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INNOVATION ACTIVITIES EXPLAINED BY FIRM ATTRIBUTES AND LOCATION

Börje Johansson[℘] and Hans Lööf[⊗]

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[℘] Royal Institute of Technology, Centre of Excellence for Studies in Innovation and Science and Division of Economics.
Address: Teknikringen 78B, S-100 44 Stockholm, Sweden. Email: jobo@jibs.hj.se
[⊗] **Corresponding author.** Royal Institute of Technology, Centre of Excellence for Studies in Innovation and Science and Division of Economics.
Address: Teknikringen 78B, S-100 44 Stockholm, Sweden.
Email: hansl@infra.kth.se, Phone: +46 8 790 80 12, Mobile: +46 768 55 69 21

Abstract

This paper examines systematically the importance of location versus a vector of firm attributes on firms' innovation engagements. The various factors that can influence a firm's innovation efforts are divided into (i) firm location, reflecting the regional milieu, and (ii) firm attributes such as corporate structure, nature of the knowledge production, type of industry and a set of specific firm characteristics. The study is based on information about 2, 094 individual Swedish firms, where a firm may be non-affiliated or belong to a group (multi-firm enterprise), domestically or foreign owned. The study concludes that the propensity to be innovative differs between the five macro-region investigated. Among innovative firms, however, the R&D intensity as well as most other innovation-activity characteristics remain invariant with regard to location, when controlling for the skill composition, physical capital intensity, industry, corporate structure firm, size and market extension.

Keywords: Functional regions, innovation systems, corporate structure, R&D
JEL: C21, G34, L22, O33

1. INTRODUCTION

1.1 Innovativeness and Innovation Systems Interaction

A classic issue in the economics of innovation is how characteristics of markets and firms influence industrial innovation efforts and innovation output (Cohen, 1995, Cohen and Klepper 1996). Traditionally, many studies in this field have been occupied with explaining firms' R&D intensity (innovation effort), using firm size and market extension as typical explanatory variables. In Europe there is growing group of studies that employ information from the Community Innovation Survey (CIS-data) for individual countries, with observations of individual firm attributes such as R&D, patents, collaboration on innovation, physical capital, human capital, firm size and sales (for an overview, see Kleinknect and Mohen, 2002).

Recent studies have extended the perspective by controlling for corporate structure and especially making a distinction between multinational enterprises (MNEs) and other firms (Pavitt and Patel, 1999; Cantwell and Janne, 1999; Pfaffermayr and Bellak, 2002; Narula, 2003; Dachs, Ebersberger and Lööf 2006). These and similar contributions represent an attempt to combine traditional Schumpeterian explanations of R&D and firm performance (Klette and Kortum 2004) and models which consider the globalization of innovation (Kuemmerle, 1996, Naurla, 2005, Criscuolo, Narula and Verspagen 2005).

Quite another strand of analysis has shifted the focus by investigating how a firm's innovation activities are affected by the characteristics of the functional urban region where it is located. An underlying assumption is that the propensity of firms to agglomerate is associated with the advantage that urban regions and urban proximity can afford with regard to innovation opportunities. Following the literature, large urban regions can be expected to have higher rates of innovation and adopt innovations more rapidly. See, for instance, Antonelli (1994), Glaeser (1999) and Feldman and Audretsch (1999)

A third approach to investigate the innovation activities and innovativeness of firms strives to identify innovation systems in which an individual firm can be embedded. In these efforts innovation systems are recognised as institutional arrangements and agreements designed to facilitate a firm's collaboration with research organisations, with competitors, and with suppliers and customers, etc. Fischer and Fröhlich (2001) suggest that an innovation system consists of a set of actors that interact in the generation and diffusion of new and economically useful knowledge. Within this strand, Cassiman and Veulgelers (2002) differentiate between incoming and outgoing spillovers when exploring how firms' R&D cooperation with external partners affects the appropriation of knowledge flows. A rational firm has to contemplate its role as receiver and transmitter of knowledge, and such a knowledge flow account may be different for small and large firms.

In this third approach, research universities have been identified as location factors of growing importance (Hendersson, Jaffe and Trajtenberg 1995; Zucker, Darby and Brewer, 1998; Adams 2002; Hall, Link and Scott 2003; Zucker and Darby 2005, Brennenraedts, Bekkers and Verspagen, 2006). It has been suggested that regions with strong research universities have better opportunities to attract and support innovative industries than other regions. Extending this idea, regionally based university research-parks can institutionally integrate university and firm resources (Luger & Goldstein, 1991). Several authors note the growing importance of network-type innovation interactions among firms, and private and public research institutions (Lundvall, 1992; Nelson, 1993; Etzkowitz & Leydersdorff, 2000; Charles, 2003).

Sternberg (2000) and Evangelista et al (2001) represent an emerging branch of literature on regional innovation using standardized survey data such as European Regional Innovation Survey and Community Innovation. To our knowledge, however, there are still very few attempts to includes the traditional Schumpeterian innovation variables as well as external networks, regional information, and global knowledge diffusion through foreign affiliates in a micro economic analysis on the firms innovation efforts.

1.2 Research Questions

The research strategy of this study is to examine how firm attributes influence innovation activities of individual firms, while at the same time controlling for location. The first research question is to examine how the attributes and the location of a firm influence the firm's probability of being innovative, where a firm is classified as innovative if it has completed a product and/or process innovation, and/or has ongoing innovation activities. The second question concerns only innovative firms, for which we examine how location and firm attributes influence (i) a firm's R&D intensity (R&D input per employee), (ii) a firm's collaboration in its local scientific innovation system (SIS), where scientific refers to universities, as well as private and public research laboratories, (iii) a firm's collaboration in its local vertical innovation system (VIS), referring to R&D interaction with customers and suppliers, and (iv) a firm's collaboration in its local horizontal innovation system (HIS), referring to interaction with competitors and consultants.

The CIS data does not provide information on the exact location (address) of the firms, only on the regional location. This has forced us to divide Sweden into not more than five macro regions. Only one of these regions is a so-called functional region – in the sense that it is an arena for frequent face-to-face contacts. Such an interaction arena is also considered to be a prerequisite for a region's innovation systems. In view of this, a local innovation system refers primarily to an innovation system in the functional region hosting a firm (Johansson and Karlsson, 2001). This implies that our empirical analysis will first and foremost compare the consequence of a location in Stockholm versus a location in the rest of Sweden.

The study may schematically be described as follows. A major effort is made to investigate how firm attributes influence the innovation activities of individual firms. In this endeavour it distinguishes between four categories of firm attributes: (i) corporate structure, (ii) knowledge production, (iii) other firm characteristics, and (iv) industry classification. When these phenomena have been taken into consideration we can ask: does location still matter, is there any effect associated with a location in the Stockholm region?

Controlling for firm size, industry sector, markets, human capital and physical capital, major conclusions include that the propensity of being an innovative firm differs between regions. The likelihood of finding an innovative firm in the Stockholm region is greater than elsewhere in Sweden. Among innovative firms, however, the R&D intensity is not influenced by location in a statistically significant way, whereas location influences the frequency of interaction in scientific innovation-systems. Thus, innovative firms have a similar R&D intensity irrespective of where they are located. Moreover, the frequency of collaboration in vertical and horizontal innovation systems does not vary across regions in a statistically significant way. As will be discussed later, this does not imply that location is irrelevant, since it is more likely to find an innovative firm in the Stockholm region than in the rest of Sweden. In a sense, innovative firms tend to be intrinsically similar wherever they are located, but the frequency of innovative firms is different in different regions.

1.3 Outline of the Study

Section 2 presents a theoretical framework and elaborates on findings in previous studies. The discussion is focused in sequence on knowledge flows and innovation systems, innovation activities and firm attributes, and innovation activities in the context of functional regions. Section 3 provides an overview of data, presents knowledge resources and R&D conditions in functional regions in Sweden. In addition, attributes of three types of corporate structure are compared across the five regions in the study. Section four introduces the econometric approach and provides an assessment of econometric results with regard to innovativeness, R&D intensity and innovation system interaction. The concluding section provides a critical assessment of the role of location and firm attributes as explanatory factors.

2. THEORETICAL FRAMEWORK

2.1 Knowledge Flows and Innovation Systems

The empirical analyses renounce from investigating the consequences of a firm's innovation activities, of its R&D intensity, and of its participation in innovation systems (IS) of different kinds. In order to explain the focus in this study, the subsequent text motivates our interest in innovation activities and, in particular, IS interaction.

Innovation processes generate new products and new routines of an innovating firm (Nelson and Winter, 1982). Information and knowledge are inputs to this process. The explicit or implicit distinctions made by many scholars imply that knowledge is more durable and less easy to transfer or transmit than information (Fischer and Fröhlich, 2001).

Knowledge for innovation takes several forms: (i) scientific knowledge in the form of basic principles, (ii) technological knowledge in the form of “technical solutions”, and (iii) entrepreneurial knowledge about product attributes, customer preferences and market conditions, business concepts etc. (Karlsson and Johansson, 2004). With these distinctions it becomes clear why knowledge networks may have many different participants representing different types of knowledge (Batten, Kobayashi and Andersson, 1989).

Knowledge flows can occur inside the firm in its internal networks, but can also be received from the environment of the firm, including the innovation systems in which the firm participates. An external inflow can be based on commercial agreements (transactions) between the firm and various forms of knowledge providers but it may also occur as a spillover phenomenon, e.g. as a residual from a firm’s transaction-related communication with suppliers and customers (Johansson, 2004). Other forms of spillover occur as a consequence of spin offs and spin outs. In addition, ideas will spread when employees move from one firm to another (Zucker, Derby and Brewer, 1998). In a similar way knowledge diffuses from universities when newly trained graduates and university researchers move to industry or start new firms (Jensen and Thursby, 1998; Shartinger and Rammer, 2002).

A major issue is the transmission, transfer and acquisition of knowledge. Many scholars make a distinction between knowledge that can be codified into transmittable information and knowledge that is difficult or even impossible to codify. Knowledge that is difficult to codify has been termed complex by Beckmann (1994), tacit by Polanyi (1966) and sticky by von Hippel (1994), where “complex” in a direct way refers to non-codified knowledge, whereas “sticky” refers to knowledge that is strongly attached to given persons or groups of individuals. As argued by Antonelli, Marchionatti and Usai (2003) this may imply that knowledge can be shared by firms in a local environment with little risk that the knowledge is spread outside the local context. A general assumption is that face-to-face contacts facilitate communication and transfer of complex knowledge. This conclusion relates to the observation that complex knowledge flows require that sender and receiver have the opportunity to calibrate their communication activities.

In view of the above discussion, we recognize that innovation activities do not only consist of inflows of knowledge to a firm. Instead the knowledge creation process also involves various forms of interaction with the external environment. Both knowledge inflows and knowledge interaction can be classified as innovation system interaction. For example, firms derive information and knowledge for innovation from their participation in external professional networks, often called regional innovation networks or regional innovation systems. A single firm will often simultaneously participate in a range of discrete or interlinked networks of suppliers, customers, or neighboring firms. (Karlsson and Johansson, 2004). This study uses the distinctions offered by Cox, Mowatt and Prevezer (2003) between a firm's horizontal and vertical innovation systems. Firms are embedded in horizontal innovation network relationships with similar firms (competing, consulting and collaborating) and in vertical innovation network relationships with suppliers and customers.

Finally, a series of studies argue that interaction with the scientific community is crucial for firms' innovation activities, especially in the context of patenting (Varga, 1997, Zucker, Derby and Brewer, 1998). Some innovative firms are highly dependent on knowledge generated by local university R&D (Feldman and Audretsch, 1999). The knowledge transfer between universities and industry may use many different links or mechanisms, (see Johansson and Karlsson, 2004 for a review). These channels of knowledge flows include

(i) a flow of newly trained graduates from universities to industry, (ii) technological spillovers of newly created knowledge from universities to industry, (iii) industrial purchases of newly created university knowledge or intellectual property, (iv) university researchers consulting to industry or serving on company boards. (v) university researchers leaving universities to work for industry, and (vi) university researchers creating new firms, i.e. academic entrepreneurship[2]. In addition, universities may create incubators, enterprise centres and science parks to improve interaction with industry and to facilitate university knowledge transfers.

2.2 Innovation Activities and Firm Attributes

This subsection discusses firm attributes that are expected to influence the intensity and the nature of a firm's innovation activities. The attributes are arranged in four groups, namely sector classification, specific firm characteristics, knowledge production and corporate structure. These categories are used as explanatory variables in the estimation of innovativeness that is presented in subsection 4.2.

Industry classification. In the history of innovation studies it was early understood that innovation intensity differs considerably between industries (overviews in Patel and Pavitt, 1995; Cohen, 1995). In this study the approach is to first separate manufacturing from service industries and then to consider the R&D intensity of industries when arranging them into nine groups of industrial sectors. The primary aspect is that in our assessment of each individual firm's innovation activities, the analysis should control for industry classification.

[2] Slaughter & Leslie (1997) provide a comprehensive overview of the phenomenon in question.

Specific firm characteristics. Previous studies of firm attributes that can influence a firm's innovation efforts include capital assets, market extension, firm size, age and history (Mansfield, 1963; Geroski, 1995; Cohen, 1995). In the subsequent empirical analysis we include physical and human capital as two separate asset measures, where previous research indicates that both variables could have an influence (Cohen and Klepper, 1996; Crepon et al, 1998; Lööf and Heshmati, 2006). Next, we observe that R&D spending implies that a firm invests into its knowledge assets, and this means that the sales volume has to be sufficiently large to enable the firm to cover the fixed costs related to the acquired knowledge capital. In small economies, like the Swedish, this is only possible if the firm can find its way to export markets (e.g. Fischer and Johansson, 1994). In this context we can also remark that the size of a firm is related to the extension of the market. The literature presents a picture, in which the likelihood of being innovative is positively related to the size, whereas the R&D intensity does not increase with firm size (Patel and Pavitt, 1995; Cohen, 1995; Janz, 2004).

The history of a firm may matter for several different reasons. A newly-established firm does not necessarily have the same likelihood of being innovative as other firms. The incidence of merger and acquisitions implies that different knowledge assets are combined. One example is that large firms "buy innovation" when acquiring smaller firms with an innovation history.

Knowledge production of the firm. A firm's history also includes its knowledge production record, which is reflected in our study by several components. The first is the R&D intensity which may influence the firm's participation in innovation systems. The second is the firm's R&D persistence or recurrence, which can reflect a firm's learning to carry out innovation activities. A third component is the firm's valid patents, and a forth is protection of protection of intellectual property through copyrights.. In addition to this, knowledge production is also distinguishes between product and process innovation efforts, which relates to the observation (hypothesis) that significant R&D obtains when product and process R&D are combined (Nyström, 2006).

Corporate structure. Corporate structure and ownership is the last category of firm attributes that will be used in the analysis. Compared to non-affiliated and uninational firms (multi-firm enterprise, with all units in Sweden), multinational firms (MNEs) differ in particular by having a wider market area and by being larger. As will be shown, the MNEs have a larger R&D staff than other firms and should as consequence also have a larger absorptive capacity as regards external knowledge flows. Pfaffermayr and Bellak (2002) argue that this gives them an advantage in both knowledge absorption and creation. In addition, an MNE has a global internal network for knowledge exchange, in which knowledge from different sources can be transmitted in a partly closed system so that the pertinent knowledge can be protected and form the basis for temporary monopoly positions.

The above implies that multinational enterprises, with their different international locations, have both access to various local knowledge sources and the ability to develop proprietary information within the corporation (Dunnings, 1993; Cantwell and Janne, 1999; Kummerle, 1999; and Criscuolo, Narula and Verspagen, 2005). A recent study by Eberberger and Lööf (2005), using data from Swedish firms, indicates that multinational firms have a significantly larger probability of patenting and introducing radical innovations than uninational firms. The same study also observes that Swedish-owned MNEs are more active than foreign-owned MNEs with regard to IS interaction.

2.3 Innovation Activities and the Functional Region

This study specifically compares the relative importance of firm attributes and the location of each firm. In other words, if firm attributes are accurately recorded, is there anything left for location to explain about a firm's innovation efforts? The location of a firm should matter to the extent that knowledge resources and flows are different in different regions. As already discussed, a firm's innovation activities and IS interaction is affected by proximity externalities. If such self-organised externalities are weak in a region, this fact could imply that innovative firms in such a region have incentives to establish and organise IS interaction in a more explicit way, based on formal agreements and planning. A vast majority of scholars now agree that the proximity afforded by locating in large urban regions creates an advantage for firms by facilitating information and knowledge flows, following arguments presented early in Artle (1959) and Vernon (1962), and later in Glaeser (1999) and Feldman and Audretsch (1999). The nature of this phenomenon may be classified as a proximity-based communication externality (Fujita and Thisse, 2002; Johansson and Quigley, 2004).

In previous parts of the presentation we have stressed that proximity externalities are to be found inside the borders of functional urban regions, as they define the geographical area within which frequent face-to-face interaction can take place. In studies of comparative urban growth in Europe Cheshire and Gordon (1995, 1998) provide a definition of a functional urban region. Using this concept in the Swedish context, we can follow Johansson, Klaesson and Olsson (2002), who identify each functional urban region as a set of municipalities (cities and towns) between which the labour-market commuting is mutually intense. This delineation implies that (i) travel between zones in a municipality varies in the range 8-15 minutes, (ii) travel between zones in different municipalities has an average time distance of 20-50 minutes, and (iii) travel between municipalities that belong to different functional regions in most cases extends 60 minutes. With this construction, we argue that proximity externalities occur mainly within functional regions (Karlsson and Manduchi, 2001).

How and to what extent do functional regions differ in their capacity to foster innovation activities by firms? First, they can differ in the amount and richness of knowledge resources and possibilities for an innovative firm to interact with other actors that embody various "pieces" of knowledge. Second, they can vary in the local (intraregional) supply of knowledge-intensive labour, whose knowledge diffuses as they find new workplaces over time. We suggest that large functional urban regions offer firms accessibility to customers, suppliers and competitors, and to knowledge providers in universities, laboratories, consultancy firms, etc (Henderson, 1974; Karlsson and Johansson, 2004). This also implies that an individual firm may benefit from good accessibility to other firms that carry out R&D (Audretsch and Feldman, 1996; Gråsjö, 2005)

There are two competing views as regards how a functional region influences the innovation options of the firms residing in the region. One hypothesis is related to the idea of clustering of firms belonging to the same industry, and identifies localisation economies of an innovative milieu. This view is often referred to as the Marshall-Arrow-Romer externality and emphasises intra-industry knowledge flows (Glaeser et.al., 1992) The second hypothesis has been called the Jacobs externality and assumes that innovation activities are primarily influenced by a diversity of inter-industry knowledge flows, including spillovers (Jacobs, 1984). The ideas related to Jacobs make a reference to urbanisation economies, implying that innovation activities are stimulated especially by the milieu and innovation systems in a metropolitan region. Capello (2002) concludes that a metropolitan region may be viewed as an area that can encompass many different industry clusters, and hence there would then exist an advantage for large urban regions under both of the hypotheses discussed.

A major element in the analysis of regional innovation systems is the assumption about distance-sensitive knowledge flows, implying that knowledge spillovers (Varga, 2002). Some studies in this filed distinguish clearly between pecuniary and technological externalities, their public and club good features, and various forms of private intellectual property. Mowery & Ziedonis (2001), for example, find knowledge flows from universities through market transactions to be more geographically localised than those operating through non-market "spillovers". This indicates that intense contact intensity is especially important when knowledge must be specified as a commodity for which property rights are clearly defined. This observation provides a further argument in favour of large urban regions, since they offer both clusters in specific industries as well as a diverse range of industries. (Lagendijk, 2001).

3. DATA, DESCRIPTIVE STATISTICS AND HYPOTHESES

3.1 Observables in the Data Set

The empirical analyses in this study are based on data from the Community Innovation Survey (CIS) III for Sweden. The survey was conducted in 2001 and it covers the period 1998-2000. The focus is on both the manufacturing sector and business service sectors. The sample contains 2 094 firms of which 51% are defined as innovative firms. In order to provide an overview, the set of variables included in the analysis is presented in table A2 in the Appendix.

The CIS has become a popular data source for statistical studies regarding innovation, since it allows for broad comparisons across firms and countries. The firms are asked to report on their innovation activities. The reporting units are firms, whose geographical locations are known. However, when a firm informs about the location of innovation-system interaction the distinction is between local and global, which means that all domestic interaction is classified as local. On the other hand, statements are made by and about each individual firm, not about the group to which the firm may belong. With reference to other studies (e.g. Andersson and Ejermo, 2004) and our theoretical framework, we assume that each individual firm's collaboration in innovation processes is concentrated in the functional region in which the firm is located. Thus, the non-global innovation networks are assumed to be local.

3.2 Functional Regions in Sweden

The presentation in section 2 clarifies our interest in functional urban regions. With the regional delineation in Johansson, Klaesson and Olsson (2002), Sweden is divided into 81 functional regions. In this subsection the intention is to provide a picture of the Stockholm region as a host region for innovation activities, and to illuminate the differences in this regard vis-à-vis the rest of Sweden. As a first step, consider table 3.1, which describes the population size of the Stockholm region and the scope of the region's economy in terms of the number of industries that are present in Stockholm and other regions.

Table 3.1: Characteristics of Swedish functional regions 1997

LA-region	Population in thousands (per region)	Number of industries	Number of sectors with high knowledge-intensity
Stockholm	1 810	592	165
Göteborg and Malmö	881 and 651	546 and 545	149
7 largest medium-sized	169-292	357-440	85-112
15 other medium-sized	97-160	279-370	65-93
Smaller regions	51-90	210-262	46-72
Small regions	ca. 10	ca. 100	ca. 20

Source: Andersson and Johansson (2000). Industries are identified at the 5-digit level.

The table illustrates that the Stockholm region has the most diversified economy in Sweden, while at the same time having the largest number of knowledge-intensive sectors. The region's share of Sweden's total population was 20 percent. At the same time the region's share of the country's wage sum was 60 percent for financial services, 53 percent for IT-consultancy services, 46 percent for recreation and culture services, and 45 percent for producer services.

Compared to other functional regions in Sweden, Stockholm has the most knowledge-intensive labour force, the largest share of R&D workers, the largest share producer services, the largest export and import values, where the knowledge intensity is measured as the share of the labour force that has three years or longer university education. These are all conditions that have been recognised in the literature as important for innovation activities.

Nearly one out of three multinational companies with facilities in Sweden are located in the Stockholm region and about two thirds of all multinational companies in Sweden are located in the Mälar Valley, which includes the Stockholm region. Since multinationals account for approximately 60 percent of all industrial output and almost 90 percent of Sweden's industrial R&D spending in 1990 and 2001 (Fors and Svensson, 2002; Johansson and Lööf, 2005), the Stockholm region has by far the strongest concentration of R&D expenditures. These patterns are also present in the data set examined in this study, which can be assessed in the next subsection.

3.3 Firm Attributes and Internal Networks Across Macro Regions

Let us first consider the distribution of observations across regions in the sample, as presented in part I of table 3.2. A major conclusion is that observations are spread in proportion to the size of the macro regions. Moreover, firms which belong to a multinational group are well represented in all regions.

Information about the average size of firms is presented in part II of table 3.2, and we can note that firms in the Stockholm region are larger for each of the three categories of corporate structure. The second observation is that firms that belong to a multinational enterprise are larger than other firms, and this feature is present across all five regions.

Table 3.2: Firm observations, employees and innovative firms

	Stockholm	Region 2	Region 2	Region 4	Region 5	Sweden
I. Numbers of firms and shares						
TOTAL	523	294	299	417	561	2,094
-Non Affiliate, %	0,37	0,39	0,44	0,47	0,46	0,43
-Uninational, %	0,34	0,38	0,35	0,33	0,39	0,36
-Multinational, %	0,28	0,23	0,21	0,19	0,15	0,21
II. Number of employees per firm in total sample						
AVERAGE	484	199	139	213	142	249
-Non Affiliate	301	104	47	51	49	111
-Uninational	588	187	154	250	150	278
-Multinational	600	381	301	547	400	476
III. Share of innovative firms						
AVERAGE	0.57	0.53	0.49	0.49	0.48	0.51
-Non Affiliate	0.47	0.45	0.41	0.41	0.39	0.42
-Uninational	0.65	0.48	0.44	0.47	0.47	0.51
-Multinational	0.63	0.75	0.73	0.72	0.79	0.68

Remark: Part A and B of the table contain all firms, that is, both innovative and other firms.

Our next concern is the share of innovative firms in the macro regions, as presented in part III of the table. For this subcategory we can conclude that the Stockholm region has a larger share of innovative firms than the rest of the country both among non-affiliated and uninational firms. However, the same is not true for multinational firms. The observation tells us that in other regions, the innovativeness is more dependent on the advantages that large international firms have, whereas the regional economic milieu in Stockholm supports the non-affiliated and uninational firms to be innovative.

For firms classified as innovative, we may collect a set of observations from table A1 to establish additional differences between the Stockholm region and the rest of the country. Compared to other locations, the Stockholm region has (i) larger knowledge intensity, a larger frequency of process as well as product innovations, a larger R&D intensity, and a larger share of firms with sales of new products (innovation sales). All this matches the general picture of the Stockholm region that has been painted earlier in section 3.

Table A1 also tells us that innovative firms in the Stockholm region do not collaborate more intensively in scientific, vertical and horizontal innovation systems than what can be observed for other parts of Sweden. In particular, innovative firms in the Stockholm region have the lowest share of firms with patent applications and patent possessions, which clearly shows that the firms in the Stockholm region are less patent oriented than other regions in their innovation efforts. This may relate to the Geroski (1995) hypothesis that for cumulative technology fields, firms have a stronger motive to open up for knowledge spillovers rather than to protect their ideas by means of patents. Similar arguments can be found in Antonelli, Marchionatti and Usai (2003).

3.4 Hypotheses

The expected result from the econometric exercises in section 4 can be ordered in three groups of basic hypotheses. With regard to the likelihood that a firm will be innovative, previous studies together with theoretical arguments in section 2 give rise to the following hypotheses: The probability of finding innovative firms (i) is positively influenced by location in the Stockholm region, (ii) is greater for MNEs , (iii) increases with a firm’s size, market extension, knowledge intensity and past experience of innovation activities.

Although innovativeness is positively related to firm size, the literature suggests that R&D intensity may not increase with firm size. However, we expect R&D intensity (i) to be larger for domestic MNEs, and previous experiences of innovation efforts.

Interaction in innovation systems is a major issue in this study. From the literature we expect positive effects from domestic MNEs, R&D intensity, persistence of R&D efforts, and firm size. With regard to location, the literature seems to suggest that the Stockholm region should provide great opportunities for IS interaction, because it offers a firm accessibility to customers, suppliers, universities and research laboratories, and global innovation systems. In line with this, the a priori expectation is that the frequency of interaction in innovation systems should be larger in the Stockholm than in other parts of the country. However, we have already seen from the descriptive statistics that empirical observations have a different story to tell.

EMPIRICAL RESULTS AND ASSESSMENT

4.1 Econometric Approach

A simple econometric model is used to determine the relationships among factors affecting firms' innovation activities. For estimation purposes we apply a probit equation and a two-step estimation procedure. In order to estimate of a firm's propensity to be innovative we apply a probit equation. In the analyses of innovation activities we use a generalised Tobit model (the Heckman two-step estimator), comprising the selection equation in (1) and the performance equation in (2), using observations on both innovative and other firms. This approach provides consistent and asymptotically efficient estimates for all parameters in the model.

The described two-step estimation procedure is designed to solve the econometric problem of selection bias. Our approach takes into account that not all firms are engaged in innovative activities. When only the innovation sample is used in some part of the model, the firms are not randomly drawn from the larger population, and selection bias may arise.

The two-step model used in the analyses accounts for this possible problem by formulating the following choice structure. In the first step firms decide whether to engage in innovation activities or not (selection equation). Given that a firm has decided to invest in innovation projects, the 4 different performance variables are estimated. More specifically, we are using the following model:

$$y_{0i} = \begin{cases} 1 & \text{if} \quad y_{0i}^{*} = X_{0i}\beta_0 + \varepsilon_{0i} > 0 \\ 0 & \text{if} \quad y_{0i}^{*} = X_{0i}\beta_0 + \varepsilon_{0i} \le 0 \end{cases} \tag{1}$$

$$y_{1i} = y_{1i}^{*} = X_{1i}\beta_1 + \varepsilon_{1i} \quad \text{if} \quad y_{0i} = 1 \tag{2}$$

where y_{1i}^{*} is a latent innovation decision variable measuring the propensity to innovate, y_{0i} is the corresponding observed binary variable being 1 for innovative firms and zero for others. y_{1i} signifies the different dependent variables. X_{0i} and X_{1i} are vectors of various variables explaining innovation decision and innovation activities (performance). The β -vectors contain the unknown parameters for each equation. ε_{0i} and ε_{1i} are independent and identically distributed drawings from a normal distribution with zero men In addition, we also estimate the correlation, ρ , of the two residuals in equation (1) and (2). For each selection estimated equation in the appendix, a chi-square test is reported to decide if ρ is significantly different from zero. The selection equation is not necessary when there is no correlation.

4.2 Innovativeness

In accordance with the Oslo manual that guides the CIS (OECD, 2005), this study identifies an innovative firm as a firm that in its recent history has developed new products and/or processes and/or has ongoing innovation activities. A probit function is employed to examine determinants of innovativeness, and the estimation results are presented in table

A3 in the appendix. The table also report the marginal effects of the probit estimates. These have all the same and degree of significance as the probit estimate, and in order to reduce the space we will not comment them in the continued text.

According to the estimation, the innovativeness of firms is positively influenced by location in the Stockholm region and the following five categories of firm attributes: (i) multinational enterprise, (ii) firm size, (iii) recent merger and acquisition (M&A), (iv) market extension, and (v) type of industry. Many of these finding are in accordance with the Schumpeterian literature (Cohen and Klepper, 1996; Crepon, Duguet and Mairesse, 1998; Lööf and Heshmati, 2006). We shall comment on the statistically significant determinants and also discuss some variables that do not have any influence on the innovativeness.

Compared with the rest of Sweden (four different macro regions), innovativeness is positively associated with the Stockholm metropolitan region, with significance on the 5% level. This result is also compatible with the descriptive statistics presented earlier. In addition, the result suggests that the milieu in the Stockholm metropolitan region is favourable for a clustering of firms that are innovative. Following Geroski (1995), this may reflect local spillovers with regard to technologies that are cumulative, such that last periods innovations lay the groundwork for subsequent periods innovation activities.

The corporate structure influences innovativeness. There is a significant increase in the frequency of innovativeness for multinational firms. In this context we observe that on average multinational firms are larger than other firms and there is no additional effect of firm size on the propensity to be innovative. Moreover, there is no significant influence from the extent of the firm’s market. However, a recent history of M&A is positively related to firm innovativeness, which may reflect that larger firms use acquisition as a means to buy technology. In accordance with the literature, we find that human capital intensity and physical capital intensity is significantly associated with engagement in R&D.

4.3 R&D Intensity

R&D intensity is measured as a firm's expenditures on R&D and other innovation activities per employee. The estimated equation uses observations from all firms, where 1, 074 observations are uncensored (innovative firms). The estimated R&D-intensity equation has five explanatory variables with significant parameter values. All these variables refer to firm attributes. Two of these variables have a negative parameter, namely domestic non-affiliated firms, and firm size. The three variables with positive parameters are (i) domestic MNE, (ii) persistent (recurrent) R&D, and (iii) physical capital intensity. The following remarks can be made:

(i) The R&D intensity rises sharply (compared to the reference variable) for firms classified as domestic MNEs, an effect that is not present for foreign MNEs. This finding supports the assumption, discussed in subsection 2.2, that multinational firms exploit knowledge resources in the home country and apply their innovations across their global networks. For the non-affiliated firms (with a negative coefficient), the conditions are exactly the opposite.

(iii) A high R&D intensity of a firm is strongly related to the persistence of the firm's R&D effort.

(iv) A firm's R&D intensity tends to be higher when the capital intensity is high.

(v) As firm size increases, R&D intensity reduces. This finding relates to similar findings saying that R&D grows less than proportionally as firm size increases (Cohen, 1995; Acs and Audretsch, 1991; Nyström, 2006).

(vi) The location of a firm has no statistically significant influence on the firm's R&D intensity.

Our final question is then: why does not the location affect the R&D intensity of a firm? The results presented seem to indicate that once a firm is innovative, then its R&D intensity is determined by firm attributes and nothing else. Thus, there is a higher frequency of innovative firms in the Stockholm region, but there is no additional effect from the regional milieu on the intensity of R&D efforts.

4.3 Collaboration in Innovation Systems

The empirical analyses make a distinction between three types of innovation systems, labelled SIS, VIS and HIS, and considered to refer to local innovation systems – in contradistinction to the global innovation networks. This subsection presents econometric results that can inform us about factors that influence a firm's interaction in the three types of local innovation systems. The information is collected from table A4 in the appendix and summarised in table 4.1.

Table 4.1: Determinants of a firm's interaction in innovation systems

Explanatory variables	Scientific IS	Vertical IS	Horizontal IS
Stockholm region	--		
Domestic MNE	++	+++	++
Domestic non-affiliated		++	
R&D intensity		++	++
Physical capital intensity		+++	
Protection through trademark	++	+++	
Persistent R&D	+++	+++	+++
Firm size	+++		+++

Remark: Further details in the Appendix, table A.4. (+++) positively significant at 1% level, (++) positively significant at 5% level, and (--) negatively significant at 5% level.

The basic influence comes from firm attributes, of which the following two sharply increase the probability of interaction all three types of IS: (i) the firm is a domestic MNE, (ii) the firm is persistently R&D active. In other respects the three innovation systems have idiosyncratic properties. For SIS location, protection of the firm's intellectural property rights through trademark and firm size matters, for VIS we find an influence from (I) domestic non-affiliated firms, (II) R&D intensity, (III) physical capital intensity, and (IV) protection through trademark, and for HIS R&D intensity and firm size have a positive effect. All this signals that each of the three innovation systems have to be analysed separately and cannot be seen as one single phenomenon.

Partly in conflict with the discussion in the theoretical framework, the results indicate that a location to the Stockholm region has a negative impact on participation in local scientific innovation systems. For other innovation systems there are no significant effects. Formally this implies that for a firm with given attributes, a location in the Stockholm region reduces the probability of local IS interaction, and it does not add anything for the other two innovation systems.

Combining the results from this and the previous subsection we may thus conclude that for a firm with given firm attributes, the likelihood of being innovative is greater when the firm has Stockholm as the host region, whereas the same location does not increase that the probability of interacting in local innovation systems.

CONCLUDING DISCUSSION

In this concluding section we shall briefly discuss four issues. First, we ask why it is more likely to find innovative firms in the Stockholm region than in the rest of the country. Second, we discuss specifically the role of market extension. The third issue concerns the lower level of IS-interaction in the Stockholm region. The final issue focuses on why domestic MNEs have a large frequency of IS-interaction, and why this frequency is lower for foreign MNEs.

Why is Innovativeness more likely in the Stockholm Region?

The major advantages that the Stockholm region can offer, compared to other parts of Sweden is a larger local market, with proximity externalities relating to customers, suppliers, universities and knowledge service providers. In addition, the share of knowledge-intensive labour is greater in Stockholm than elsewhere. The problematic aspect of this conclusion is that the accessibility advantages in the region are not reflected by a higher degree of IS interaction than in other regions. One may point at two distinguishing features of the Stockholm region: it has a larger share of knowledge-intensive service firms than elsewhere and the R&D of the firms in the region are less patent oriented than in the other Swedish regions.

Why is IS interaction not more Intense in the Stockholm region?

Both descriptive statistics and econometric estimations tell us that innovative firms in the Stockholm region do not have a higher probability of collaborating in local innovation systems. For interaction in scientific innovation systems, the intensity of Stockholm firms is even lower in a statistically significant way. There are three aspects that relate to this finding. The first is that firms in the Stockholm region are less oriented towards R&D that aims at patenting, compared to firms located elsewhere. Second, the Stockholm region has a higher density and diversity than other urban regions in Sweden. In particular, it hosts a larger share of knowledge-intensive service firms than other regions do. This could imply that knowledge spillovers – in contradistinction to IS-related knowledge flows – play a special role in Stockholm region. Third, a major conclusion in the study is that location can affect innovativeness. However, once a firm is classified as innovative, then firm attributes affect its R&D intensity and its collaboration in innovation systems.

Domestic and Foreign Multinational Firms

Firms that belong to a domestic MNE are to a considerable degree more actively collaborating in local innovation systems than similar firms with a different corporate structure. This phenomenon is not present for foreign MNEs. This finding is supported by multinational firms tend to locate their R&D efforts in the home country, while exploiting the R&D results across their subsidiaries in domestic and foreign locations. This explains the difference between domestic and foreign MNEs. At the same time, the MNE effect on IS interaction remains strong also when we control for firm size, R&D intensity and persistence.

Final Observations

The findings in this paper suggest the following summary conclusions. First, in less dense and less diversified urban environments firms rely more on scientific innovation systems than in the Stockholm region. Second, the economic milieu in a functional region affects the likelihood of finding innovative firms. Third, once a firm satisfies the criterion of being innovative, the firm's innovation activities depend strongly on firm attributes. Fourth, the size of firm has a positive effect on IS interaction. In essence, there are two issues. First, different regions are likely to have different shares of firms with given attributes. Second, when firm attributes are accurately recorded the location variable will not reveal any additional innovation features. Thus, further research should focus more on the first issue, which includes the question: why is the propensity to innovate different for different regions?

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APPENDIX

Table A.1: Firm attributes for innovative firms, mean values and standard deviation

	Stockholm	REG 2	REG 3	REG 4	REG 5
Number of observations	298	155	147	204	270
Innovative firms	0.57 (0.50)	0.53 (0.50)	0.49 (0.50)	0.49 (0.50)	0.48 (0.50)
R&D intensity, log	1.54 (2.09)	1.32 (1.66)	1.14 (1.91)	1.09 (1.72)	1.05 (1.62)
R&D Staff/Employment	0.051 (0.13)	0.033 (0.10)	0.042 (0.13)	0.036 (0.12)	0.021 (0.07)
New product sales, log	2.43 (2.16)	184 (1.95)	2.02 (1.88)	2.19 (1.77)	1.97 (1.80)
Patent application	0.26 (0.43)	0.38 (0.49)	0.37 (0.48)	0.34 (0.47)	0.31 (0.46)
Protection through trademarks	0.33 (0.47)	0.30 (0.46)	0.34 (0.47)	0.29 (0.45)	0.27 (0.44)
Valid patents	0.32 (0.46)	0.41 (0.49)	0.41 (0.49)	0.40 (0.49)	0.40 (0.490)
Non-imitation innovation	0.41 (0.49)	0.370 (0.48)	0.31 (0.46)	0.40 (0.49)	0.36 (0.47)
R&D-subsidies	0.17 (0.37)	0.17 (0.38)	0.14 (0.35)	0.16 (0.37)	0.23 (0.42)
Scientific innovation system	0.21 (0.41)	0.30 (0.46)	0.20 (0.40)	0.26 (0.44)	0.23 (0.42)
Vertical innovation system	0.29 (0.45)	0.37 (0.48)	0.25 (0.44)	0.30 (0.46)	0.30 (0.46)
Horizontal innovation system	0.22 (0.42)	0.21 (0.41)	0.18 (0.38)	0.23 (0.42)	0.24 (0.43)
Human capital	0.29 (0.29)	0.13 (0.22)	0.20 (0.25)	0.19 (0.25)	0.13 (0.20)
Recurrent R&D	0.51 (0.50)	0.53 (0.500)	0.53 (0.50)	0.49 (0.50)	0.52 (0.50)
Process innovation	0.56 (050)	0.50 (0.50)	0.51 (0.50)	0.48 (0.50)	0.48 (0.50)
Product innovation	0.73 (0.44)	0.66 (0.47)	0.61 (0.49)	0.69 (0.46)	0.65 (0.48)
Newly established	0.11 (0.31)	0.05 (0.20)	0.07 (0.25)	0.09 (0.28)	0.03 (0.18)
Merging and acquisition	0.14 (0.35)	0.10 (0.30)	0.12 (0.32)	0.12 (0.32)	0.14 (0.35)
Firm size, log	4.45 (1.76)	4.52 (1.50)	4.22 (1.37)	4.32 (1.54)	4.17 (1.42)

Table A2: Explanatory and dependent variables

Explanatory variables	Definition
REGIONAL LOCATION	
Stockholm	
East Central Sweden	Uppsala, Sörmland, Örebro, Östergötland
South Sweden	Blekinge, Skåne
West Sweden	Västra Götaland, Halland
Other Sweden	Småland, Öland, Gotland, Värmland, Dalarna, Gävleborg, Västernorrland, Jämtland, Västerbotten, Norrbotten
CORPORATE STRUCTURE	
Non Affiliated firm	Domestically-owned firm without affiliates
Uninational firm	Domestically-owned firm belonging to a group with only Swedish affiliates
Domestic Multinational Enterprise	Domestically-owned firm belonging to a group with foreign affiliates
Foreign Multinational Enterprises	Foreign-owned firms (belonging to a group)
KNOWLEDGE PRODUCTION	
R&D intensity	Expenditures on R&D and other innovation activities
Persistent (recurrent) R&D	Dummy for continuous R&D engagement
Process innovation	Dummy indicating the introduction of an improved process
Product innovation	Dummy indicating the introduction of a new product
Valid patents	
FIRM CHARACTERISTICS	
Size	Number of employees
Gross productivity	Turnover per employee
Human capital	Share of the employment with a university degree
Physical capital	Gross investment per employee
Newly established	The firm has been established during the last three years
Newly merged	The firm has been involved in M&A during the last three years
Market extension	The firms' most significant market is local, national or global
INDUSTRY CLASSES	
1 Nace 15-19	Food product and beverages, tobacco, textiles, wearing apparel, leather
2 Nace 20-23	Wood and wood products, pulp, paper and paper products, publishing, coke
3 Nace 24	Chemicals and chemical products
4 Nace 25-27	Rubber and plastic, other non metallic mineral, basic metal
5 Nace 28-29	Fabricated metal products, machinery and equipment
6 Nace 30-33	Office machinery and computers, electrical machinery and apparatus, radio, television, and communication, medical, precision and optical instruments
7 Nace 34-37	Motor vehicles, transport instruments, other transport equip, furniture
8 Nace 40-69	Public utilities, wholesale trade, land, water air transport, post and tele, finance and insurance
9 Nace 72-74	Business related services
Dependent (explained) variables	**Definition**
Innovative firm	Completed product and/or product innovation and/or ongoing innovation activities
R&D intensity	Expenditures on R&D and other innovation activities
Interaction in the local scientific innovation system	Composite dummy for collaboration on innovation with universities and private and public R&R laboratories
Interaction in the local vertical innovation system	Composite dummy for collaboration on innovation with customers and suppliers
Interaction in the local horizontal innovation system	Composite dummy for collaboration on innovation with competitors and consultants

Table A3: Probit estimation of innovativeness and estimation of R&D intensity with a Heckman selection model

Dependent variables	Dependent variable: Propensity to be innovative				Dependent variable Innovation effort (R&D intensity)[1]		
	Coeff	Sign	P-value	Dy/dx	Coeff	Sign	P-value
Stockholm	0.176	**	0.044	$ 0.069**	0.310		0.101
Region 2	0.026		0.781	$ 0.010	0.220		0.260
Region 3	-0.007		0.941	$ -0.002	0.109		0.640
Region 4	0.073		0.933	$ 0.002	-0.087		0.696
Region 5	Reference				Reference		
MNE	0.186	**	0.036	$ 0.073**	-	-	-
Foreign MNE	-	-	-	-	-0.086		0.679
Domestic MNE	-	-	-	-	0.626	***	0.003
Domestic non-affiliate	0.259		0.133	$-0.003	-0.325	**	0.038
Domestic uninational	Reference				Reference		
Market Global	0.625	***	0.000	$ 0.241***	-	-	-
Market National	0.346	***	0.000	$ 0.137***	-	-	-
Market Local	Reference				-	-	-
Human capital intensity	0.761	***	0.000	0.303***	-	-	-
Physical capital intensity, log	0.072	***	0.000	0.029**	0.234	***	0.000
Newly established	-0.007		0.951	$-0.002	-	-	-
Newly MA	0.319	***	0.000	$ 0.124***	-0.055		0.768
Recurrent R&D	-	-	-	-	1.282	***	0.000
Valid Patents	-	-	-	-	0.163		0.321
Trademark	-	-	-	-	0.146		0.268
Process innovation	-	-	-	-	0.170		0.236
Gross labor productivity. log							
Firm size, log	0.197	***	0.000	0.078***	-0.432	***	0.000
9 Industry dummies	Included				Included		
Selection equation (Propensity to be engaged in innovation activities).	-				Included		
Observations	2, 094				2, 094		
Uncensored observations	0				1, 074		
LR test of independent equations (rho=0): Chi2 (Prob>chi2)	-				6.07 (0.014)		

Note: Significant at the <1% (***) and 1-5% (**)levels of significance

Sample weights (pw) included in the selection equation

Selection equation variables for the R&D intensity equation: employment (log), gross labor productivity (log), newly established, gross investment per employee (log), human capital (share), most important market (3 dummies), industry (9 dummies).

Dy/dx is marginal effects after the probit.

$ is for discrete change of dummy variable from 0 to 1.

Table A 4: Estimation of innovation-system interaction with a Heckman selection model

Dependent variables	Scientific Collaboration			Vertical Collaboration			Horizontal Collaboration		
	Coeff	Sign	P-value	Coeff	Sign	P-value	Coeff	Sign	P-value
Stockholm	-0.375	**	0.035	-0.242		0.133	0.069		0.662
Region 2	0.314		0.192	0.284		0.152	-0.031		0.876
Region 3	-0.177		0.420	-0.281		0.101	-0.082		0.661
Region 4	0.013		0.183	0.218		0.203	0.244		0.173
Region 5	Reference			Reference			Reference		
Foreign MNE	0.259		0.133	0.133		0.396	-0.072		0.671
Domestic MNE	0.725	**	0.031	1.456	***	0.000	0.553	**	0.015
Domestic Independent	0.259		0.133	0.312	**	0.032	0.121		0.408
Domestic UNI	Reference			Reference			Reference		
R&D-intensity	0.063		0.118	0.085	**	0.013	0.082	**	0.015
Human capital intensity	0.364		0.336	-0.353		0.382	-0.078		0.806
Physical capital intensity	0.067		0.163	0.109	***	0.009	0.116	***	0.001
Recurrent innovation	0.645	***	0.000	0.525	***	0.002	0.764	***	0.000
Product innovation	0.093		0.526	0.216		0.098	0.075		0.555
Valid patents	0.164		0.337	0.179		0.218	0.057		0.685
Protection through trademark	0.318	**	0.036	0.331	***	0.007	0.194		0.107
Firm size	0.254	***	0.000	0.105		0.055	0.196	***	0.000
9 Industry dummies	Included			Included			Included		
Selection equation (Propensity to be engaged in innovation activities) is included.									
Observations	2, 094			2, 094			2, 094		
Unceonsored observations	1, 074			1, 074			1, 074		
LR test of independent equations (rho=0): Chi2 (Prob>chi2)	3.41 (0.065)			3.77 (0.052)			4.22 (0.040)		

Note: Significant at the <1% (***) and 1-5% (**)levels of significance
Sample weights (pw) included in the selection equation
Selection equation variables all three equations: employment (log), gross labor productivity (log), newly established, gross investment per employee (log), human capital (share), most important market (3 dummies), industry (9 dummies).