (two measures), and the introduction between 2002 and 2004, of a product or process new to the firm's market (two measures).

Each observation is classified at the three-digit North American Industry Classification System (NAICS) level. Sectors are classified into HT, MT and FST (Table 1). This classification reflects sectors that have a high, medium and low reliance on information provided by internal research and development staff,[5] which we assume reflects the sector's R and D intensity (Table 2).

Access to these data, despite the fact that they are publicly funded, is restrictive. Analysis, quite understandably, takes place in secure data centres. Each researcher is security vetted before obtaining access to the data, and all results taken out of the centre are also vetted. This limits the amount of descriptive data that can be presented since, for reasons of confidentiality and consistency, frequency tables are discouraged.[6] However, this type of restriction is inevitable—and indeed desirable when micro-data are being analysed. Individuals and firms reply to government surveys on the understanding that their answers will remain strictly confidential, and compliance with all measures required to ensure this confidentiality (and to ensure the appearance of confidentiality) is a necessary component of the research. A second type of restriction is also applied: the data analysed in this article are only a selection of the whole array of variables, for which a considerable access fee has been paid for 12 months of access. The initial request was made before any analysis of the new questions being addressed in this article had been performed. Over the course of investigation, as research directions have become clearer, it has not been possible to alter the initial selection of

Table 2
Innovation in three different sectors

Sector: Innovation type:	High tech	Medium tech	1st and 2nd transformation
Minor product	66%	53%	41%
Major product	48%	40%	26%
Minor process	57%	56%	54%
Major process	18%	20%	14%

NOTE: The table presents the percentage of establishments that introduce this type of innovation.

[5] Question 25a asks each respondent to indicate, on a four point scale (one of which is 'not relevant'), the 'importan[ce] to your plant's innovation activities .... of the following information sources: Research and development (R&D) staff'. The results to this question are dichotomized, to identify establishments for which R&D staff are a source of high or medium importance, then aggregated by sector. Sectors within which the highest proportion of establishments assign some importance to R&D staff are those classified as HT, those where a medium proportion assign an importance are classified as medium tech, and the rest are first and second transformation.

[6] Although frequency tables cannot always be presented for the data used in this paper, descriptive analysis published by the Institut Québécois de la Statistique (ISQ 2008) provides a good overview of the regional distribution of observations and of the basic innovation variables for Québec.

variables. Furthermore, the short time slot[7] of data availability means that follow-up analyses, once ideas and concepts have matured, are problematic. These types of restrictions considerably hinder research efforts, and the wider policy of reasonable access to publicly funded data is one that needs to be addressed in Canada.

Methodology

Given these data, the exploratory model that is applied at the establishment level (by way of logistic regression) is the following:

$$Innov = f(C, d, y, c') + \varepsilon \quad (1)$$

where *Innov* is the dichotomous innovation variable (four measures of innovation, see text), C the vector of basic control variables: establishment size, establishment sector (3 digit SIC classification, see Table 1) and percentage of sales outside Québec, d is the vector of distance variables. The following distance variables are analysed, d_m the log of Euclidian distance to closest metropolitan area, rd_m^2 the residual, r' of regression $d_m^2 = a + b.d_m + r$, d_s the log of Euclidian distance to closest small city, rd_s^2 the residual, r'' of regression $d_s^2 = a' + b'.d_s + r'$.

Distance units are in kilometres and a minimum distance of 1 km is imposed. Note also that regression residuals are taken for the quadratic terms in order to avoid multi-collinearity problems. Y is a set of dummy variables for 50 regions (see text for details). c' are the other available control variables: part of a larger firm (1 or 0), over 90 percent of inputs purchased in Québec (1 or 0).

The basic control variables, C, are chosen because it is already well established that there are considerable spatial variations in industry, establishment size and exports (Polèse and Shearmur 2002). The other control variables, c', are the only variables in the database available that have been answered by innovators and noninnovators alike. It should be noted that the results for all three sectors are valid within a range of about 400 km from metropolitan areas. Beyond this distance there are few high-tech firms (Appendix B). Given that distances are logged, distance outliers do not have an undue effect on the coefficients.

The approach to this analysis is as follows. First a base model is run containing only C (model A in Tables 3–5), then a model containing C and d to test whether innovation varies with distance (model B in Tables 3–5): the best selection of variables is identified by way of a backwards stepwise selection process. The criterion for inclusion is a *chi-square* significantly different from 0 at the 90 percent confidence level. The purpose of the analysis is to identify whether innovation varies significantly with distance, and if so, the shape of this relationship.

The second stage of the analysis consists of adding the regional dummy variables, Y, and the other controls, c' (model C in Tables 3–5). The purpose of this stage is to verify whether the patterns that emerge in the first stage disappear once unobserved regional attributes and other firm level information are inserted. The method used is identical to the first stage: backwards stepwise selection, with the entire regional effect entering or leaving the model in one block. If the spatial patterns persist or if the regions do not successfully enter the model then this will show that it is distance, and not discrete regional entities, that is the principal organizing factor of innovation over space in Québec. If the spatial pattern disappears, this will show that, although distance plays a role, it can be explained by the variation across regions of underlying factors of innovation. It will suggest that innovative regions are not distributed randomly in space but in accord with the spatial pattern that their insertion into the model has absorbed.

The results of this analysis will be of interest provided that spatial patterns of innovation are identified and that they do not disappear with trivial controls such as establishment size or sector: these controls are trivial (from a spatial perspective) because it is well established that sector and size vary across space, and that innovation varies across these dimensions. Were the spatial patterns to disappear after nontrivial controls are added (factors associated with

[7] Different concepts of time seem to apply: in academia, it is generally accepted that an original research program can take three to four years to mature into scientific discovery, often through iterative processes (such as writing up initial findings, discussing them at conferences, and returning to the data with clearer ideas). Government agencies often consider 12 months to be a long time over which to conduct research.

Table 3
High tech manufacturing

	Product						Radical product						Process						Radical process					
	A1		B1		C1		A2		B2		C2		A3		B3		C3		A4		B4		C4	
Model name	***Chi-square***	**ß**	***Chi-square***	**ß**	***Chi-square***	**ß**	***Chi-square***	**ß**	***Chi-square***	**ß**	***Chi-square***	**ß**	***Chi-square***	**ß**	***Chi-square***	**ß**	***Chi-square***	**ß**	***Chi-square***	**ß**	***Chi-square***	**ß**	***Chi-square***	**ß**
% Local sales	5.94^{+}	−0.13	5.94^{+}	−0.13	X		10.9^{*}	−0.16	15.8^{*}	−0.18	11.7^{*}	−0.16	2.23	0.07	X		4.43^{+}	0.10	0.01	−0.00	X		X	
Size (df = 3)	8.64^{+}	-	8.64^{+}	-	11.9^{*}	-	2.52	-	X		X		14.3^{*}	-	11.9^{*}	-	13.9^{*}	-	11.7^{*}	-	14.6^{+}	-	11.7^{+}	-
Sector (df = 3)	15.8^{*}	-	15.8^{*}	-	17.6^{*}	-	1.80	-	X		X		6.00	-	$7.32^{\#}$	-	X		3.92	-	X		X	
Dm			X		X				9.01^{*}	0.18	9.53^{*}	0.18			X		X				$3.63^{\#}$	0.12	X	
rdm^2			X		X				8.52^{*}	0.16	9.16^{*}	0.16			X		X				X		X	
Ds			X		X				11.9^{*}	0.21	11.5^{*}	0.21			4.94^{+}	−0.11	4.48^{+}	−0.10			$2.74^{\#}$	0.12	X	
rds^2			X		X				X		X				X		X				X		X	
Y (df = 50)					X						X						X						X	
Subsidiary (=1)					$2.92^{\#}$	−0.09					X						X						X	
Local inputs >90%					23.8^{*}	−0.23					$3.64^{\#}$	−0.09					12.1^{*}	−0.16					7.58^{*}	−0.22
Pseudo-R^2	0.081		0.081		0.083		0.039		0.065		0.072		0.044		0.050		0.071		0.040		0.051		0.051	
−2 *LL* nul	1087.4		1087.4		1087.4		1178.4		1178.4		1178.4		1162.9		1162.9		1162.9		793.6		793.6		793.6	
−2 *LL*	1044.0		1044.0		1024.9		1157.5		1142.8		1139.1		1139.1		1136.1		1129.4		775.6		775.4		770.0	
df	7		7		8		7		4		5		7		7		6		7		5		4	
p(*chi-square*) = 0	<0.0001		<0.0001		<0.0001		0.0049		<0.0001		<0.0001		0.0028		0.0012		0.0012		0.0093		0.0022		0.0004	
Weighted *n* : 1	564		564		564		412		412		412		484		484		484		150		150		150	
Weighted *n* : 0	287		287		287		439		439		439		366		366		366		700		700		700	

NOTE: * = significant at 99%, + = significant at 95%, # = significant at 90%. Standardized regression coefficients are presented in this table (for dichotomous and continuous variables) and the *chi-square* for each effect is also shown.
The first three effects (% local sales, size and sector) are forced into the models as controls. The rest are selected using a backwards stepwise process. The criterion for exclusion is *p*(*chi*-square) > 0.1, and X indicates that the effect has been excluded.

Table 4
Medium tech manufacturing

	Product						Radical product						Process						Radical process					
	A1		B1		C1		A2		B2		C2		A3		B3		C3		A4		B4		C4	
Model name	***Chi-square***	**ß**	***Chi-square***	**ß**	***Chi-square***	**ß**	***Chi-square***	**ß**	***Chi-square***	**ß**	***Chi-square***	**ß**	***Chi-square***	**ß**	***Chi-square***	**ß**	***Chi-square***	**ß**	***Chi-square***	**ß**	***Chi-square***	**ß**	***Chi-square***	**ß**
% Local sales	12.8*	−0.14	20.4*	−0.17	11.1*	−0.14	5.76+	−0.10	7.90*	−0.11	7.09*	−0.12	6.99*	−0.10	7.68*	−0.10	4.00+	−0.08	9.61*	−0.15	12.8*	−0.17	16.0*	−0.18
Size (df = 3)	2.59	-	X		X		7.38#	-	7.86+	-	X		8.95+	-	9.83+	-	9.55+	-	8.25+	-	7.04#	-	X	
Sector (df = 3)	31.5*	-	31.5*	-	34.1*	-	27.0*	-	26.2*	-	33.5*	-	6.40	-	X		X		9.13	-	X		X	
dm			9.05*	−0.11	X				16.8*	−0.16	2.85#	−0.25			X		X				X		X	
rdm^2			9.05*	−0.11	X				14.1*	−0.15	4.47+	−0.16			3.76+	−0.07	X				X		X	
ds			X		X				X		X				X		X				X		X	
rds^2			X		X				X		X				X		X				4.31+	−0.11	4.61+	-0.11
Y (df = 50)					73.9+	-					68.4+	-					X				X		X	
Subsidiary (=1)					X						X						X						5.57+	0.10
Local inputs >90%					6.12+	−0.10					12.0*	−0.15					4.84+	−0.10					X	
Pseudo-R^2	0.055		0.073		0.181		0.051		0.086		0.199		0.035		0.032		0.034		0.046		0.041		0.039	
−2 *LL* nul	1991.3		1991.3		1991.3		1942.4		1942.4		1942.4		1976.5		1976.5		1976.5		1421.2		1421.2		1421.2	
−2 *LL*	1942.3		1925.9		1820.5		1898.0		1864.9		1754.4		1945.5		1948.1		1947.1		1385.4		1389.5		1391.4	
df	10		12		57		10		12		59		10		5		5		10		5		3	
p(*chi-square*) = 0	<0.0001		<0.0001		<0.0001		<0.0001		<0.0001		<0.0001		0.0008		<0.0001		<0.0001		0.0001		<0.0001		<0.0001	
Weighted *n* : 1	758		758		758		582		582		582		802		802		802		281		281		281	
Weighted *n* : 0	681		681		681		857		857		857		637		637		637		1158		1158		1158	

NOTE: * = significant at 99%, + = significant at 95%, # = significant at 90%. Standardized regression coefficients are presented in this table (for dichotomous and continuous variables), and the *chi-square* for each effect is also shown.
The first three effects (% local sales, size and sector) are forced into the models as controls. The rest are selected using a backwards stepwise process. The criterion for exclusion is *p*(*chi-square*) > 0.1, and X indicates that the effect has been excluded.

Table 5
FST manufacturing

	Product						Radical product						Process						Radical process					
	A1		B1		C1		A2		B2		C2		A3		B3		C3		A4		B4		C4	
Model name	***Chi-square***	**ß**	***Chi-square***	**ß**	***Chi-square***	**ß**	***Chi-square***	**ß**	***Chi-square***	**ß**	***Chi-square***	**ß**	***Chi-square***	**ß**	***Chi-square***	**ß**	***Chi-square***	**ß**	***Chi-square***	**ß**	***Chi-square***	**ß**	***Chi-square***	**ß**
% Local sales	33.8*	−0.19	44.2*	−0.20	21.6*	−0.16	29.0*	−0.19	38.6*	−0.21	17.9*	−0.16	22.7*	−0.15	22.7*	−0.15	12.4*	−0.12	21.6*	−0.22	20.4*	−0.21	9.68*	−0.15
Size (df = 3)	1.47	-	X		X		2.20	-	X		X		11.2+	-	12.7*	-	10.8+	-	7.84+	-	8.20+	-	6.43#	-
Sector (df = 3)	47.3*	-	46.8*	-	38.3*	-	25.4*	-	26.2*	-	20.7*	-	82.9*	-	81.1*	-	79.8*	-	45.1*	-	45.5*	-	37.9*	-
dm			X		X				X		X				X		3.06#	0.06			X		X	
rdm^2			X		X				X		X				8.94*	−0.09	8.07*	−0.09			6.73*	−0.14	6.10+	−0.13
ds			X		X				X		3.56#	0.16			X		X				X		X	
rds^2			3.27#	−0.06	X				X		X				X		X				3.48#	0.08	3.66#	0.08
Y (df = 50)					85.4*	-					62.8#	-					X						X	
subsidiary (=1)					X						X						X						6.08+	0.11
Local inputs >90%					20.2*	−0.16					20.5*	−0.18					12.3*	−0.11					10.3*	−0.16
Pseudo-R^2	0.065		0.066		0.147		0.054		0.053		0.134		0.097		0.104		0.114		0.087		0.096		0.112	
−2 *LL* nul	2740.9		2740.9		2740.9		2326.1		2326.1		2326.1		2786.6		2786.6		2786.6		1623.4		1623.4		1623.4	
−2 *LL*	2656.0		2654.1		2541.03		2259.7		2261.9		2156.4		2657.0		2647.8		2633.3		1533.5		1524.2		1506.8	
df	9		7		56		9		6		60		9		10		12		9		11		13	
p(*chi-square*) = 0	<0.0001		<0.0001		<0.0001		<0.0001		<0.0001		<0.0001		<0.0001		<0.0001		<0.0001		<0.0001		<0.0001		<0.0001	
Weighted *n* : 1	838		838		838		531		531		531		1091		1091		1091		279		279		279	
Weighted *n* : 0	1182		1182		1182		1489		1489		1489		929		929		929		1740		1740		1740	

NOTE: * = significant at 99%, + = significant at 95%, # = significant at 90%. Standardized regression coefficients are presented in this table (for dichotomous and continuous variables), and the *chi-square* for each effect is also shown.
The first three effects (% local sales, size and sector) are forced into the models as controls. The rest are selected using a backwards stepwise process. The criterion for exclusion is *p*(*chi-square*) > 0.1, and X indicates that the effect has been excluded.

innovation but which are not currently understood to vary across space in a continuous fashion—such as collaborative behaviour or sources of information), then this would show that these control factors follow the type of spatial pattern initially revealed. The model does not contain many firm-level attributes (except for a few basic controls) because, in the database available, detailed questions on knowledge use, collaborations and sources of information are only addressed to innovators: this limits our capacity to explore the underlying mechanisms that drive observed spatial patterns.

The Variation of Manufacturing Innovation Across Space

The rate at which establishments innovate varies across economic sector (Table 2). HT establishments introduce considerably more product innovations than MT ones, which in turn are considerably more product innovative than FST firms. Differences between sectors in terms of process innovations are less marked, with FST establishments only slightly less process innovative than HT and MT firms.

For all three sectors, and for the four types of innovation, the propensity of establishments to innovate varies across space. Detailed results are given in Tables 3–5, and the variation of innovation across space is illustrated in Figures 2–4. Only general remarks will be made about the tables—detailed comments will be reserved for the figures, which summarize the key findings.

On the whole, these logistic regressions that include few firm-level variables and that focus upon geographic factors have relatively low explanatory power. Thus, even though innovation does vary significantly across space—and principally it varies with distance from large and small cities, not with regions—the degree of this variation should not be overstated. Distance variables either add between 0.01 and 0.03 to the pseudo-R^2 of the base control model, which is itself relatively modest (0.04–0.09 depending on the type of innovation and sector), or override other variables and improve the degrees of freedom without increasing overall explanatory power.

Having said this, not only does distance enter the base model significantly in all but two cases (HT product and FST radical product innovations), it tends to remain in the model after the regional and other controls are added. Although distance drops out for HT radical process, MT product and process, and FST product innovations, it actually enters for FST process innovation for which it was absent without the controls. In short, most types of innovation in most sectors display some degree of continuous variation across of space.

The nature of this variation is difficult to assess from the regression coefficients in Tables 3–5. Therefore, Figures 2–4, provide visual representations of this variation: ignoring all other variables (the mean propensity to innovate on each figure is set to zero),[8] these figures show how innovation in each sector varies as one moves away from a metropolitan area, which is located at distance 0. Given that the four smaller cities included in the analysis are all between 120 and 200 km away from a metropolitan area, a small city has been arbitrarily located at 150 km from the metro area.

Radical innovation in HT establishments tends to rise with distance from a metropolitan area, and nonradical innovation occurs irrespective of this distance. Process innovation in this sector rises in frequency with proximity to small cities (Figure 2).

These results run counter to the idea that innovative high-tech firms locate in and around metropolitan areas, but are compatible with the alternative interpretation proposed, that is, they corroborate the hypothesis that HT firms either internalize their innovations in distant areas, or that there is a survivor bias which means that, outside of large urban areas, only the most innovative HT establishments survive. Unlike MT and FST establishments, HT ones are probably much less sensitive to cost and natural resource issues—they therefore have little economic incentive to locate in remoter areas, and must overcome this remoteness by being innovative. MT establishments, contrary to HT ones, behave in a more intuitive fashion (Figure 3). In this sector all types of innovation, except for radical process, decrease with distance from a metropolitan area: radical process innovations rise in

[8] The figures represent variation in the logit function: only the shape of the relationship should be interpreted and the amplitude of the variation, since the values in the figure are arbitrary.

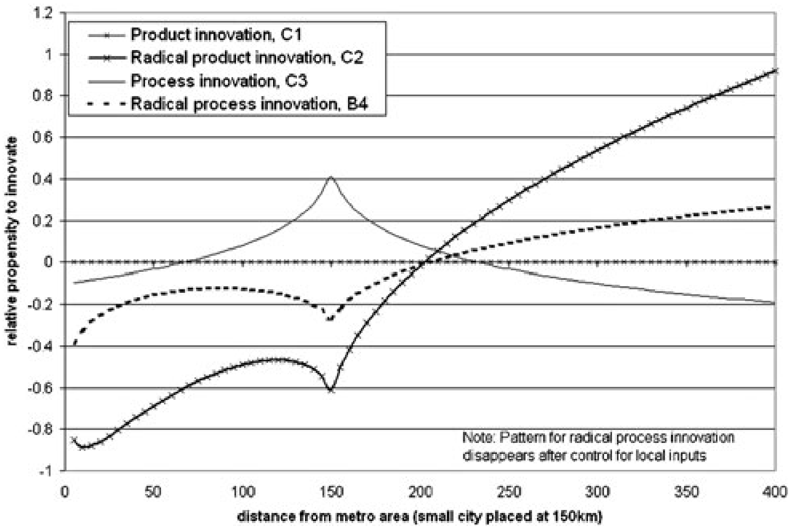

Figure 2
High-tech manufacturing: spatial variation of propensity to innovate

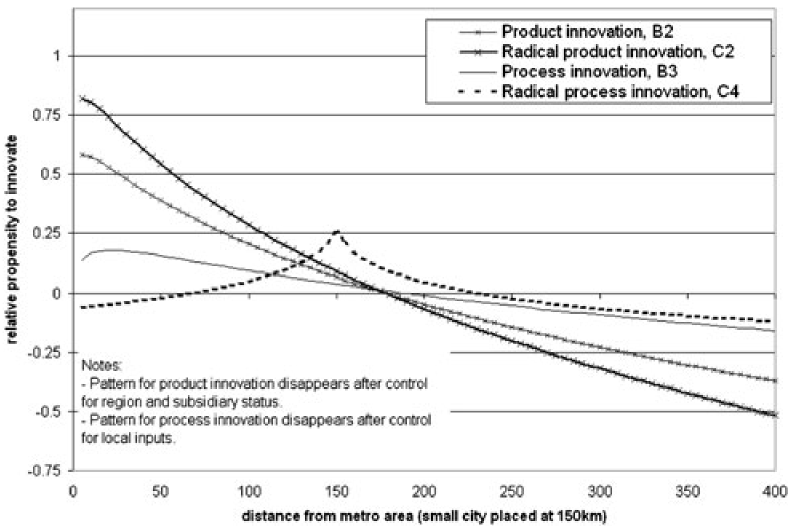

Figure 3
MT manufacturing: spatial variation of propensity to innovate

frequency closer to small cities. In this sector it appears that noninnovators, no doubt attracted by cheaper land and labour, locate away from cities. The more innovative firms seem willing to pay the higher costs associated with central and suburban locations.

The variation across space of innovation in FST does not behave in a straightforward way (Figure 4). Process innovations rise as one approaches metropolitan areas, but peak at about 40 km from the core, then decrease. This is compatible with the idea that noninnovators

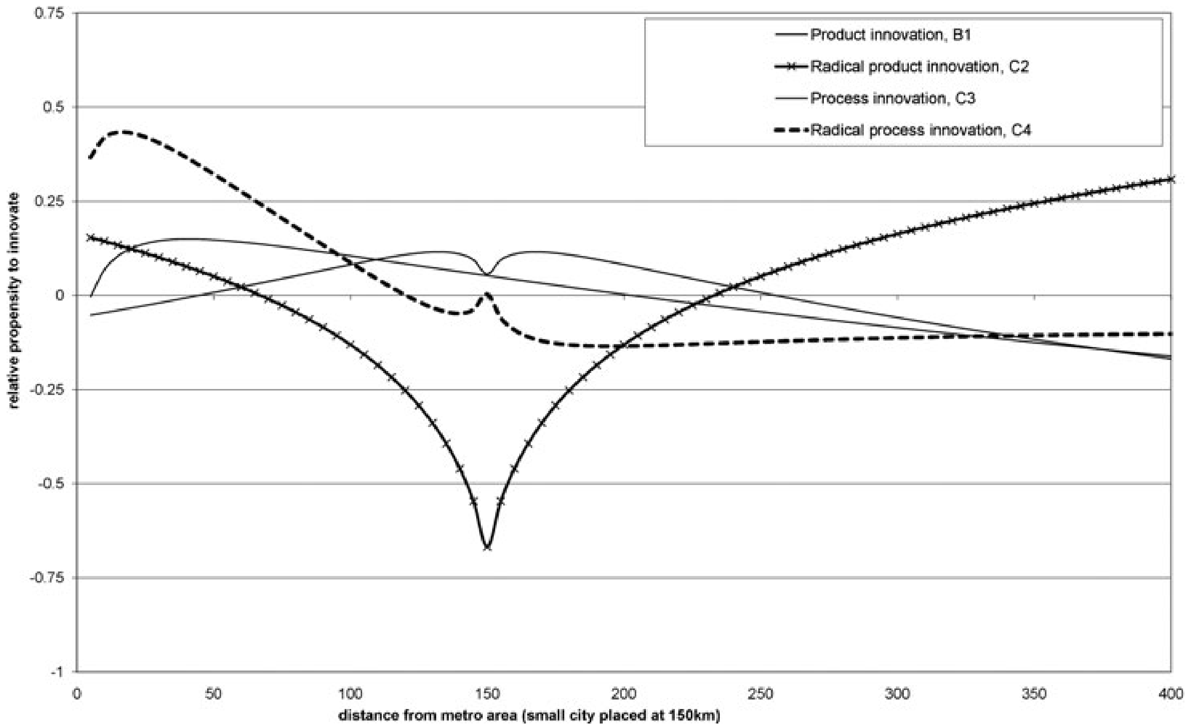

Figure 4
FST manufacturing: spatial variation of propensity to innovate
NOTE: Pattern for product innovation disappears after control for region and local inputs.

benefit from low costs and access to resources in remoter areas, whereas innovators benefit from proximity to metropolitan areas. It is interesting to note that the peak in innovation occurs further out than the peak observed for MT establishments: this is compatible with McCann's (2007) theory that innovators who have a lower requirement for metropolitan factors (in this case FST manufacturers) will be crowded out by those with a higher requirement (in this case MT manufacturers).

FST product innovations, however, are insensitive to distance from metropolitan areas. They are least frequent *in* small cities, but whereas radical product innovations rise with distance from small cities (and this may, indirectly, indicate a rise as one gets closer to metropolitan areas), nonradical product innovation tends to rise up to a distance of about 30 km from these small cities, then decreases. FST radical process innovation peaks both in metropolitan suburbs (the peak is closer to the metropolitan core than nonradical process innovations—compatible with McCann 2007) and in the core of small cities (compatible with Duranton and Puga 2003).

In order to relate these various spatial patterns to each other, Figure 5 summarizes Figures 2–4. The 12 innovation types (three sectors × four innovations) are mapped onto two axes, one of which indicates proximity to a metropolitan area, the other proximity to a small city. HT innovations stand out. Their frequency is either independent of distance to a metro area (nonradical innovation) or increases with distance: they tend to be in the lower half of the figure, and particularly in the lower left quadrant. Conversely, all MT innovations tend to occur more frequently as one approaches metropolitan areas (upper right quadrant). FST innovators, except for radical product innovators, tend to be closer to the centre of the figure,

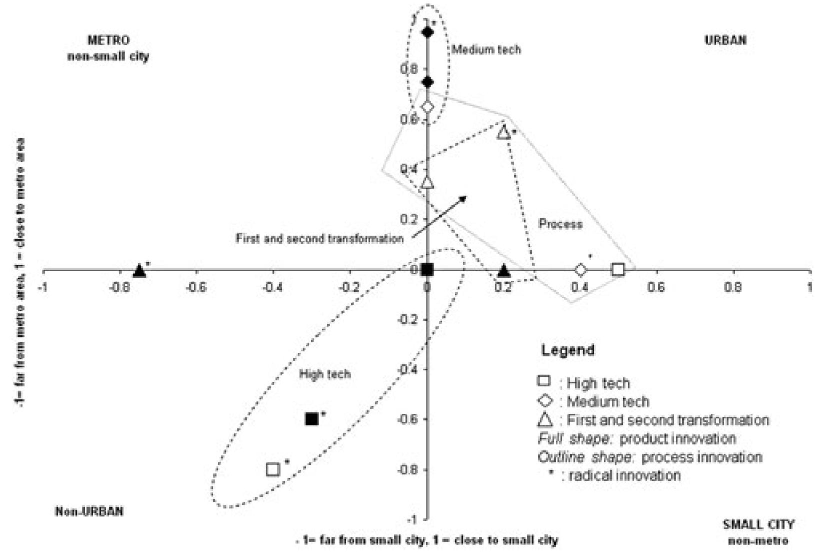

Figure 5
Innovation and proximity to large and small cities: summary of results

reflecting the fact that there is less variation across space for this type of innovation. Although not noted on Figure 5, it is only product innovations that vary significantly across regions: even though our analysis does not explore why this is the case, it suggests that there could be local innovation dynamics at play for this type of innovation. The regional innovation system approach may assist in understanding this type of innovation. Process innovation; however, does not vary across regions: innovation systems for this type of innovation may operate at a wider scale,[9] or this type of innovation may occur independently of local context.

Discussion and Conclusion

Over the last 15–20 years there has been considerable research devoted to understanding the social dimensions of innovation. Invariably these social dimensions involve the exchange and use of tacit information, which in turn requires face-to-face contacts and a cultural and institutional framework conducive to these activities. It has been noted by many researchers that these conditions are better met in some regions than in others, and that often the regions most propitious to innovation are in or around large metropolitan areas. These ideas have led to concepts such as regional systems of innovation or innovative milieu, used to denote bounded localities within which conditions for innovation are met.

Only quite recently has it been suggested that bounded localities may not be the appropriate (or, at least, the only) way of understanding the geography of innovation. On the one hand, Lundvall (2007) reminds us that the scale at which innovation processes and institutions exist is often national as opposed to regional. On the other hand, it has been suggested that it is *access to,* not necessarily *co-location with,* a variety of factors of innovation that may distinguish certain locations from others in terms of their innovation potential. Given the difficulty in locating factors such as ‘local culture’ and ‘institutions’, the idea is difficult to implement. However, if one assumes that factors of innovation tend to concentrate in urban and metropolitan areas, then it can be expected that the

[9] It is possible that they operate at a smaller scale. This is unlikely given the detailed subdivision of Québec that has been used.

propensity to innovate will vary with distance from urban centres.

Testing this hypothesis is complicated because one needs to distinguish between firm-level and regional-level innovation. It is conceivable, in the light of work on industrial districts and innovative milieu, that a particularly innovative region, one from which notable new products and processes emerge, actually contains relatively few innovative firms. Indeed, if networks of specialized firms innovate by recombining existing products and processes in new ways, then only the few firms who happen to market the end product will appear to be innovative (and will give positive replies to the innovation questions in innovation surveys). Conversely, it may also be the case that, as firms become more distant from these innovative networks, they are driven by necessity to innovate internally (thus giving positive responses to innovation questions). It is also possible that innovative firms in knowledge intensive sectors seek out remote locations in order to promote secrecy.

To explore these various ideas, this article sets out to compare the way in which innovation varies with distance from urban areas in three different manufacturing sectors. The working hypothesis is that, in lower-tech sectors, those that benefit from remote areas because of the cost and availability of labour, land and resource inputs, innovation will tend to occur close to urban areas (because only the more competitive firms in these low-tech sectors need to be there). However, cost-saving process innovations in these sectors may also tend to occur in smaller more specialized cities. A related hypothesis is that high-tech firms, those that are usually assumed to rely more heavily on information and knowledge exchange, will display reverse spatial patterns. These firms may appear to be less innovative in large urban areas, or at least indifferent to urban areas for innovation purposes (because their products feed into wider innovations), but more innovative further away (because innovation is increasingly internalized, either by necessity or design). For these firms, which are largely insensitive to the locational advantages of remote areas, innovation may also be a survival strategy because they are removed from their basic inputs (information and knowledge, generated and exchanged in cities): they rely on internal innovation to compensate for this.

The strength of the geographic effect revealed in this article should not be over-stated—although the geographic variables are significant, the overall explanatory power of the models is low: clearly firm-level factors are of key importance, and this is evident when the control variables are considered. Given this proviso, the empirical results tend to corroborate these hypotheses. MT firms are systematically more innovative closer to metropolitan areas, and are less so as one moves further away. Process innovation in FST establishments displays tendencies that are similar to MT but the relationship between innovation and distance is not as strong. Furthermore, radical process innovations in FST and MT sectors, and nonradical process innovations in HT all peak in small urban areas.

For high-tech (HT) manufacturers, the results are on the whole as would be expected if innovation is a survival strategy in remoter areas and is system-wide in cities (the pattern is also compatible with the idea that HT firms choose to locate in remoter regions for reasons of secrecy). Radical innovations increase with distance from large and small urban areas. Minor process innovations increase with proximity to smaller cities. Only minor product innovations do not increase (but neither do they decrease) with distance from cities of either type.

Finally, there is evidence to suggest that product innovations may be associated with particular localities, whereas there is no local variation of innovation for process innovation.

The results presented in this article are suggestive, and the explanations put forward to back up and explain the observed spatial patterns remain unproven. That is the nature of exploratory analysis. However, two clear conclusions can be drawn. First, there is a geography of establishment level innovation (particularly process innovation) that is not associated with discrete regions. This geography plays out in a continuous fashion across space, and it is only by having access to spatialized data sets and by applying spatial analytical techniques that it will be better understood. Such quantitative spatial analyses can only lead to hypotheses and suggestions, and it will be necessary to integrate these insights into future surveys or qualitative fieldwork to better understand the processes that underpin the observed geographies of innovation. This has implications for our national and provincial statistical agencies: until there is more willingness to make firm-level micro data available to researchers—conditional only upon appropriate confidentiality safe-guards—the type of research presented here will always remain incomplete and well below its real potential.

Second, whatever the geography of innovation and its underlying causes, this geography differs by economic sector and by type of innovation: there is not one geography of innovation, but a variety of such geographies, some of which play out over space as a continuum, and others which seem to espouse discrete (but nevertheless spatially patterned) regional boundaries. The observed patterns are in many cases compatible with McCann's (2007) model—which posits that the more radical and interaction-intensive innovations will occur closer to the metropolitan core—and with Duranton and Puga's (2003) prediction that radical product innovation occurs in large metropolitan areas and cost-saving process innovation in smaller more specialized cities. Although an attempt has been made in this article to describe and explain these various geographies, much more remains to be done in this field.

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APPENDIX A

Innovation questions (Canadian Survey of Innovation, 2005):

1. Product innovation new to firm (yes to a or b):

A PRODUCT INNOVATION is the market introduction of a new good or service or a significantly improved good or service. The innovation (new or improved) must be new to your plant. Exclude the simple resale of new goods purchased from other plants and changes of a solely aesthetic nature.

During the three years, 2002 to 2004, did your plant introduce

a. New or significantly improved goods
b. New or significantly improved services

2. Major product innovation:

Did your plant introduce ANY new or significantly improved products (goods or services) onto your market before your competitors during the three years, 2002 to 2004?

3. Process innovation new to firm (yes to a, b or c):

A PROCESS INNOVATION is the implementation of a new or significantly improved production process, distribution method, or support activity for your goods or services. The innovation (new or improved) must be new to your plant.

During the three years, 2002 to 2004, did your plant introduce

a. New or significantly improved methods of manufacturing or producing goods or services
b. New or significantly improved logistics, delivery or distribution methods for your inputs, goods or services
c. New or significantly improved supporting activities for your processes, such as maintenance systems or operations for purchasing, accounting or computing.

4. Major process innovation

During the three years, 2002 to 2004, were ANY of your new or significantly improved processes

a. a first in your province/territory;
b. a first in Canada?;
c. a first in North America;
d. a world first?

NOTE: In this article, a major process innovation is one for which an affirmative response is given to a, b, c or d.

APPENDIX B: Spatial distribution of firms in survey

1. Distance from a major metropolitan area

Km	HT	MT	FST
0–10	14.3%	20.3%	21.4%
10–20	35.2%	22.4%	21.7%
20–50	17.9%	18.6%	14.4%
50–100	17.8%	20.8%	20.3%
100–200	12.6%	12.7%	15.5%
200–300	1.2%	0.9%	2.3%
300+	1.0%	4.2%	4.3%

2. Distance from a small urban area

Km	HT	MT	FST
0–10	5.0%	4.0%	5.0%
10–20	1.6%	1.6%	1.1%
20–50	4.4%	6.0%	6.1%
50–100	18.2%	21.3%	22.4%
100–200	69.5%	62.6%	61.6%
200–300	0.3%	2.5%	2.0%
300+	1.0%	2.0%	1.7%

The percentages in each column sum to 100.