Centre of Excellence
for Science and Innovation Studies

CESIS Electronic Working Paper Series

Paper No. 260

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October 2011

The Royal Institute of technology
Centre of Excellence for Science and Innovation Studies (CESIS)
http://www.cesis.se

Innovation, Metropolitan and Productivity

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Abstract

This paper assesses the contribution to productivity of firms' internal innovation efforts and spatially-specific factors. A dynamic GMM-estimator is applied to a panel of close to 3,000 firms located in 81 Swedish regions and observed over a 10-year period. The magnitude of benefits from the knowledge milieu of an agglomeration is sizeable, but varies between firms depending on their particular R&D-strategy and location within a metropolitan region.[2]

Keywords: R&D, innovation-strategy, productivity, metropolitan, externalities
JEL-Codes: C23, O31, O32

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[2] The authors have benefited from comments by the seminar participants at the 51st WRSA conference in Monterey 2011, the 51 st ERSA conference in Barcelona 2011 and the 17 th International Panel Data conference in Montreal 2011. Financial support from the Swedish governmental agency VINNOVA is acknowledged.

1. INTRODUCTION

An extensive literature has convincingly demonstrated a link between innovation and growth. Similarly, there is substantial evidence that a portion of the business performance can be explained by spillovers from the surrounding geography, although the exact size is still an open question (Greenstone, Hornbeck and Moretti, 2010). However, the empirical literature on the importance of innovation and geography combined is limited.

This paper addresses the question of internal and external contribution to firms' productivity by considering different categories of local environment and different innovation strategies. To do this it tests various hypotheses on the relationship between R&D-strategies and location.

We show that firms' self-declared R&D-strategy at a single point in time is a good predictor of their long-run innovation activity. By grouping firms into three different categories of innovation activities, we can reduce the selection bias characterizing the R&D variable in most micro-data studies. The literature suggests that innovative firms tend to cluster in agglomeration areas, but most data indicate annual innovation expenditures over time only for large firms. Moreover, large firms often have research labs across geographical borders. In contrast, R&D and location are highly correlated among small firms (Lychagin et al. 2010). Our representative sample, where the median firm has about 30 employees, reveals that agglomeration areas do not have disproportionately more firms than other areas. Still, for firms within an agglomeration, the benefits from the knowledge milieu differ substantially depending on R&D strategy and the particular location in the area.

Information on firms in this study comes from two sources. The first is the Community Innovation Survey (CIS) of Swedish manufacturing and service firms conducted in 2002-2004. The second source is firm level information from Statistics Sweden. Combining these two sources, each individual firm is followed over the period 1997-2006 with information on economic performance, the firm's internal resource base and location. The unbalanced panel consists of 2,600-2,895 firms and the total number of observations is 25,892.

To analyze the data we employ a dynamic two-step system GMM estimator (Arellano and Bover 1995, Blundell and Bond 1998). The variable we would like to explain is labour productivity, and the key interest is exploitation of internal knowledge accumulation created by a particular R&D-strategy and external knowledge spillovers from the local milieu. We use the firms' self-declared R&D-strategy as a proxy for the internal knowledge process, and location in a Metropolitan region as an indicator that the firm can benefit from a local milieu characterized by advantageous knowledge sources.

Sweden's three metropolitan regions (Stockholm, Gothenburg and Malmö) are all integrated labour market regions, and their respective metro-city is the largest city in each region. All three regions are separated by long distances. The empirical analysis decomposes the Swedish geography into the following sets: (i) all non-metropolitan areas, (ii) the three Swedish metropolitan regions as a group, and (iii) the three Swedish metropolitan cities as a group (iv) the largest metropolitan region, (v) the largest metropolitan city, For each individual firm in each specific location we distinguish between firms with persistent, occasional and no R&D-efforts.

We quantify agglomeration spillovers by estimating the difference in labour productivity for various combinations of innovations efforts with respect to the reference alternative, which is a firm not engaged in R&D and located in a metropolitan region, controlling for lagged level of productivity, export intensity, human capital, physical capital, equity capital, corporate ownership structure, firm size, sector and time trend.

We find that a firm located within the largest metropolitan city and conducting R&D on a regular basis has 17-21 percent higher productivity than the counterfactual. About half of this difference is explained by internal knowledge accumulation through successive annual R&D investments and the rest by agglomeration spillovers. The spillover effect reduces to 3 percent if the firm is located in a random place within Sweden's three regions and increases in accordance with closeness to a metropolitan city. Firms that are in non-metropolitan areas, and conduct innovation on an occasional basis, have no productivity advantages compared to the reference group. Only in an agglomeration will their R&D-expenditures be reflected in increased productivity, and the maximal effect is 7-10 percent. We also find some evidence of influence of the knowledge milieu of a metropolitan area among no R&D-firms, but this proximity premium is restricted to location in the largest metropolitan city.

The rest of the paper is organized as follows. Section 2 presents a theory framework for understanding the innovating firm, where the framework separates internal factors and the knowledge environment of a firm. Section 3 provides information about data sources and outlines descriptive statistics. Methodology and empirical strategy of the paper are discussed in Section 4, while Section 5 contains the econometric results. Section 6 concludes the paper.

2. PREVIOUS LITERATURE

Separately or jointly, innovation and geographic agglomeration are major topics in a broad literature on productivity, growth, urbanization and industrial organization. Firms are benefiting not only from their own investments in new knowledge but also from other firms that are close to them. Estimating a panel of U.S. firms for a twenty year period, Bloom, Schankerman and Van Reenen (2010) suggest that the social rate of return to R&D is more than 30 percentage points above the private rate of return.

A large body of theoretical literature consider the mechanisms of increasing returns due to agglomeration. Two main categories are the frequency of interactions among agents and the highly refined division of labour. Fujita and Thisse (2002) and Duranto and Puga (2005) provide recent surveys of the theoretical literature. Bacolod, Blum and Strange (2009) contribute to the empirical literature on spillovers by documenting the productivity premium associated with agglomerations, as measured by wages, by comparing workers who interact well with others to those who do not. Similar results are also reported by Glaeser and Mare (2001) and Wheeler (2001, 2006).

Another strand of the agglomeration and growth literature employs national input-output matrices in order to identify pecuniary externalities and other kinds of local interactions operating through the markets for intermediate goods. Using spatial econometrics, Lamorgese and Ottaviano (2006) verify that input-output linkages matter in explaining local productivity growth and that their importance decreases with distance.

While most early spillover studies rely on aggregate data, the increased availability of firm level data opens up new possibilities of exploring the existence and magnitude of spillovers. Griliches (1979) propose three empirically testable hypotheses of knowledge spillovers, where closeness between firms makes sense. The first concerns learning from product market rivals. Ornaghi (2006) provides recent evidence on how firms that produce similar products benefit from each other's R&D activities. The second hypothesis considers learning from firms conducting similar type of research. Starting with Jaffe (1986), a growing stream of studies uses patent citations as a proxy for technological spillovers between firms within and across sectors. A third channel of knowledge flow, suggested by Griliches (1979), consists of learning from suppliers and retailers. Early contributors in this area are Griliches and Lichtenberg (1984) and Scherer (1982).

Lychagin et al. (2010**)** consider two of the sources of spillovers discussed by Griliches (1979) in order to assess the relative contribution of geographical proximity to firms' productivity. The conclusion is that geographic location matters even after controlling for horizontal learning (from product market rivals) and technological learning (from technology market spillovers). The study also finds that geographical markets are very local, which is in line with Lamorgese and Ottaviano (2006) and others who recognise that spillovers rapidly fade with distance.

A basic micro econometric approach to testing for the impact of spillover is to relocate a hypothetical firm across different locations. Assuming that incumbent plants in "losing counties" form a valid counterfactual for the incumbents in "the winning counties", after controlling for differences in pre-existing trends, plant fixed effects, industry-by-year fixed effects, and other control variables, Greenstone, Hornbeck and Moretti (2010) estimate a sharply increased productivity of incumbents in winning counties when a large plant relocates into their county. The effect is found to be largest for incumbent plants that share similar labour and technology pools with the new plant. The empirical approach in our study has similarities to Greenstone, Hornbeck and Moretti (2010), but instead of examining how the relocation of a firm affects the new environment, we investigate how the geography affects the relocated hypothetical firm.

The possibility of identifying and assessing the importance of spillovers related to the external geographical environment of a firm, as well as the internal capacity to absorb external knowledge, can provide insights into important questions such as why there are persistent differences in firm performance and characteristics across firms.

The orthodox neoclassical view of the firm is expressed in models that emphasise that the individual firm is forced to imitate and adopt the best practice among its competitors, such that the outcome is a convergence towards states in which firms in each industry or product segment are alike. According to this view, a firm may temporarily gain a monopoly-like position by means of innovations, but the response from competitors brings about a process of equilibrium adjustment that inevitably reduces the differences between an innovating firm and its competitors (e.g. Cefis and Cicarelli, 2005; Roberts, 2001).

According to a contrasting view, firms are heterogeneous, also within narrow segments of a market. Based on empirical observations, advocators of this view claim that the asymmetries among firms are enduring and persistent, implying that differences between firms in the same industry display a greater variation than the average difference between different industries. Lasting differences are observed with regard to size, innovation, productivity, profitability and growth. This view relates to an evolutionary theory of firms and markets (e.g. Klette and Kortum, 2004; Dosi and Nelson, 2010), but also has a strong affinity with the resource-based model of the firm (Penrose, 1959; Barney, 1991 and Teece, 2007).

The resource base of a firm can be classified into internal and external factors that affect performance. Knowledge is a strategic element of the internal factors, and it is often linked to firms' long-term ambitions regarding R&D and innovation. While the R&D-intensity differs across firms as well as within firms across time, there are empirical observations which suggest that firms can be grouped into two basic and quite robust categories where the transition between them takes place with a very low frequency. The first category consists of a minority of firms committed to endurable innovation efforts, and the second comprises a majority of firms that do not make any innovation efforts at all. In contrast to these two groups of firms with a fairly time-invariant strategy, there is a group of firms that engage in innovation only occasionally. Our data, presented in Section 3, suggests large similarities between firms not engaged in innovation at all and firms conducting innovation activities on an occasional basis. In contrast, persistent innovators are substantially different from other firms with regard to several key-characteristics. How can the differences in long-term R&D or innovation strategy and the difference in firms' characteristics be explained?

Besides generating innovations, persistent R&D efforts bring about two additional consequences for the firm. It increases the stock of knowledge assets of the firm in the form of technical solutions as well as other business routines, and novel and/or customised product varieties (Griliches, 1995: Geroski, van Reenen and Walters, 1997; Hall, 2007). In addition, with persistent R&D efforts a firm builds up skills, procedures and routines for how to carry out innovation activities. (Nelson and Winter, 1982; Teece, 2007).

Our analysis is based on the following interpretation of the two outcomes from innovation activities. First, the stock of knowledge assets represents achievements by the firm that generically erode over time if the achieved performance is not supported by subsequent innovation efforts. Second, the development and maintenance of an organisation and routines for innovation activities provide a capability of both continuing R&D efforts and absorbing knowledge flows from the environment of the firm. Here, we assume that this type of capability cannot be acquired through one-shot R&D investments, but has to be developed over a sequence of years in a process where learning and shaping of routines take place. Thus, the pertinent advantage can be assumed to resist and survive occasional R&D attempts by competitors, and it can therefore provide the R&D-persistent firm with a sustainable performance advantage

External factors that may influence a firm's productivity performance and innovation activities can be related to the firm's local and regional environment, and the opportunities for global knowledge access that a particular location may afford. As emphasised by the theory of agglomeration economies, a metropolitan region offers a firm both accessibility to local and regional knowledge sources and greater opportunities to access global knowledge sources than other regions do. The corresponding benefits from metropolitan diversity of novelties and flows of ideas are often classified as Jacobs' externalities or urbanisation economies (Jacobs, 1969, 1984), and they may be perceived as the consequence of a metropolitan region as a cluster of clusters (Johansson and Forslund, 2008).

Large urban regions have large labour markets with a rich variety of specialist competence structures. As a rule they also host universities with a considerable output of prospective employees with educations that represent recent advances in science. Both these phenomena provide the typical metropolitan region with advantages. When an individual changes jobs by moving from one employer to another, there is also a transfer of knowledge embodied by the individual who changes job. Inter-firm job mobility is more frequent among knowledge-intensive labour and in large urban regions

(Cohen and Levintal, 1990: Almeida and Kogut, 1999; Andersson and Thulin, 2008). Hence, the proximity to universities and other organisations with research capacity in large urban regions constitutes an additional advantage for innovation activities in these regions.

Yet another feature of metropolitan regions is their concentration of knowledge-intensive labour, which can be measured as the share of the labour force with at least three years of university education (e.g. Glaeser, 2008). In 2007 the Stockholm region had more than 28 percent knowledge-intensive labour, and for the other two metropolitan regions, Gothenburg and Malmö, the shares were 24 and 23 percent, respectively. This should be compared with an average of 18 percent for medium-sized and 15 percent for smaller regions (Johansson, et.al., 2010). The associated knowledge advantage, which can be related to Rauch's (1993) claim that human capital in a region has the role of a local public good, also finds support in Lucas (1988).

Given these observations, it is especially feasible to make a distinction between metropolitan and non-metropolitan regions in Sweden. The reason is that the Swedish metropolitan regions are 10-20 times as large as the country's medium-sized regions, and this makes it possible to distinguish the metropolitan regions with just a dummy variable

3. DATA AND DESCRIPTIVE STATISTICS

We base our econometric analysis on observations from a set of Swedish manufacturing and service firms with 10 or more employees in a representative sample from Community Innovation Survey (CIS) IV. The survey we use took place in 2005, and covers the period 2002-2004. The rate of response was close to 70 percent. The original sample contains 3,094 firms, and to obtain the full data set we have merged the survey data with information from a database which contains information about all firms in Sweden including human capital measured as employees with at least three years of university education, physical capital, sales, value added, exports, equity, total assets and corporate ownership over a ten year period. The matching process resulted in an unbalanced data set with 2,600-2,895 firms observed over the period 1997-2006. The total number of observations of the 10-year period considered is 25,892 for all variables except the equity ratio, which by construction loses one year (Equity/total physical assets_{t-1}) of observations.

Table 1 presents summary statistics from the above data set referring to the period 1997-2006, where firms are separated into three groups, reflecting their reported type of innovation strategy during the three-year period 2002-2004. The table also reveals statstics for the whole sample. Nearly 60 per cent of the population consists of firms that do not report any innovation activities, whereas more than 17 per cent report occasional innovation, and 24 per cent are persistent innovators. All this means that we have (i) one group of firms in which the firms remained R&D-inactive in 2002-2204, (ii) a second group in which firms switched between being R&D-active and R&D-inactive, and (iii) a third group in which firms were R&D-active the entire period 2002-2004. Firms in these three groups remained systematically different during the whole period 1997-2006, which means that they were different both before and after the classification period 2002-2004.

This paper, which covers approximately 2/3 of all relevant services and manufacturing firms in Sweden, identifies the R&D-strategy of a firm by only one indicator variable. The pragmatic justification is that we do not have a better alternative for the period considered, given that strategy is interpreted as “a long-term plan for decision making into the future”. The choice can also be motivated by arguments in the literature. Investigating the prevalence of persistent innovators, Cefis and Orsenigo (2001) found that both “great innovators” and non-innovators have a strong tendency to remain in their respective categories. But they also reported that, in order to maintain innovative activities, persistence rather than the size of R&D expenditures might be important. There are two interesting aspects of this finding. One has to do with knowing how to organize R&D efforts and the other is about accumulating knowledge. In both cases persistence per se is a crucial feature.

As suggested by Nelson and Winter (1982), permanent engagement in innovation efforts makes it possible for the firm to collect experiences through learning-by-doing and thereby develop innovation skills and establish routines for carrying out development activities. Such routines also include exploitation of networks for knowledge flows into the firm. The second aspect refers to the argument that the continuity of development efforts facilitates the cumulation of knowledge and that disruptions of R&D engagement can cause the results from previous efforts to be lost. Continuity ensures maintenance of both routines and knowledge.

A third argument relates to observations in CBO (2005), which contains a discussion of the limitations of the R&D measure for both small and larger firms. Since the R&D budget of a firm only contains a fraction of its total innovation efforts, the presence of persistent R&D efforts may better represent the importance of innovation efforts than the size of R&D spending does (Duguet and Monjon, 2002).

Similar to what Cefis and Ciccarelli (2005) report for a panel of 267 UK manufacturing firms in a cross-sectional dimension, we find that persistent R&D-firms are different from the two other groups in several respects. They are considerably larger and more export oriented, they are more skill intensive, have higher sales and value added per employee and, in contrast to the other two, they typically belong to a multinational company group.

The monetary terms in the data are deflated by the Swedish Consumer Price Index. In order to reduce the influence of possible errors in our extensive database comprising three data sets of firm level data over the period 1997-2006 (current account, educational statistics and export statistics), we have transformed all observations below the 1th percentile to be equal to the 1th percentile and applied the corresponding procedure for observations above the 99th percentile. In a sensitivity analysis, we remove this trimming procedure.

Table 1 shows that 59 percent of the population consists of firms that do not conduct any R&D activities, whereas 17 percent of the firms report occasional R&D, and 24 percent are persistent innovators reflected by recurrent R&D efforts year after year.

We distinguish between three types of locations: “metro-region”, “metro-city”, and “non-metro regions”. Sweden’s three metropolitan regions (Stockholm, Gothenburg and Malmö) are all integrated labour market regions, and their respective metro-cities are the largest in each region. Table 1 presents statistics for the two metro definitions, where *M1* is Region Stockholm, Gotenburg and Malmö (39 percent of the firms), *M2* is City Stockholm, Gothenburg and Malmö (22 percent of the firms), M3 is Region Stockholm (21 percent of the firms), and M4 is City Stockholm (12 percent of the firms).

It is notable that, according to our data, which cover approximately 2/3 of all relevant services and manufacturing firms in Sweden, agglomeration areas do not have disproportionately more firms than other areas. This is in sharp contrast to the literature on innovation and geography, which suggests that innovative firms tend to cluster in agglomeration areas (Ref.??) But most data observing longitudinal R&D activity cover mainly the behavior of large firms. By grouping firms into three different categories of innovation activities, we hopefully can reduce selection bias characterizing the R&D variable in most micro-data studies. Our representative sample, where the medium firm has about 30 employees, has one additional advantage compared to the existing literature. The sample consists mainly of small firms. Large firms often have research labs across geographical locations, whereas R&D and other firm activities tend to be co-located among small firms (van Reenen, 2010**).** This means that we are better able to distinguish between internal and external knowledge sources of productivity.

The middle section of Table 1 reports descriptive statistics for the dependent variable, labour productivity, and five regressors that we will treat as endogenous or predetermined in the regression analysis. They are skills, expressed as (log) number of employees with at lest 3 years of education, (log) physical capital which is total physical assets, (log) ordinary labour defined as labour other than skilled labour, the exports to sales ratio and (log) equity, normalised by total assets in the preceding period. Substantial differences are observed between firms with persistent R&D-efforts and other firms; they have a larger intensity of both human capital and physical capital, and their labour productivity is superior. Moreover, the exports to sales ratio is 0.30 for persistent R&D-firms compared to 0.17 for firms doing R&D on an occasional basis and only 0.08 for non-R&D-firms. The difference between persistent R&D-firms and the two other groups is even more pronounced regarding the size of equity capital.

The bottom part of Table 1 presents statistics for two categories of exogenous control variables. With regard to the corporate ownership structure, it is shown that non-MNE firms are overrepresented among non-R&D firms, while foreign-owned MNEs are underrepresented among firms conducting R&D annually. We can then see that the proportion of medium-technology manufacturing firms is larger within the persistent R&D group, compared to their proportion among all firms.

Some additional insights associated with the sector classification are provided in Table 2: Persistently innovative high-technology manufacturing firms are considerably overrepresented in metropolitan regions and more than 50 percent of all persistently innovative firms are classified as business services with location in the metropolitan cities, compared to only 13 percent for the whole country.

Table 3 introduces the structure for our empirical analysis and for the estimates reported in Table 4-6. The focus here is pair-wise correlation with labour productivity, and rows 1-5 report results for five composite variables combing location (M) and R&D-strategy (R). The reference is firms located in non-metro-regions and not engaged in R&D-activities (MR1). This group of firms is compared with metropolitan firms with no R&D (MR2), non-metro firms with occasional R&D (MR3), metro-firms with occasional R&D (MR4), non-metro firm with persistent R&D (MR5), and metro-firms persistently conducting R&D. Thus, the horizontal dimension of the table investigates the relation between productivity on the one hand and R&D-strategy and metropolitan versus non-metropolitan location on the other.

The vertical dimension enables us to add the aspect of possible differences between different categories of metropolitan areas. In particular, we are interested in potential divergences between metropolitan regions and metropolitan cities. The vertical dimension also investigates if the high knowledge intensity (number of research universities, the level of education, knowledge-intense business firms, the total amount of R&D-investments), which distinguishes Stockholm from the two other Swedish metropolitan areas, constitutes an additional advantage for innovation activities.

In the table, the three metropolitan regions as a group are referred to as M1, the three metropolitan cities are referred to as M2, Stockholm metropolitan region is referred to as M3, and Stockholm city is referred to as M4.

Table 3 also presents correlation coefficients for the covariates human capital, physical capital, firm size, export intensity and access to equity capital. Both skilled labour and physical capital are closely related to labour productivity. Only metro firms doing R&D on a persistent basis (MR6) have some meaningful correlation with labour productivity.

The year-to-year transition matrix in Table 4 reveals that firms tend to remain in the same location over the whole 10-year period considered. No differences with respect to R&D-strategy can be found.

The exception is a small tendency for R&D-firms to move from non-metro-region to metropolitan areas.

4 . METHODOLOGY AND EMPIRICAL STRATEGY

4.1 General framework

The data are repeated measurements at different points in time for the same firms. Variation in data can be decomposed into variation between firms of different sizes, characteristics such as industry classification, and variation within firms. Our empirical model is a Cobb-Douglas firm level production function for firm *i* with capital, labour, skills, equity and exports included as inputs. The variable we would like to explain is labour productivity and the key interest is internal knowledge accumulation created by a particular R&D-strategy and external knowledge spillovers from the local milieu. We use firms' self-declared R&D-strategy (R) as a proxy for the internal knowledge process, and location in a Metropolitan region (M) as an indicator that the firm can benefit from a local milieu characterized by advantageous knowledge sources. Our general model is as follows

$$Y_{it} = A_{it}[F(K_{it}, L_{it}, H_{it}, E_{it}, X_{it})] \tag{1}$$

where Y_{it} is value added, A_{it} is the technology shifter, K_{it} is firm capital stock, L_{it} is the number of ordinary labour and H_{it} is the skill indicator measured as number of employees with at least three years of university education, E_{it} is equity capital normalized by total assets in the preceding period, and X_{it} is exports over sales. The total number of employees equals $L_{it} + H_{it}$.

If we take logs and express value added in levels per employee (Y/(L+H)), we get the following expression for the log of labour productivity:

$$y_{it} = a_{it} + \beta_1 k_{it} + \beta_2 l_{it} + \beta_3 h_{it} + \beta_4 e_{it} + \beta_5 x_{it} \tag{2}$$

where it should be noted that we consider ordinary labour (*l)* as a size variable. We incorporate the location of each firm and its R&D-strategy into this framework through the shift-factor in the production function in the following way:

$$a_{it} = \alpha_0 + \alpha_1 M_{it} + \alpha_2 R_i + \alpha_3 Z_{it} \tag{3}$$

where *M* is a dichotomous variable separating firms located in a metropolitan area from firms located in the rest of Sweden, *R* is the firms R&D-strategy which can take three different values, and *Z* is a vector of firm characteristics that includes ownership status, sector classification of firm *i* and a year dummy.

Adding a dynamic component to equation (2), merging *M* and *R* into a composite variable, RM**,** and including an error term, we can express the regression as:

$$y_{it} = \alpha_0 + \alpha_1 RM_{it} + \alpha_2 Z_{it} + \beta_1 k_{it} + \beta_2 l_{it} + \beta_3 h_{it} + \beta_4 e_{it} + \beta_5 x_{it} + \beta_6 y_{i,t-p} + \varepsilon_{it} \quad (4)$$

$$\varepsilon_{it} = \omega_i + \mu_{it} + \upsilon_{it}$$

where ω refers to the time-invariant firm-specific fixed effects, μ refers to serially correlated unobservables and ν refers to the idiosyncratic error term. Allowing for a one-period lag of the non-shift variables and up to a four-period lags of the dependent variable, the base regression can be re-formulated as

$$\begin{aligned} y_{it} &= \alpha_0 + \alpha_1 RM_{it} + \alpha_2 Z_{it} + \beta_1 k_{it} + \beta_2 k_{i,t-1} + \beta_3 l_{it} + \beta_4 l_{i,t-1} \\ &+ \beta_5 h_{it} + \beta_6 h_{i,t-1} + \beta_7 e_{it} + \beta_8 e_{i,t-1} + \beta_9 x_{it} + \beta_{10} x_{i,t-1} + \gamma_1 y_{i,t-p} + \varepsilon_{it} \\ p &= 1, 2, 3, 4 \end{aligned} \quad (5)$$

4.2 Endogenous and exogenous variables

The dynamic model that we employ when estimating the impact of R&D strategy and location on firm performance is the two-step system GMM estimator (Arellano and Bover 1995, Blundell and Bond 1998). In order to apply equation (5) in this framework, we need to specify the variables as endogenous, predetermined, weakly exogenous and strictly exogenous.

Based on the literature we treat the controls *y, h, k, l, e*, and *x* as endogenous, predetermined or weakly exogenous regressors. The endogeneity concern is a possible correlation between these variables and unobserved productivity shocks. When firms experience a large productivity shock, they might respond by increasing their inputs.

The system GMM estimator uses the levels equation to obtain a system of two equations: one differenced and one in levels. The endogenous variables in the first difference equation are instrumented with their own level but lagged, while the endogenous variables in the levels equation are instrumented with their own first differences. The basic model specifies 3 lags and deeper for the instruments in the first difference equation, and 2 lags for instruments in the levels equation. This implies that 215 instruments are employed in the system of two equations. Since the GMM-estimator can generate too many instruments, we test the robustness by changing the lag structure of the instruments for the endogenous regressors and thereby reducing number of instruments.

We assume that the composite variable MR is exogenous. Is it reasonable to assume that firms are not influenced in their choice of R&D strategy or location of a productivity shock? Consider first the R&D-strategy. Our assumption is that firms' self-declared R&D-strategy over a three-year period 2004-2004 can be used as a proxy for long-term commitment to innovation activities. We use two sources of information for testing the relaibility of this assumption, one of which is overlapping CIS data. Four out of ten of these firms are also found in the CIS-Survey 2000. Table I in the appendix reports that, in a selected overlapping sample of firms observed in both surveys, 75% of the firms that declared themselves as persistent R&D conductors over the period 2002-2004 also claimed the same status for the period 1998-2000. The corresponding figure is almost identical for R&D firms. In contrast, the table show that firms classified as occasional R&D-firms in CIS 2004 can be regardes as switchers. Thus, almost every other one (46%) of these firms had a non-R&D-status in CIS 2000, while about one-third considered themselves as persistent R&D-firms in the same survey. The information from two overlapping innovation surveys suggests that non-R&D firms tend to remain not engaged in innovation investments, occasional R&D-firms tend to switch to non R&D or persistent R&D, and persistent R&D firms tend to have a long-term commitment to innovation.

The other source of information is patent statistics. Table II, Panel A in the appendix reports that, of the 3,096 firms observed in the 2004 CIS sample, 778 applied for at least one patent over the period 1997-2008. The patent data comes from from PATSTAT and the Swedish Patent Office PRV, and covers about 80% of all national and international patent applications by Swedish companies in the period 1997-2008.

Among firms which declared that they were persistently engaged in R&D over the period 2002-2004, 42% applied for a patent between 1997 and 2008. The corresponding figures for firms that declared themselves as occasional R&D investors and non-R&D investors are 15% and 6%, respectively. Panel B considers the distribution of applications over the time period 1997-2006. One out of five firms that declared themselves as persistent innovators in CIS 2004 also applied for patents persistently over the period 1997-2008, when persistence is defined as at least 6 years of repeated applications. Almost 100% of non-R&D-firms and 95 percent of occasional R&D firms did not apply for patents persistently.

The overall picture using information from both overlapping innovation surveys and patent data shows that the reported innovation strategy for a three year period from a single CIS-survey may be regarded as a relatively robust indicator of the long-term innovation strategy. This is important since the R&D-variable typically suffers from selection bias in panel data studies. Most data bases, including ours, observe annual R&D-expenditures over time only for large firms. By employing firms' own declared long-term commitment to innovation activities instead of the particular amount, we can include a representative population with both small and large firms in the analysis. The median firm in our study has only about 30 employees. Moreover, including small innovative firms in the analysis contributes to a deeper understanding of externalities, since for many small firms the location of production and research are highly correlated, while large firms often have research labs in different locations

Turning then to location, which is the second part of the composite variable, the empirical literature shows that location decisions strongly influence firms' innovative performance. But typically this literature considers the localized innovative potential to be an exogenously determined explanatory variable (Immarino, 2005). Location decisions occur with low frequency, so that location remains a historically given fact for a sequence of dates, which is also confirmed in our data discussed in Section 3. Regarding the second part of the interaction variable, the R&D-strategy, we first establish that the strategy classification of firms explains differences in firm performance in the period 2002-2204. We then ask if the same differences in performance could be predicted for the subsequent years 2005 and 2006. Finding that such differences could be predicted, we also investigate if the same differences in firm performance could be detected and ascertained for the preceding years 1997- 2001. Confirming that this is the case, we make the assumption that the strategy classification of firms for 2002-2004 is valid for the entire ten year period 1997-2006. Thus, the MR-variable is almost a constant, and finding a plausible instrument for this variable is not possible in the present application (for a similar case, see Lychagin , 2010).

5. RESULTS

This section is divided into three subsections. The first presents the structure of Tables 5-8. The second shows the baseline estimation results, and the third contains the test statistics and robustness checks.

5.1 Structure of the presentation

The basic results are given in Table 5, which displays the productivity equation using real prices and Winsorized data. Tables 6 - 8 contain further estimates of the production function. Table 6 reports the relationship between productivity and its determinants when possible outliers in the data are included. Table 7 provides estimates with reduced number of instruments in the specification of the GMM-estimator. Table 8 shows the elasticity of productivity when estimated with current prices and Winsorized data. Presuming that the audited data provided by Statistics Sweden, and used in aggregated form for constructing annual GDP-figures, are of the highest possible quality, we consider the coefficient estimates from the four different equations presented in Table 6 as our preferred results.

The analysis explores the joint impact of geography and innovation on firm performance. The reference group is firms with no R&D and non-metropolitan location, all else equal (MR1). The estimated coefficients MR2-MR6 measure the level of labour productivity for various combinations of location and R&D-strategy in relation to the counterfactual.

The results are presented in four columns, M1-M4. In column (M1) labour productivity for an average firm location in a metro-region (Stockholm, Gothenburg and Malmö) is compared with location in a non-metro-region (Rest of Sweden). Column (M2) compares location in a metro-city with location in a non-metro-city. Column (M3) compares labour productivity for a hypothetical firm in the Stockholm region with firms in the rest of Sweden. In order to disentangle the specific metro-effect for the Stockholm region, firms located in region Gothenburg and region Malmö are not put into the Rest-of-Sweden category. Column (M4), presents the corresponding estimates for City-Stockholm versus the rest of Sweden with firms hosted in City Gothenburg and City Malmö excluded.

Across all the columns of Tables 5-8, the first panel shows results for the six key-variables, which combine R&D-strategy and location. The first two variables, MR1 and MR2, represent R&D inactive firms. MR1 refers to firms located in a non-metro area, while MR2 report results for metro-firms. The results for the reference group, (MR 1) are not reported since they always take the value zero by definition. MR3 and MR4 correspond to firms investing in R&D only occasionally over time. MR3 shows the results for a non-metro-location and MR4 for a location in a metro region or a metro city. The last pair, MR5 and MR6, represents the firms that have chosen a persistent R&D-strategy. The MR5 coefficients reveal differences in productivity between doing R&D persistently or not at all when located in a non metro-region. MR6 report the relative impact of persistent R&D in a metro-region. In order to interpret the interaction variables as difference in percentage compared to the reference group, we transform the estimated MR-coefficient by $100\times(e^{MRi}-1)\%$

The mid-panel of the Tables 5-8 shows coefficient estimates for selected covariates. Two categories of test-statics are reported in the bottom panel. The first is a Wald test investigating equality of means for the estimated MR-coefficients. The second reports whether we have been successful in eliminating the serial correlation in the error term (AR 2), and clarifies the validity of the instruments in our model specification (Hansen).

5.2 Empirical analysis

The coefficients of the MR-variables in Tables 5-8 are within a range of 0.01-0.19, which corresponds to a productivity level 1-21 percent larger than the reference group. Comparing across, we see an increasing productivity when firms are located closer to a center of a metropolitan area and when firms are more engaged in innovation.

Overall, the analysis shows four regularities that persist in alternative specifications of the model. First, persistent R&D always outperforms other R&D-strategies for a given location. Second, the estimates of spillover effects for a given R&D strategy are always larger in the largest metropolitan city. Third, occasional R&D influences productivity relative to non-R&D only if firms are located in a metropolitan area. Finally, non-R&D firms benefit from a metropolitan region, only if they are located in a metropolitan city, and in particular in the largest metropolitan city.

To examine the joint effect of innovation and geography in more detail, first consider Table 5, which contains all our combinations of R&D-strategy and location using real prices and Winsorized data. We start by reporting the four regressions displayed in columns (M1) – (M4) separately and then compare the results.

Column (1) presents the results for the whole sample, and metro is defined as the ensemble of the Stockholm, Gothenburg and Malmö regions. The key-variables are reported in three different pairs, where the first consists of non-R&D firms, the second represents occasional R&D firms, and the third persistent R&D-firms. Each pair reports the results of non-metropolitan firms and metropolitan firms.

Starting with the first pair, which includes the reference (MR1), we see that without innovation efforts there are no benefits from the knowledge milieu of a metropolitan region. The order magnitude of the MR2-estimate is only slightly larger than the reference alternative and the null hypothesis of equality of means cannot be rejected. This result is noteworthy. Although agglomeration literature mainly deals with interactions, very few empirical studies explicitly address the issue of distribution of spillover effects between heterogeneous firms. In particular, we do not know much about the impact of spillovers on firms with respect to their innovation activities.

Consider then the second pair, which consists of firms doing R&D only occasionally. The MR3 variable is of low magnitude and insignificant, suggesting that occasional R&D efforts do not make a significant difference when compared to no R&D engagements at all in a metropolitan location. This finding gives some support to Klette and Kortum (2004), who claim that temporary innovation often represents a defensive strategy applied by firms when their product(s) becomes obsolete. A possible alternative to this strategy is downsizing or closure. But interestingly the MR4-estimate shows a significant and more sizeable result; the combination of occasional R&D and location in a metropolitan area is associated with about 4% higher productivity compared to the reference group.

The final MR-pair reports that the productivity premium on persistent innovation (MR5) is 8.5% in a non-metro region relative to no R&D in the same region. This figure supports a large literature which claims that R&D is good for productivity. Our contribution here is that we also consider possible influence from the surrounding milieu. In the first case we can assume that the externalities are limited, but if we relocate a firm with recurrent innovation activities to a metropolitan region, the productivity premium increases, on average, to 11.5%.

In Table 5 the columns M2-M4 contain further estimates of the production function and reveal a consistent pattern across the alternative specifications of a metropolitan milieu. To disentangle the separate effect of a metropolitan city, column M2 defines a metropolitan area as the cities of Stockholm, Göteborg and Malmö, while the rest of these three regions is included among non-metropolitan areas. The literature surveyed in chapter 2 suggests that accessibility and proximity are of particular importance for firms engaged in innovation, and especially for firms with regular innovation efforts. This is also confirmed in the regression. Compared to being located somewhere in a metropolitan region, the productivity premium on occasional R&D increases from 4.3 percent to 6.6 percent when the firm is relocated to the city of a metropolitan region. The corresponding relative productivity effect for a persistent R&D firm is an increase from 11.5 percent to 14.2 percent. Interestingly, a small spillover effect can also be found for non R&D-firms located in a metropolitan region. The estimated effect is nearly 3 percent, but significant only at the lowest acceptable level of significance.

Columns M3 and M4 present results only for the largest metropolitan region (Stockholm region) and the largest metropolitan city (Stockholm city). Consider first the regional dimension; the coefficient of the MR2-variable still indicates that non-R&D-firms do not benefit from a metro-region.

The coefficient estimate for occasional R&D-firms in the Stockholm region (MR3) is somewhat larger compared to the corresponding estimate for all three metropolitan regions together (0.056 versus 0.042), indicating that the spillover-effect on firms engaged in innovation increases with spatially concentrated activities. Consistent with this finding, the table reports that the coefficient estimate for persistent R&D-firms is higher if such firms are located in the Stockholm region (0.122) instead of any of the three metropolitan regions defined as a group (0.109).

Column M4 estimates the metropolitan effect for the Stockholm-city alone. Persistent R&D-firms (MR6) in the most agglomerated area of the country have a productivity premium equivalent to 17 percent compared with the reference alternative. About half of this effect is explained by firms' internal knowledge development through successive R&D investments. This follows from a comparison with the estimate for firms with a persistent R&D strategy and located in a non-metropolitan area. The MR5-estimate is 0.084 and equivalent to 8.8 percent, and the rest of the productivity difference to the reference group is the result of the geography. Thus, firms with the largest accumulated knowledge potential through successive R&D-investment have a substantial advantage of being located in the most knowledge-concentrated area of the country.

Across Table 5, the controls are the dependent variable lagged, human capital, physical capital, firm size, equity ratio, export intensity, sector and year. The level of productivity in the previous year is a good predictor of current productivity. In contrast to the close correlation between human capital and productivity displayed in the pair wise correlation table (Table 2), the GMM-estimates show no association between the variables. The explanation is that the major impact of knowledge capital is captured by the R&D-strategy variable. The estimate for physical capital enters into the equation with a positive and significant coefficient. As expected, the sign of the firm size is negative, although not significant. The relative size of equity (equity/total physical $assets_{t-1}$) has a positive covariance with productivity, but the estimates are not significant when firms in the metro-regions Gothenburg and Malmö are excluded from the sample.

We find no impact of export intensity on the level of labour productivity for the average firm in the sample. This is consistent with the findings by Andersson and Lööf (2009) who report a productivity-enhancing learning effect from exports which is present only among persistent exporters with high export intensity, but not among the vast majority of exporting firms consisting of occasional exporters or persistent exporters with low export intensity. For reasons of space, the estimates for corporate ownership, sector classification and year dummies are not reported.

Turning to Table 6, which contains measures based on real prices but not non-censored (but audited) data, the estimated parameters show a pattern similar to the results presented in table 5. However, one significant difference can be noted; the parameter estimates for firms located in the largest metropolitan city become larger. Thus, column M4 reports that the productivity premium for non-R&D firms is now 7.5 percent and the estimated effect is highly significantly different from zero. Furthermore, the externality and other localization effects associated with Stockholm city increase the relative productivity of occasional R&D-firms by close to 11 percent. As expected, we also find a substantial productivity effect on persistent innovative firms from spillovers in the largest metropolitan center. While the relative productivity level on average is 11.5 per cent higher when a firm is located in a metropolitan region (See the first column of Table 6) and increases to 14.5 if the firm is placed in the largest metropolitan region (Column 2), it increases to 21 percent when the location is in the city of the largest metropolitan area.

5.3 Test statistics and robustness check

The last panel (Tables 5-8) reports two categories of tests-statistics. The first is a Wald test of the equality of estimated means of the MR2-MR6 variables, and the second is a test of the reliability of the model specification. While the GMM-estimates in the top panels of tables 5-8 report the MR coefficients relative to the reference group, the Wald-test consider the equality of means between MR6 and MR5-MR2 and between MR5 and MR4-MR2, respectively. Two regularities can be noted across the columns and tables. First, columns M1 and M3 in Tables 5-8 consistently report larger coefficients for MR6 than for MR5. However, no statistically significant difference in productivity between persistent R&D inside or outside a metro region can be established. Second, persistent R&D within a metropolitan city always generates higher productivity than persistent R&D in a non-metro city, everything else equal. Notable is that only 2 out 16 test show that persistent R&D in a non-metro area generates significantly higher productivity than occasional R&D within a metro-area.

Across the regressions, we employ a lag structure that consists of 3 lags of the dependent variable and one lag of the covariates. The AR2-statistics cannot reject the hypothesis that the idiosyncratic error term is not serially correlated, since all p-values are above the critical 0.05. In the regression we use 215 instruments in order to estimate 34 parameters, and the null hypothesis that the model specification is correct cannot be rejected when the p-value>0.05. The Hansen test confirms that the instruments are valid and no correlation exists between the instruments and the error term. When the number of instruments are reduced to 163, table 7 reveals only minor difference to table 5. Table 7 analyzes the interaction between innovation and location employing current prices and Winsorized data. The results are almost identical to those reported in Table 5.

6. SUMMARY AND DISCUSSION

The advantages of geographical agglomeration are associated with R&D and innovation. Location-specific factors influence firms' innovative performance, but the magnitude of this spillover effect is still an open question. In this paper we show how different combinations of locations and R&D-strategies affect firm's productivity. To do this, a dynamic GMM-estimator is applied to a panel of close to 3,000 firms located in 81 Swedish regions and observed over a 10-year period. Using extensive firm characteristics for two different data sources, a reference group is identified by lagged level of productivity, export intensity, human capital, physical capital, equity capital, corporate ownership structure, firm size, sector classification and R&D-strategy and location. Firms in this group are located in a non-metropolitan region and their R&D-engagement is lacking.

In contrast to Simmie (2003), who suggests that innovative firms tend to cluster in agglomeration, our data show a striking similarity in distribution between innovative and other firms. Thus, 39 percent of all non-R&D firms in our sample are located in one of the three Swedish metropolitan regions Stockholm, Gothenburg and Malmo. The corresponding figure for firms with continuous R&D is 40 percent. The pattern is the same if we only consider the cities of the three metro-regions. These are populated by 22 per cent of the firms in our sample, which consists of 2/3 of all the relevant Swedish firms, in the manufacturing and service sector, with at least 10 employees in 2004. The share of innovative firms located in these three cities is exactly the same. In Stockholm city, which is the largest metropolitan city, we find 12 percent of all firms and 12 percent of the innovative firms.

What is the explanation for this discrepancy between our data and those expected according to the literature? Lychagin (2010) is one of the studies closest to ours, but in the selected sample only 13 percent of the firms have fewer than 500 employees. This skewed distribution is typical for the spillover literature based on micro data. In our representative data based on the 2004 Community Innovation survey, however, the median firm has about 30 employees. Since small businesses, unlike large companies, tend to have both research and production in one place, our data provide unique opportunities to study the relationship between innovation and spatial spillover.

In our econometric analysis, we first note that the temporary R&D efforts only increase the value added per employee marginally more than the increased investment costs for the average firm in a non-metropolitan region. But if a company, which is otherwise identical to the reference group, chooses a strategy with long-term sustainable engagement in R&D, we see a productivity premium of around 8 percent. The explanation is that persistent innovation effort has two consequences for the firm. It increases the stock of knowledge assets of the firm in the form of technical solutions as well as the knowledge about novel and customised product varieties. In addition, with persistent R & D effort a firm builds up skills, procedures and routines for how to carry out innovation activities. Together, these provide a capability of both continuing R & D effort and absorbing knowledge flows from the environment of the firm. We assume that this type of capability cannot be acquired through one-shot R & D investments. But we also assume that the external knowledge available for absorption in a non-metropolitan environment is limited by the low level of density of businesses and people.

Next, we have studied pairs of twin companies, with one twin in the reference set and one located in a metropolitan region. Across various specifications we have found no benefit for a non-R&D firm to be located in a metropolitan region. The presumed positive externalities appear to be offset by higher floor costs and other costs. The productivity level of the average R&D-inactive firm in a metropolitan region is not different from the counterfactual. However, our results indicate a productivity premium (2-7 per cent) for R&D-inactive firms in the largest metro-city.

Somewhat more robust evidence was provided with regard to firms engaged in R&D only occasionally. These firms can profit from metropolitan spillovers, and the effect increases with closeness to the metropolitan cities. It exceeds the reference group by 5-10 percent (depending on the specification of the data used) in the regressions where the metro-city is represented by Stockholm, which is Sweden's dominant knowledge environment in terms of R&D, human capital and access to knowledge-intensive service.

The study's most clear-cut results refer to companies that declared themselves as persistent innovators over the period 2002-2004. We have three arguments for our assumption that only these companies are likely to have been persistent innovators for the entire period 1997-2006. First, for variables such as labor productivity, exports per employee and profitability, which are positively correlated with innovation, they exhibit persistently higher levels than other companies. Second, using information from two overlapping innovation surveys we have found a high probability that persistent innovators in the period 2002-2004 were persistent innovators during the 1998-2000 period as well. Third, persistent innovators in the 2004 innovation survey displayed a radically different propensity to recurrently apply for patents in the period 1997-2008.

Our regression results for persistent innovators show that the productivity difference relative to the counterfactual increases from 10 percent when located in a non-metro region, to14 percent in a metropolitan region according our preferred model, and the maximal productivity premium of 21 percent is reached when the firm is located within the largest metropolitan city. About half the effect is explained by internal knowledge accumulation through successive annual R&D investments and the rest by agglomeration spillovers.

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Table section

Table 1: Summary statistics over the period 1997-2006.

		All firms		Non R&D		Occas. R&D		Persist.R&D	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
$R1_i$	Non R&D	0.59	(0.49)	1.00	(0.00)				
$R2_i$	Occasional R&D	0.17	(0.37)			1.00	(0.00)		
$R3_i$	Persistent R&D	0.24	(0.43)					1.00	(0.00)
$M1_{it}$	Region Sthlm, Gbg, Malmö	0.39	(0.49)	0.40	(0.49)	0.33	(0.47)	0.40	(0.49)
$M2_{it}$	City Sthlm, Gbg, Malmö	0.22	(0.41)	0.23	(0.42)	0.16	(0.37)	0.22	(0.41)
$M3_{it}$	Region Sthlm	0.21	(0.40)	0.21	(0.41)	0.17	(0.38)	0.21	(0.40)
$M4_{it}$	City Sthlm	0.12	(0.32)	0.13	(0.33)	0.10	(0.30)	0.12	(0.32)
y	labour productivity (log)[A]	6.18	(0.48)	6.14	(0.47)	6.17	(0.46)	6.30	(0.49)
h	Skilled labour (log)	0.36	(2.29)	-0.18	(2.13)	0.25	(2.04)	1.77	(2.26)
k	Physical capital (log)	7.78	(2.88)	7.40	(2.80)	7.72	(2.73)	8.77	(2.97)
l	Ordinary labour (log)	3.40	(1.59)	3.17	(1.44)	3.34	(1.47)	4.04	(1.84)
e	Equity/total assets$_{t-1}$ (log)	0.13	(1.76)	0.06	(1.80)	0.06	(1.64)	0.37	(1.73)
x	Exports/sales	0.16	(0.27)	0.09	(0.20)	0.18	(0.28)	0.32	(0.35)
	Skilled/total employment	0.11	(0.16)	0.08	(0.14)	0.10	(0.16)	0.17	(0.20)
O1	Dom Non Aff Enterp	0.33		0.40		0.35		0.32	
O2	Dom Uninat Enterp	0.30		0.34		0.25		0.33	
O3	Dom Mult Enterp	0.20		0.14		0.17		0.21	
O4	For Mult Enterp	0.17		0.12		0.22		0.14	
S1	High tech manufact	0.06		0.04		0.04		0.06	
S2	High techmedium manufact	0.16		0.13		0.06		0.21	
S3	Low tech medium manufact	0.15		0.16		0.06		0.24	
S4	Low tech manufact	0.23		0.25		0.18		0.27	
S5	Knowledge intense services	0.17		0.12		0.31		0.08	
S6	Other services	0.24		0.30		0.35		0.14	
	Observations, fraction	1,00		0.59		0.17		0.24	

Notes:

Mean and overall standard deviation reported.

A: Value added of ordinary labour.

Number of observations is 25,892 for all variables except variable E, which by construction loses one (Equity/total assets$_{t-1}$) year of observations.

Total number of observations for E is 22,517.

Table 2: Distribution of firms after sector classification, percent.

	Sweden		3 Metro regions		3 Metro cities		Region Stockholm		City Stockholm	
	NP	P	NP	P	NP	P	NP	P	NP	P
Manu HT	4.0	5.0	4.7	11.5	4.4	7.4	4.3	12.1	3.1	5.5
Manu HMT	13.1	19.7	8.8	17.7	6.5	12.1	7.0	13.8	3.3	6.8
Manu LMT	15.3	20.9	7.6	8.9	5.9	4.6	5.8	6.3	4.0	3.9
Manu LT	23.9	24.7	17.8	9.4	18.3	8.1	17.2	8.6	21.2	8.7
Know serv	15.8	13.4	26.1	34.9	32.4	49.8	32.4	41.8	39.4	61.2
Other serv	27.9	16.3	34.9	17.6	32.2	18.0	33.4	17.3	28.9	14.0
Total	100	100	100	100	100	100	100	100	100	100

Notes:

NP is non-persistent R&D firms. P is persistent R&D firms.

Manu HT: High technology manufacturing; ISIC 353, 2433, 30, 32, 33
Manu HMT: High medium technology manufacturing; ISIC 24 (excl 2433), 29, 31, 34, 352,359
Manu LMT: Low medium technology manufacturing; ISIC 23, 25, 26, 26, 28, 351, 354
Manu LT: Low technology manufacturing; ISIC 15, 16, 17, 18, 19, 20, 36, 37
Know serv : Knowledge-intense business services; ISIC 64, 65, 66, 67, 71, 72, 73, 74
Other serv: Other services

Table 3: Pair wise correlation with labour productivity (y) 1997-2006. Fourdifferent definitions of metropolitan area.

	(M1)	(M2)	(M3)	(M4)
MR1	Ref	Ref	Ref	Ref
MR2	0.06	0.06	0.02	0.01
MR3	0.00	-0.01	-0.01	-0.01
MR4	0.05	0.06	0.04	0.04
MR5	0.03	0.02	0.01	0.02
MR6	0.10	0.11	0.08	0.09
h	0.53	0.51	0.53	0.53
k	0.44	0.44	0.44	0.44
l	-0.59	-0.59	-0.60	-0.60
e	0.20	0.20	0.21	0.21
x	-0.01	0.00	-0.02	-0.01

Notes:
MR1 is reference for MR2-MR6.
Labour productivity is expressed as value added per ordinary labour

M1: Region Stockholm, Gothenburg and Malmö versus Rest of Sweden
M2: City Stockholm Gothenburg Malmö versus Rest of Sweden
M3: Region Stockholm versus Rest of Sweden. Region Gothenburg and region Malmö not included
M4: City Stockholm versus rest of Sweden. City Gothenburg and City Malmö not included

MR1=Non Metro× Non R&D
MR2=Metro × Non R&D
MR3=Non Metro × Occasional R&D
MR4=Metro × Occasional R&D
MR5=Non Metro × Persistent R&D
MR6=Metro × Persistent R&D

h=log number of skilled labour
k= log physical capital (stock)
l= log number of ordinary labour
e=log equity/total assets $_{t-1}$
x= exports/sales

Table 4: Year–to-year transition in whether remaining in the classification of the key variables.

Variable	Definition	0/0	1/1
$MR1_{it}$	Non Metro × Non R&D	99.65	99.40
$MR2_{it}$	Metro × Non R&D	99.68	99.53
$MR3_{it}$	Non Metro × Occasional R&D	99.90	99.40
$MR4_{it}$	Metro × Occasional R&D	99.91	97.22
$MR5_{it}$	Non Metro × Persistent R&D	99.82	99.17
$MR6_{it}$	Metro × Persistent R&D	99.84	97.12

Notes
0/0: Firms that did not belong to this group one year did not belong to this group the next year either
1/1: Firms that did belong to this group one year also belonged to this group the next year.

Table 5: Dependent variable is log value added per ordinary labor (y). Real prices and Winzorised data

	(M1)	(M2)	(M3)	(M4)
Key-variables				
MR2 [a]	0.012	0.026*	0.028	0.052
	(0.012)	(0.015)	(0.018)	(0.022)**
MR3 [a]	0.014	0.016	0.018	0.015
	(0.012)	(0.011)	(0.012)	(0.011)
MR4 [a]	0.042	0.064	0.056	0.070
	(0.017)**	(0.025)**	(0.028)**	(0.030)**
MR5 [a]	0.082	0.084	0.093	0.081
	(0.022)***	(0.021)***	(0.025)***	(0.022)***
MR6 [a]	0.109	0.133	0.122	0.157
	(0.024)***	(0.030)***	(0.034)***	(0.041)***
Controls				
y_{t-1}	0.551	0.540	0.516	0.517
	(0.095)***	(0.092)***	(0.090)***	(0.090)***
h	-0.031	-0.043	-0.043	-0.042
	(0.031)	(0.027)	(0.028)	(0.028)
k	0.040	0.039	0.037	0.037
	(0.015)***	(0.014)***	(0.013)***	(0.013)***
l	-0.071	-0.050	-0.014	-0.017
	(0.043)*	(0.039)	(0.041)	(0.041)
e	0.033	0.033	0.049	0.049
	(0.020)	(0.020)	(0.019)**	(0.019)**
x	-0.124	-0.123	-0.172	-0.162
	(0.232)	(0.204)	(0.225)	(0.225)
Equality of means[b]				
MR6=MR5	0.105	0.032**	0.261	0.030**
MR6=MR4	0.002***	0.021**	0.036**	0.037**
MR6=MR3	0.000***	0.000***	0.001***	0.000***
MR6=MR2	0.000***	0.000***	0.001***	0.001***
MR5=MR4	0.073*	0.452	0.216	0.713
MR5=MR3	0.000***	0.000***	0.001***	0.000***
MR5=MR2	0.002***	0.010**	0.011**	0.255
Observations	19,551	19,551	14,672	17,539
AR (2)	0.082	0.081	0.335	0.225
Instruments, no	215	215	215	215
Hansen overid	0.097	0.091	0.416	0.217

Notes:

Estimation of equation (5). Selected variables reported.

Interpretation of the interaction variables MR*i*: $100\times(e^{MRi}-1)\%$

* significant at 10%; ** significant at 5%; *** significant at 1% . Windmeijer corrected standard error within parentheses. (a) Reference:MR1= Non-Metro&Non-R&D.

(b) Wald test, prob>Chi2, null hypothesis is that the means are equal

Unbalanced data. Dynamic GMM, two-step.

Binary location variables included in the interaction variables MR1-MR6:

M1: Region Stockholm, Gothenburg and Malmö versus Rest of Sweden

M2: City Stockholm Gothenburg Malmö versus Rest of Sweden

M3: Region Stockholm versus Rest of Sweden. Region Gothenburg and region Malmö not included

M4: City Stockholm versus rest of Sweden. City Gothenburg and City Malmö not included

Table 6

Dependent variable is log value added per ordinary labour (y). Real prices and Non-Winzorized data

	(M1)	(M2)	(M3)	(M4)
Key-variables				
MR2 [a]	0.014	0.028	0.038	0.072
	(0.013)	(0.017)	(0.022)*	(0.025)***
MR3 [a]	0.018	0.021	0.016	0.017
	(0.012)	(0.011)	(0.014)	(0.013)
MR4 [a]	0.045	0.059	0.064	0.102
	(0.020)**	(0.031)*	(0.034)*	(0.035)***
MR5 [a]	0.081	0.080	0.101	0.101
	(0.028)***	(0.027)***	(0.029)***	(0.026)***
MR6 [a]	0.107	0.129	0.136	0.191
	(0.028)***	(0.036)***	(0.041)***	(0.046)***
Equality of means[b]				
MR6=MR5	0.107	0.025**	0.255	0.028**
MR6=MR4	0.006***	0.021**	0.051*	0.018***
MR6=MR3	0.000***	0.000***	0.001***	0.001***
MR6=MR2	0.000***	0.000***	0.004***	0.009***
MR5=MR4	0.168	0.435	0.291	0.983
MR5=MR3	0.013**	0.012**	0.001***	0.005***
MR5=MR2	0.020**	0.044**	0.030**	0.344
Observations	19,551	19,551	14,672	17,539
AR (2)	0.475	0.502	0.562	0.635
Instruments, no	215	215	215	215
Hansen overid	0.097	0.089	0.487	0.330

Notes:

Estimation of equation (5). Selected variables reported.

Interpretation of the interaction variables MR*i*: $100\times(e^{MRi}-1)\%$

* significant at 10%; ** significant at 5%; *** significant at 1% . Windmeijer corrected standard error within parentheses. (a) Reference:MR1= Non-Metro&Non-R&D.

(b) Wald test, prob>Chi2, null hypothesis is that the means are equal

Unbalanced data Dynamic GMM, two-step.

Binary location variables included in the interaction variables MR1-MR6:

M1: Region Stockholm, Gothenburg and Malmö versus Rest of Sweden

M2: City Stockholm Gothenburg Malmö versus Rest of Sweden

M3: Region Stockholm versus Rest of Sweden. Region Gothenburg and region Malmö not included

M4: City Stockholm versus rest of Sweden. City Gothenburg and City Malmö not included

Table 7: Dependent variable is log value added per ordinary labor (y). Robustness test of results displayed in Table 4, column 3, by changing laglimits. Model M3

	(M1)	(M2)	(M3)	(M4)
Key-variables				
MR2 [a]	0.008	0.019	0.017	0.040
	(0.021)	(0.016)*	(0.017)	(0.021)*
MR3 [a]	0.015	0.016	0.017	0.014
	(0.011)	(0.010)	(0.011)	(0.010)
MR4 [a]	0.034	0.050	0.032	0.051
	(0.017)*	(0.024)**	(0.026)	(0.028)*
MR5 [a]	0.082	0.082	0.082	0.071
	(0.023)***	(0.022)***	(0.025)***	(0.022)***
MR6 [a]	0.103	0.124	0.103	0.143
	(0.025)***	(0.031)***	(0.033)***	(0.040)***
Equality of means [b]				
MR6=MR5	0.216	0.065*	0.378	0.029**
MR6=MR4	0.001***	0.011**	0.017**	0.019**
MR6=MR3	0.000***	0.000***	0.005***	0.000***
MR6=MR2	0.000***	0.000***	0.001***	0.004***
MR5=MR4	0.028**	0.190	0.085*	0.482
MR5=MR3	0.001***	0.000***	0.003***	0.000***
MR5=MR2	0.001***	0.004***	0.009***	0.215
Observations	19,551	19,551	14,672	17,539
AR (2)	0.085	0.165	0.348	0.165
Instruments	163	163	163	163
Hansen overid	0.105	0.173	0.337	0.173

Notes:

Estimation of equation (5). Selected variables reported.

Interpretation of the interaction variables MR*i*: $100\times(e^{MRi}-1)\%$

* significant at 10%; ** significant at 5%; *** significant at 1% . Windmeijer corrected standard error within parentheses. (a) Reference:MR1= Non Metro&Non R&D.

(b) Wald test, prob>Chi2, null hypothesis is that the means are equal

Unbalanced data. Dynamic GMM, two-step.

Binary location variables included in the interaction variables MR1-MR6:

M1: Region Stockholm, Gothenburg and Malmö versus Rest of Sweden

M2: City Stockholm Gothenburg Malmö versus Rest of Sweden

M3: Region Stockholm versus Rest of Sweden. Region Gothenburg and region Malmö not included

M4: City Stockholm versus rest of Sweden. City Gothenburg and City Malmö not included

Table 8: Dependent variable is log value added per ordinary labour (y). Current prices and winzorised data

	(M1)	(M2)	(M3)	(M4)
Key-variables				
MR2 [a]	0.011 (0.012)	0.026 (0.015)*	0.027 (0.018)	0.051 (0.022)*
MR3 [a]	0.014 (0.012)	0.017 (0.011)	0.019 (0.012)	0.016 (0.011)
MR4 [a]	0.043 (0.018)**	0.065 (0.025)**	0.058 (0.028)**	0.071 (0.030)**
MR5 [a]	0.085 (0.024)***	0.086 (0.023)***	0.097 (0.027)***	0.084 (0.023)***
MR6 [a]	0.111 (0.025)***	0.135 (0.031)***	0.125 (0.034)***	0.159 (0.041)***
Equality of means[b]				
MR6=MR5	0.117	0.038**	0.305	0.035**
MR6=MR4	0.002***	0.027**	0.037**	0.036**
MR6=MR3	0.000***	0.000***	0.001***	0.000***
MR6=MR2	0.000***	0.000***	0.001***	0.005***
MR5=MR4	0.075*	0.434	0.208	0.688
MR5=MR3	0.001***	0.001***	0.001***	0.001***
MR5=MR2	0.002***	0.0414**	0.013**	0.254
Observations	19,551	19,551	14,672	17,539
AR (2)	0.088	0.088	0.347	0.246
Instruments, no	215	215	215	215
Hansen overid	0.110	0.103	0.413	0.223

Notes:

Estimation of equation (5). Selected variables reported.

Interpretation of the interaction variables MR*i*: $100\times(e^{MRi}-1)\%$

* significant at 10%; ** significant at 5%; *** significant at 1% . Windmeijer corrected standard error within parentheses. (a) Reference:MR1= Non Metro&Non R&D.

(b) Wald test, prob>Chi2, null hypothesis is that the means are equal

Unbalanced data. Dynamic GMM, two-step.

Binary location variables included in the interaction variables MR1-MR6:

M1: Region Stockholm, Gothenburg and Malmö versus Rest of Sweden

M2: City Stockholm Gothenburg Malmö versus Rest of Sweden

M3: Region Stockholm versus Rest of Sweden. Region Gothenburg and region Malmö not included

M4: City Stockholm versus rest of Sweden. City Gothenburg and City Malmö not included

APPENDIX

Table I

Consistence of R&D-stategies across CIS-surveys. Comparison of the R&D-strategy of unique firm observed years 2000 and 2004.

R&D-strategy CIS 2004	CIS 2000: Non R&D	CIS 2000: Occasional R&D	CIS 2000: Persistent R&D
Non R&D	74.7 %	13.3 %	12.0 %
Occasional R&D	46.7 %	23.0 %	30.3 %
Persistent R&D	17.6 %	7.1 %	75.3 %

Notes:

The selected sample in table is based on the 830 Swedish firms observed in both CIS 2000 and CIS 2004.

The total number of firm observations in CIS 2000 is 2,164 and the number of firms observed in CIS 2004 is 3,096 . The number of observed in both surveys is 830.

Table II

Self declared R&D-strategy in CIS 2004 and patent applications 1997-2008

Panel A

Self-declared R&D-strategy in the CIS 2004	Firms observed in the 2004 CIS	Firms observed in the 2004 CIS and patent applicants 1997-2008	Patent applicats/ total number of CIS-firms
Non R&D	1,868	108	5.8%
Occasional R&D	507	78	15.4 %
Persistent R&D	721	302	41.9%

Panel B

Self-declared R&D-strategy in the CIS 2004	Frequency of applications 1997-2008		
	1 Year	2-5 Years	6 Years or more
Non R&D	2.5 %	2.7 %	0.6 %
Occasional R&D	4.3 %	5.9 %	5.1 %
Persistent R&D	7.2 %	16.5 %	18.2 %

Notes:
Panel A reports that of the 3,096 firms observed in the 2004 CIS sample, 778 applied for at least one patent over the period 1997-2008. The patent statistics are based on data from PATSTAT and the Swedish Patent Office PRV and cover about 80% of all national and international patent applications by Swedish companies in the period 1997-2008. Panel B considers the distribution of applications over the time period 1997-2006.