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R&D-Persistency, Metropolitan Externalities and Productivity

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R&D-Persistency, Metropolitan Externalities and Productivity

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Abstract

Firms display persistent differences as regards both internal and external characteristics, and these differences correspond to asymmetries in the performance of firms with regard to productivity level and growth as well as innovativeness. This paper focuses on one internal characteristic and one external factor by distinguishing between firms with persistent R&D efforts and other firms and firms located in a metropolitan region versus firms with other locations. Applying Swedish data on individual firms and their location, the paper shows that firms that follow a strategy with persistent R&D efforts have a distinctly higher level of productivity across all types of location. In addition, the productivity level of firms with persistent R&D is augmented in a significant way when such firms have a metropolitan location and, in particular, a location in a metropolitan city.[3]

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

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1. INTRODUTION

There is a large literature on firm heterogeneity, both in terms of the resource base and the performance level of firms. As discussed by Bartelsman and Doms (2000) these performance differentials can be verified for several different measures of performance. In a survey of the literature Dosi and Nelson (2010) emphasise that firms persistently differ over all dimensions that researchers are able to observe. In view of these assessments, the present study examines firm with persistent R&D efforts, combined with long-term maintenance of its knowledge resource base and absorptive capacity. It is shown that these firms have a productivity performance that remains higher than for other firms over a sequence of years.

There is a second literature on how the local and regional environment may affect both a firm's propensity to make innovation efforts and its output performance. This literature refers to environment features such as local clusters (Karlsson, 2008), and urbanisation economies (Feldman and Audretsch, 1999; Fischer and Fröhlich, 2001). The present paper shows that R&D-persistent firms have additional performance benefits from the advantages of metropolitan regions with their more frequent job switching, intensity of knowledge flows, and access to knowledge intense labour, generating knowledge externalities that can stimulate innovations (Fujita and Thisse, 2002; Rauch, 1993)

1.1 The Firm's Innovation Strategy

In the subsequent analysis a firm's innovation strategy is characterised in two dimensions, where the first distinguishes between (i) persistent, (ii) occasional, and (iii) no R&D efforts. In the second dimension we observe the size of the firm's knowledge resource base, measured by the size of the labour force with at least three years of university education. This latter dimension reflects the absorptive capacity (and development capacity) of the firm as suggested by Cohen and Levinthal (1990). In our analysis, the absorptive capacity remains central. However, it makes a clear difference if this capacity is combined with a long-term commitment to annual R&D efforts. The R&D persistency of firms has an independent performance effect and augments their productivity level along a sequence of years.

Information about firms in the study comes from two different sources. The first is the Community Innovation Survey (CIS) on Swedish manufacturing and service firms observed 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 about economic performance and the firm's internal resource base. Using these panel data across individual firms, the paper intends to demonstrate that firm performance depends both on the firm's specific capabilities as recognised by the size of its input of knowledge-intensive labour (Cohen, 1995), and on the persistency of its R&D efforts.

With reference to Cefis and Cicarelli (2005) we find that R&D-persistent firms are different from other firms in several respects. They are larger and more export oriented, have a higher knowledge intensity. In addition, they have higher sales value and value added per employee, and they typically belong to a multinational company group. These cross-sectional differences remain intact over the entire period 1997-2006. The arguments in the paper for this consistency refer to learning and maintenance effects of being persistent. Employing a strategy of persisting innovation efforts allows the firm to maintain and develop the heuristics and routines of its innovation activity. In the estimations labour productivity is the dependent variable, and we control for observed differences in past productivity, knowledge-intensive labour, ordinary labour, physical capital, exports and lagged equity.

Given the outlined setting, the focus is on the contribution to a firm's productivity level from (i) the nature of each firm's innovation strategy and (ii) the category of local environment in which it is located, where the major distinctions are either metropolitan and non-metropolitan region or metropolitan city and non-metropolitan locations.

1.2 Metropolitan Regions versus other Regions

In contemporary affluent economies, economic activities take place primarily in urban space, reflecting the importance of agglomeration. This idea can be traced back both to Adam Smith in his emphasis on the size of a local economy and Alfred Marshall in his discussions of external economies of scale. The current understanding of agglomeration is in a clear way based on a contribution by Fujita (1988), in which he demonstrated how the monopolistic competition model of Chamberlin (1933) could be reformulated to generate spatial agglomeration, such that standard market processes based on price interaction alone could bring about increasing returns to agglomeration. More recently, Fujita and Thisse (2002) illuminate this issue in a sequence of models. In their book communication externalities explain the existence of agglomeration economies, where the basic mechanism is that mutual proximity between many firms improve the productivity of all firms and in particular the productivity of those firms which have the largest accessibility to other firms. In a similar spirit Glaeser and Gottlieb (2009) stress that agglomeration advantages primarily are caused by a higher intensity of knowledge flows and exchange of ideas in metropolitan environments .

In order to examine the impact of metropolitan economies for innovating firms, the present study considers the following three types of locations: metropolitan region labelled "metro-region", metropolitan city labelled "metro-city", and other (non-metropolitan) locations labelled "non-metro regions". 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 mutually separated by long distances.

The examination of how location affects firm performance has the ambition to match information about the innovation strategy of individual firms with their location. This approach can provide answers to a set of questions. First, given that we can show that a strategy with persistent R&D efforts has higher productivity effects than other innovation strategies, then we can find out if this observation is valid for all types of locations. In other words, does R&D persistency augment productivity both in metro regions and other regions of medium size and small regions. Second, does the combination of R&D persistency and location in a metro-region correspond to higher productivity performance than R&D persistency in non-metro locations? Third, is the productivity performance of an R&D-persistent firm higher when the firm is located in a metro-city compared to a typical location in the entire metro-region. Forth, we investigate if there are indications which imply that the largest metro-region and metro-city (Stockholm) is hosting R&D persistent firms with higher productivity than any other location, observing that in the delineation of regions in our study Stockholm is the largest, Gothenburg the second largest and Malmö the smallest metro region[4]. Finally, we can pose the following question: do firms which lack R&D persistency have any observable productivity advantage when they are located in a metro region or are metropolitan economies specifically affecting knowledge-oriented firms with R&D persistency?

In order to provide answers to the above questions, the empirical analyses decomposes the Swedish geography into the following sets: (i) all non-metropolitan regions referred to as NM-regions, (ii) the Stockholm metropolitan region referred to as M1, (iii) the Stockholm city referred to as M2, (iv) the three metropolitan regions as a group referred to as M3, and (v) the three metropolitan cities referred to as M4. Given this decomposition the analyses match in turn M1, M2, M3 and M4 against NM.

1.3 Outline of the Paper

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 reports on the econometric results. Section 6 concludes.

[4] This study makes use of a decomposition of Sweden into 81 labour-market regions, labeled LA-regions.

2. THEORY OF THE INNOVATING FIRM

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 each other. According to this view a firm may by means of innovations temporarily gain a monopoly like position, 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 has also a strong link to the resource-based model of the firm (Penrose, 1959; Barney, 1991 and Teece, 2007).

The strategic choice and resource base of a firm can be classified as internal factors that affect the performance. 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 bring about. 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 what 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).

In view of the above, the choice of location is also a choice of knowledge support, and through such a choice the individual firm can add to its internal knowledge by dwelling in an environment with high accessibility to knowledge sources. Based on this conclusion, it has been suggested that innovative firms tend to concentrate in a minority of key metropolitan regions in which firms can benefit from both local and global knowledge flows (Acs and Armington, 2004; Simmie, 2003). In the subsequent analysis, we discuss internal and external factors that can improve the performance of the innovating firm, and why metropolitan regions may be considered to offer a more innovation-friendly milieu than other locations.

2.1 Strategy and Resource Base of the Innovating Firm

Consider now that a firm can select a strategy that prioritises persistent R&D efforts which continue over a sequence of years. Then we may conjecture that firms with such a strategy are able to persistently perform better than firms with other strategies that either avoid to make R&D efforts or initiate such efforts occasionally in situations when strong R&D stimuli appear, due phenomena such as reduced sales of certain products, intensified price competition in certain markets and other negative performance signals, but also unexpected opportunities that make innovation efforts more promising. Is it possible to formulate theoretical frameworks, according to which firms with persistent innovation efforts are rewarded higher profits than other firms?

Consider Schumpeter's (1934) model of the innovating firm. In the picture painted by Schumpeter the innovating entrepreneur's expectation to obtain temporary monopoly profits is a necessary driving force. However, the prediction is that gradual equilibrium adjustments in the economy will make these profits transitory as other firms adjust their products and routines and skills in response to the novelties introduced by the innovating firm. In this sense the Schumpeter model is a special case of the general equilibrium framework, where innovations play the role of moving the economy through a sequence of equilibrium adjustments. Moreover, the Schumpeter model is compatible with the idea that firms with invariantly sustained innovation activities may retain a superior performance over a long sequence of years. But why do certain firms select and develop such a strategy, whereas others do not?

For models which are based on a general equilibrium framework, an innovating firm may be rewarded by higher profits than other firms. However, such a position is a transitory state which disappear as other firms adjust their products and routines in response to the novelties introduced by the innovating firm. One may argue that such imitation-like adjustments occur at a slow pace, which could help to explain why a firm may keep a front position by continuing to make innovation efforts along a sequence of years. However, as this paper shows there are empirical observations which suggest that firms can be grouped into three categories, where the first category consists of firms committed to endurable R&D efforts, the second of firms that make R&D efforts only occasionally, and the third of firms that rarely make any R&D efforts. Moreover, as will be illustrated in this paper by means of Swedish data, the transition of firms between the three categories takes place at a very low frequency. How can this be explained?

Persistent R&D efforts bring about two 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). The present 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 provides 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 occasional R&D attempts by competitors, and it can therefore provide the R&D-persistent firm with a sustainable performance advantage.

The above conclusion can be compared to Geroski's (1998) so-called stylized facts, where we stress the observation that heterogeneities in economic performance between firms is a long-run phenomenon that remains intact regardless of how performance is measured. At the same time Geroski claims that technological performance, measured by counts of major innovations, lack the same invariance over time. This latter conclusion is partly valid also when technological performance is measured by the number of patents (Cantner and Krueger, 2004). In the present study, we make use of direct statements by individual firms about their innovation strategy and match these statements against the corresponding economic performance over a longer time period. Our claim is that a firm's statement about its R&D persistency is a strong predictor of its economic performance. Contrary to what is reported in Klette and Raknerud (2002 ; 2005), we find that R&D persistency and labour productivity correlate when performance of individual firms are traced over of a sequence of years.

2.2 The Location Environment of the Innovating Firm

A firm applying an innovation strategy with persistent R&D efforts can benefit more than other firms from a steady an rich flow of innovation ideas, combined with knowledge support that can facilitate the technical solutions and commercialisation of the ideas. One mechanism for collecting and absorbing ideas and solutions is the network links that the firm can establish with other actors in the local as well as global environment. In a large urban region the options for establishing such intra-regional links are richer because the alternatives are much greater in those regions (Johansson and Quigley, 2004). The same applies to global links, due to the more favourable conditions of large urban regions for international contacts and associated communication.

A firm can influence its knowledge-flow environment by forming links (interaction channels) to other actors such as its input suppliers, its customers, universities and other knowledge providers. Such network development is less costly to carry out inside a region, and the advantage of a metropolitan region lies in the fact that the number of potential contacts is much larger and more diversified than elsewhere (Simmie, 2003). Building networks for interaction requires face-to-face contacts, while established network can be employed to replace direct contacts. As emphasised in Johansson and Lööf (2008), the formation of multi-company groups can be understood as a process of establishing knowledge links between firm units located in metropolitan regions across different parts of the world. Thus, this observation adds to the special features of metropolitan regions.

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 persons with educations that represent recent advances in science. Both these phenomena provide the typical metropolitan region with advantages. When an individual shifts job 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). The proximity to universities and other organisations with research capacity in large urban regions constitutes an additional advantage for innovation activities in these regions.

An additional 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). For Sweden we may observe that in 2007 the Stockholm region had more than 28 percent knowledge-intensive labour. The same share was 24 and 23 percent, respectively for the other two metropolitan regions, Gothenburg and Malmö. 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 can be related to Rauch's (1993) claim that human capital in a region has the role of a local public good, while finding support for this idea in Lucas (1988). Although Rauch applies his arguments to the aggregate potential of an urban region, the feature of being a local public good is even more relevant in our task to identify advantages for the innovating firm (Karlsson and Johansson, 2006; Johansson and Karlsson, 2009).

2.3 Agglomeration, Knowledge and the Innovating Firm

In the previous sub section we have presented reasons for why a metropolitan region affords a advantageous milieu for the innovating firm. First, a metropolitan region has a large labour market with diversified job opportunities and a labour supply with knowledge-intensive labour embodying multiple competencies. Second, the metropolitan region is characterised by intense labour mobility of persons switching from one employer to another, including persons that change from being employed to starting new firms. Third, in a metropolitan region knowledge flows are greater and have a richer composition than elsewhere, and firms have a large access to other firms' R&D and innovation activities. This provides opportunities for knowledge externalities such that interaction and spillovers between firms can bring about mutual knowledge benefits, generating innovation ideas that spur the introduction of novel products and development of new firm routines.

Given these observation, it is especially feasible in Sweden to make a distinction between metropolitan and non-metropolitan regions. 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.

Our intention is to first establish a clear-cut effect of a firm's choice to rely on persistent R&D efforts, irrespective of its local knowledge milieu, and then to clarify the additional benefits that can arise in a large and knowledge-intensive urban environment. Our intention is to arrive at the following set of conclusions. First, firms that apply an innovation strategy with persistent R&D efforts have higher productivity than other firms in all locations. Second, there is a metropolitan-region effect such that R&D persistent firms are more productive when located in a metropolitan region than when located in other environments. Third, there is a metropolitan-city effect such that the metropolitan-region effect on productivity is especially large when a firm is located in the city of a metropolitan region. Fourth, the general metropolitan-region effect is especially marked for the Stockholm metropolitan region. Fifth, the general metropolitan-city effect is stronger in the Stockholm region than in the other two metropolitan regions

3. DATA AND DESCRIPTIVE STATISTICS

We base our econometric analysis on observations from a set of manufacturing and service firms in Sweden, with 10 or more employees in a representative sample from Community Innovation Survey (CIS) IV. The survey we use took place in 2005, and it 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$_{t-1}$) year of observations. There we have 22,517 observations in the data matrix analysed.

Table 1 presents summary statistics for all firms and the firms separated into their reported long-run R&D strategy according to the Innovation Survey.

Since we have no data on innovation strategy for the whole period 1997-2006, we assume that the 2002-2004 behaviour reflects the firms' long-run strategy. This is supported by the literature, which suggests that firms R&D-investments vary less than most investments over the business cycle. (Klette and Kortum, 2004 and Aghion et al., 2008). Moreover, Lööf and Johansson (2010) find that the relative performance of non, occasional- and persistent R&D-firms remains invariant over a long time period.

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. We also compare regression results with real prices and current prices. In the appendix, the robustness check is extended by changing laglimits in the basic GMM-equations.

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.

In the analysis 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-city is the largest city in each region. Table 1 presents statistics for the two metro definitions, where M1 is Region Stockholm (21 percent of the firms), M2 City Stockholm (12 percent of the firms), M3 Region Stockholm, Gotenburg and Malmö (39 percent of the firms) and M4 is City Stockholm, Gothenburg and Malmö (22 percent of the firms). No systematic pattern in R&D-strategy with respect to a firms' location can be identified. The variables M1-M4 are time-variant, but the variation is very limited.

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 to that of firms without persistent R&D efforts. 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. Neglecting to control for these differences , would make it hard to disentangle the separate influence of R&D-strategy on labour productivity.

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 technological 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 the Appendix, Table VI: 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 2 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 row 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 form with persistent R&D (MR5), and metro-firms persistently conducting R&D. Thus, the horizontal dimension of the table investigates the relation between productivity and the one hand and R&D-strategy and metropolitan versus non-metropolitan location on the other.

With the vertical dimension, we 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) that distinguish Stockholm from the two other Swedish metropolitan areas, constitutes an additional advantage for innovation activities. In the table, Stockholm metropolitan region is referred to as M1, the Stockholm city referred to as M2, the three metropolitan regions as a group referred to as M3, and the three metropolitan cities referred to as M4

Table 2 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 with 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 3 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. See Table 3.

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 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 long-run 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 looks 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 skill indicator measured as number of employees with at least three years 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 l is a size variable and it should be noted that a negative sign of l indicates a positive correlation between labour productivity and firm size[5]. We will 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:

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

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 on 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:

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

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

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 four periods lags of the dependent variable, the base regression can be re-formulated as

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

4.2 Endogenous and exogenous variables

The dynamic model that we will 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.

[5] Consider $Y=K^{\alpha} E^{\beta}$, where $E = L + H$ (ordinary labour + skilled labour). Then $\ln(Y/E) = \ln K + \beta \ln E - \ln E = \alpha \ln K + (\beta-1) \ln E$. Thus, since L is a large fraction of E, β_2 in equation (2) corresponds to $(\beta-1)<0$

Based on the literature we will treat the controls *y, h, k, l, e*, and *x* as endogenous, predetermined or weakly exogenous regressors. Regarding the endogeneity-issue, we assume that the R&D-strategy, and choice of location and thus also the interaction variable *MR* is exogenous in the system approach together with corporate ownership structure, sector classification and year dummies. The motivation for the exogeneity assumption on MR, is that the instruments in the GMM-matrix are deeper lags of the endogenous variables, and no such meaningful lag can be found for the almost time-invariant MR-regressors.

Will the exogeneity assumption about R&D-strategy and location yield biased estimates? Lööf and Heshmati (2006) and Mairesse and Mohnen (2010) investigate the importance of instrumenting innovation expenditures in structural models using cross-sectional data. The results are consistent between the studies and show that the estimated correlation between productivity and innovation expenditures are almost the same whether treating the latter as endogenous or not. Consider that location decisions occur with low frequency so that location remains a historically given fact along a sequence of dates. In that case location can be assumed to change on a slow time scale, which means that it can be treated as exogenous in the analysis. The interaction variable *MR*, which then can take six different values, is extremely persistent from year to year. Between 97-99% of firms that belonged to any one of these six groups one year also belonged to the same group following years (Table 3).

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. The variables in the levels equation are instrumented with their own first differences. The basic model specifies 3 lags and deeper for the instruments in 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 applied 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.

5. RESULTS

The basic results are given in Table 4, which displays the productivity equation using real prices and winsorized data. Tables 5 and 6 provide robustness checks of the results as presented in Table 4. In Table 5 the elasticity of productivity is estimated with current prices and winsorized data. Table 6 reports the relationship between productivity and its determinants when possible outliers in the data have not been eliminated. Table I-IV in the appendix provides additional robustness checks by comparing the results from the basic GMM-model with results using alternative laglimits.

Tables 4-6 are organised in the following way: The results are presented in four columns, M1-M4. Column M1 compares labour productivity for a typical firm in the Stockholm region with firms in 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 in the Rest-of-Sweden category. Column M2, presents the corresponding estimates for City-Stockholm versus the rest of Sweden with firms hosted in city Gothenburg and City Malmö excluded. In Column M3, location in a metro-region (Stockholm, Gothenburg and Malmö) is compared with location in a non-metro-region. Column M4, finally estimates the impact of metro-city externalities (Stockholm, Gothenburg and Malmö) and the reference is non-metro-city location.

The upper part of Table 4 shows results for the six key-variables, which combine R&D-strategy and location and which are labeled *MR1-MR*6. The reference group is non-metro and non-R&D-firms (MR1). MR2 estimates the productivity for non-R&D-firms if they are located in a metro-area. The variables in rows MR3 and MR4 report the corresponding coefficients for firms with occasional R&D. Rows MR5 and MR6 show regression results for R&D-persistent firms located in non-metro and metro-areas, respectively, where column M3 refers to metro-region and M4 to metro-city locations.

The mid-section of the table shows coefficient estimates for selected covariates. In the bottom part of the table, two categories of test-statics are reported. The first is a Wald test investigating equality of means. 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).
The study distinguishes between firms with persistent R&D efforts and other firms and firms located in metropolitan regions and metropolitan cities versus firms with other locations. In the empirical analysis we test the following hypotheses:

- H1: Firms that follow a strategy with persistent R&D efforts have distinctly higher level of productivity across all types of location.
- H2: Firms that follow a strategy with persistent R&D efforts in metro-regions are more productive than persistent R&D firms in other regions.
- H3: Firms that follow a strategy with occasional R&D efforts in metro regions are more productive than occasional R&D firms in other regions.
- H4: Firms that follow a strategy with persistent R&D efforts in a metro-city are more productive than persistent R&D firms with location in the metro-region as a whole.
- H5: Firms that follow a strategy with persistent R&D efforts in the largest metro-city (Stockholm) are more productive than persistent R&D firms located in the metro-region as a whole.

5.1 Empirical analysis

Starting with the hypothesis about the importance of R&D persistency, H1, we use the Wald test for comparing *MR6* and *MR5* versus *MR4-MR1*. Column M3 presents the results for the whole sample and metro is defined as the ensemble of the Stockholm, Gothenburg and Malmö regions. Examining the coefficients in column M3, the test statistics reject the null hypothesis that the coefficient estimate for *MR6* (Persistent R&D and metro) is not significantly different from the estimates for *MR4-M1*. Regarding persistent firms in a non-metro region (*MR5*), the point estimate indicates a 4 percent advantage in relation to occasional R&D-firms in the metro-region. However the Wald-test is outside the 10% level of significance, and we cannot reject the null hypothesis that the means are equal. Compared with non-R&D firms and occasional R&D in non-metro-regions, persistent R&D (MR5 and MR6) gives a premium corresponding to 6-9 percent.

Hypotheses H2 and H3, which claim that metropolitan regions give leverage effects for all types of innovation activities, are tested by a pair wise comparison between firms with the same R&D-strategy but located in different regions (*MR6* versus *MR5* and *MR4* versus *MR3*). Considering the results displayed in all columns M1-M4, the size of coefficient estimates indicates that both categories of R&D-firms are more productive when they dwell in a metro-area. Thus, the performance is augmented both for occasional and persistent R&D-firms when they are located in a metropolitan milieu.

Next, we investigate the importance of metro-city, H4. From the literature we derived the hypothesis that accessibility and proximity are of particular importance for firms engaged in innovation at a regularly basis. In order test this statement, we consider the estimates in MR6-row and compare the columns M3 and M4. The coefficient for persistent innovators in a metro-city (Stockholm, Gothenburg and Malmö) is 0.133 compared with 0.109 for the three metro-regions. Thus, we have an indication that supports the hypothesis, but the difference between the two point estimates cannot be confirmed at any acceptable level of significance.

Our final question (H5) concerns a possible extra innovation advantage that stems from being locates in the largest metro-city in Sweden (Stockholm). Do persistent R&D-firms in the Stockholm city perform better than persistent R&D-firms located somewhere else in the Stockholm region? The regression results displayed in column M1 and M2 are 0.157 and 0.122, and a recalculation[6] indicates that the Stockholm city-premium in productivity is 4%. But similar to the metro-city estimate above (2.4% metro-city-premium), the difference between the two estimates is not statistically significant.

[6] $100\times(e^{MRi}-1)\%$

The controls in the dynamic model 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 for 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 if knowledge capital is capture 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. In order to reduce the space, the estimates for corporate ownership, sector classification and year dummies are not reported.

5.2 Test statistics and robustness check

With the lag structure used, including 3 lags of the dependent variable and one lag of the covariates, we employ 19,551 observations in the full sample,[7] which is reduced when metro-regions or metro-cities Gothenburg and Malmö are excluded in order to capture the particular Stockholm effect. 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. 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.

The sensitivity analysis reported in Table 5 and Table 6 revels that the main results are robust irrespective of whether they are expressed in current prices or fixed prices, or whether or not the data are trimmed by the winsorizing procedure censoring the 1 percent highest and lowest values. The most marked effect in the sensitivity test is that the metro-effect is stronger for Stockholm when the extreme values are preserved.

[7] The theoretical specification is discussed in Section 4, and the empirical application with STATA's statistical software is presented in Appendix, Table I

Tables II-V in the Appendix provide additional robustness tests of the results shown in Table 4. For each one of the four definitions of the metropolitan areas, M1-M4 we test different lag limits of our instruments in the first-difference equation and in the level equation. The first column in Table II is identical with the results presented in the first column of Table 4, which compares metro-region Stockholm with rest of Sweden. The three other columns present results for the same observations with less instruments. Correspondingly, Table III presents a sensitivity test for metro-city Stockholm, when less instruments are exploited in the GMM-matrix. Table IV and V make the equivalent tests for metro-region and metro-city Stockholm, Gothenburg and Malmö jointly. The concluding finding from the regressions with reduced number of instruments, is that the estimates systematically have somewhat lower order of magnitude. However, the main results reported in table 4 remains.

5.3 Summarizing findings

Summarizing the results from our most preferred model as reported in Table 4, the following facts emerge:

First, persistent R&D-firms in metro-cities are significantly more productive than occasional R&D firms and non-R&D firms irrespective of location. With non-metro and non-R&D as a reference, the premium for metro combined with persistent R&D is 12-17 percent. The difference reduces to about 10 percent when non R&D-firms in a metro region is the reference. If the comparison is made with MR3 as reference (occasional R&D and non metro), there is a premium to the combination metro and R&D persistency reaching the level 10-15 percent. The same type of premium reduces to 7-10 percent when the reference is changed to be the combination metro and occasional R&D. No significant productivity difference can be established between persistent R&D-firms located in a non-metro region and occasional R&D firms hosted in a metropolitan region. The productivity level is 3-10 percent higher for persistent R&R-firms in non-metro areas than for firms that lack R&D persistency outside metro areas.

Second, persistent R&D firms in the Stockholm-city create close to 10 percent larger value added per employee than other persistent R&D-firms outside metro-city locations. The corresponding premium for Swedish metro-cities in general is 6 percent. With regard to firms with an occasional R&D-strategy, the metro-city premium is about 5 percent.

Third, the productivity level of persistent R&D-firms in metro-cities is about 2 percent higher compared to identical firms in other parts of the metro-region. In the case of Stockholm, the corresponding deviation is 4 percent. However, the difference between the metropolitan effect for metro-city and metro-region is not statistically different from zero.

6. CONCLUSIONS

This paper decomposes the national geography of firm location into non-metropolitan regions (NM), the largest metropolitan region (M1), the largest metropolitan city(M2), all three metropolitan regions (M3) and all three metropolitan cities (M4). In parallel, the study classifies the firms' long-run R&D-strategies into three distinct alternatives: No R&D-efforts (NR), Occasional R&D (OR) and persistent R&D-engagements, (PR).

Applying a two-step system GMM-estimator on a data set consisting of 26 000 Swedish firm level observations over a 10-year period, the following pattern emerges: Without innovation efforts, there are no benefits from the knowledge milieu of a metropolitan region or a metropolitan city. For firms with persistent R&D efforts, there is a markedly positive effect from location in the knowledge milieu of the metropolitan region. For non-metropolitan locations, occasional R&D efforts do not make a significant difference, when compared to no R&D efforts. We cannot distinguish between the productivity effects of an OR-strategy and NR-strategy when firms have non-metropolitan location.

However, for OR-firms we can detect a productivity effect of being located in a metropolitan region as well as in a metropolitan city. In addition, the point estimates indicate that there is a higher OR-firm productivity in a metropolitan city location than in metropolitan region locations. Moreover, the estimates give some indication that the largest metropolitan region has a stronger influence on the productivity level than the other two metropolitan regions, and that the largest metropolitan city affords the milieu where the influence on the productivity level is the highest. This applies to both OR-firms and PR-firms. These differentials are clearly systematic but not statistically significant.

Adding numbers to the main results of the study, we conclude with the following narrative description of the typical firm. The expected productivity effect will be close to zero when an NM-firm with a NR-strategy contemplates a move to an M-region, or when it assesses the benefit from staying in the NM-region while switching to an OR-strategy. If the firm instead moves to an MR-region and at the same time introduces an OR-strategy, the value added per employee (labour productivity) can be expected to increase by 4 percent. An alternative with stronger positive impact is to remain in the NM-region while taking a radical step from no R&D-efforts at all, to persistently recurrent R&D-investments year after year. Then the productivity level eventually will rise by 8 percent. Getting appetite for further productivity improvements, the firm may consider additional absorbable knowledge inputs from metropolitan externalities. Using the calculations in the present study, the firm finds that a move to metropolitan region corresponds to an additional 4 percent gain in productivity. But if it decides to change both strategy and localization, why not move to a metropolitan city? In this case, the total expected increase in productivity will be 14 percent, compared to the initial level with no R&D for the NM-firm. And if the firm compares different metropolitan cities, it will find the expected productivity gain from being hosted in the dominating metropolitan city is 17 percent.

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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	0.21	(0.40)	0.21	(0.41)	0.17	(0.38)	0.21	(0.40)
$M2_{it}$	City Sthlm	0.12	(0.32)	0.13	(0.33)	0.10	(0.30)	0.12	(0.32)
$M3_{it}$	Region Sthlm, Gbg, Malmö	0.39	(0.49)	0.40	(0.49)	0.33	(0.47)	0.40	(0.49)
$M4_{it}$	City Sthlm, Gbg, Malmö	0.22	(0.41)	0.23	(0.42)	0.16	(0.37)	0.22	(0.41)
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 over ordinary labour, B: value added over total employment.

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 on E is 22,517.

Table 2

Pair wise correlation with labour productivity (y) 1997-2006. Four different definitions of metropolitan area.

	(M1)	(M2)	(M3)	(M4)
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 versus Rest of Sweden. Region Gothenburg and region Malmö not included.

M2: City Stockholm versus rest of Sweden. City Gothenburg and city Malmö not included

M3: Region Stockholm, Gothenburg and Malmö versus Rest of Sweden,

M4: City Stockholm Gothenburg Malmö versus Rest of Sweden,

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.

y =log labour productivity,

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, *M*=Metropolitan region (Stockholm),

Table 3

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 also did not belong to this group next year

1/1: Firms who did belong to this group one year, also belong to this group next year.

Table 4

Dependent variable is log value added employee (y). Real prices

	(M1)	(M2)	(M3)	(M4)
Key-variables				
MR2 [a]	0.028	0.052	0.012	0.026*
	(0.018)	(0.022)*	(0.012)	(0.015)
MR3 [a]	0.018	0.015	0.014	0.016
	(0.012)	(0.011)	(0.012)	(0.011)
MR4 [a]	0.056	0.070	0.042	0.064
	(0.028)**	(0.030)**	(0.017)**	(0.025)**
MR5 [a]	0.093	0.081	0.082	0.084
	(0.025)***	(0.022)***	(0.022)***	(0.021)***
MR6 [a]	0.122	0.157	0.109	0.133
	(0.034)***	(0.041)***	(0.024)***	(0.030)***
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	0.261	0.030**	0.105	0.032**
MR6=MR4	0.036**	0.037**	0.002***	0.021**
MR6=MR3	0.001***	0.000***	0.000***	0.000***
MR6=MR2	0.001***	0.001***	0.000***	0.000***
MR5=MR4	0.216	0.713	0.073*	0.452
MR5=MR3	0.001***	0.000***	0.000***	0.000***
MR5=MR2	0.011**	0.255	0.002***	0.010**
Observations	14,672	17,539	19,551	19,551
AR (2)	0.335	0.225	0.082	0.081
Instruments, no	215	215	215	215
Hansen overid	0.416	0.217	0.097	0.091

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

M2: City Stockholm versus rest of Sweden. City Gothenburg and city Malmö not included

M3: Region Stockholm, Gothenburg and Malmö versus Rest of Sweden,

M4: City Stockholm Gothenburg Malmö versus Rest of Sweden

Table 5

Dependent variable is log value added per ordinary labour (y). Current prices

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

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

M2: City Stockholm versus rest of Sweden. City Gothenburg and city Malmö not included

M3: Region Stockholm, Gothenburg and Malmö versus Rest of Sweden,

M4: City Stockholm Gothenburg Malmö versus Rest of Sweden

Table 6

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

	(M1)	(M2)	(M3)	(M4)
Key-variables				
MR2 [a]	0.038	0.072	0.014	0.028
	(0.022)*	(0.025)***	(0.013)	(0.017)
MR3 [a]	0.016	0.017	0.018	0.021
	(0.014)	(0.013)	(0.012)	(0.011)
MR4 [a]	0.064	0.102	0.045	0.059
	(0.034)*	(0.035)***	(0.020)**	(0.031)*
MR5 [a]	0.101	0.101	0.081	0.080
	(0.029)***	(0.026)***	(0.028)***	(0.027)***
MR6 [a]	0.136	0.191	0.107	0.129
	(0.041)***	(0.046)***	(0.028)***	(0.036)***
Equality of means [b]				
MR6=MR5	0.255	0.028**	0.107	0.025**
MR6=MR4	0.051*	0.068*	0.006***	0.021**
MR6=MR3	0.001***	0.001***	0.000***	0.000***
MR6=MR2	0.004***	0.009***	0.000***	0.000***
MR5=MR4	0.291	0.983	0.168	0.435
MR5=MR3	0.001***	0.005***	0.013**	0.012**
MR5=MR2	0.030**	0.344	0.020**	0.044**
Observations	14,672	17,539	19,551	19,551
AR (2)	0.562	0.635	0.475	0.502
Instruments, no	215	215	215	215
Hansen overid	0.487	0.330	0.097	0.089

Notes:
Estimation of equation (5). Selected variables reported.
Interpretation of the interaction variables MRi: $100\times(e^{MRi}-1)\%$
* 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 versus Rest of Sweden. Region Gothenburg and region Malmö not included.
M2: City Stockholm versus rest of Sweden. City Gothenburg and city Malmö not included
M3: Region Stockholm, Gothenburg and Malmö versus Rest of Sweden,
M4: City Stockholm Gothenburg Malmö versus Rest of Sweden

Appendix

Table I:
Basic model, specification in STATA

xtabond2 y L.y L2.y L3.y L(0/1).(H K L E X, laglim(3 .)) O* M S* Y* ,
gmm(l.y H K L E X)
iv(O* M S* Y*) robust nomata twostep

Instruments for first differences equation:
GMM: L(3/.).(L.y H K L E X)
IV: D.(O* M S* Y*)
Instruments for levels equation:
GMM: DL2.(L.y H K L E X)
IV: C O*M S* Y*

Notes
C=constant
Key variables:
y =log labour productivity, *M*=Metropolitan region (Stockholm), *R1*=Non R&D , *R2*= Occasional R&D, *R3*=Persistent R&D, *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.
Control variables:
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, *O1*= domestic independent firm (reference), *O2*= uninational firm, *O3*= domestic MNE, *O4*= foreign MNE, *Y**= year 1997-year 2006, *S** = sector 1-sector 6.

Table II:

Dependent variable is log value added per ordinary labor (y).
Robustness test of results displayed in Table 4, column 1, by changing laglimits. Model M1

	(M1:A)	(M1:B)	(M1:C)	(M1:D)
Laglimits	(3 .)	(3 5)	(4 6)	(5 7)
Key-variables				
MR2 [a]	0.028	0.017	0.010	0.014
	(0.018)	(0.017)	(0.020)	(0.026)
MR3 [a]	0.018	0.017	0.010	0.010
	(0.012)	(0.011)	(0.010)	(0.013)
MR4 [a]	0.056	0.032	0.013	0.013
	(0.028)**	(0.026)	(0.030)	(0.035)
MR5 [a]	0.093	0.082	0.039	0.067
	(0.025)***	(0.025)***	(0.027)	(0.032)**
MR6 [a]	0.122	0.103	0.067	0.091
	(0.034)***	(0.033)***	(0.035)*	(0.041)**
Equality of means [b]				
MR6=MR5	0.261	0.378	0.214	0.397
MR6=MR4	0.036**	0.017**	0.075*	0.064*
MR6=MR3	0.001***	0.005***	0.043**	0.032**
MR6=MR2	0.001***	0.001***	0.038**	0.050*
MR5=MR4	0.216	0.085*	0.399	0.187
MR5=MR3	0.001***	0.003***	0.109	0.035**
MR5=MR2	0.011**	0.009***	0.277	0.168
Instruments				
First diff equ.	L(3/.).	L(3/5).	L(4/6).	L(5/7).
	(L.y h k l e x)	(L.y h k l e x)	(L.y h k l e x)	(L.y h k l e x)
Levels equ.	DL2.	DL2.	DL3.	DL4.
	(L.y h k l e x)	(L.y h k l e x)	(L.y h k l e x)	(L.y h k l e x)
Observations	14,672	14,672	14,672	14,672
AR (2)	0.335	0.348	0.472	0.970
Instruments	215	163	139	115
Hansen overid	0.416	0.337	0.592	0.802

Notes: Estimating equation 5. Only key variables reported.

* significant at 10%; ** significant at 5%; *** significant at 1%. Windmeijer corrected standard error within parentheses.

(a) Reference:MR1= Non Metro&Non R&D. (c) Reference: Independet domestic firms.

(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 versus Rest of Sweden. Region Gothenburg and city Malmö not included.

Endogenous and predetermined variables: y L.y L2.y L(0/1).(h k l e x)

Interpretation of the *laglimits* command ( ): Laglimits (a b) requests lag (a) through (b) of the levels of the instruments for the first difference equation and (a-1) of the difference of the instruments for the levels equation.

Table III:

Dependent variable is log value added per ordinary labor (y).
Robustness test of results displayed in Table 4, column 2, by changing laglimits. Model M2

	(M2:A)	(M2:B)	(M2:C)	(M2:D)
Laglimits	(3 .)	(3 5)	(4 6)	(5 7)
Key-variables				
MR2 [a]	0.052	0.040	0.025	0.024
	(0.022)*	(0.021)*	(0.023)	(0.027)
MR3 [a]	0.015	0.014	0.006	0.011
	(0.011)	(0.010)	(0.009)	(0.012)
MR4 [a]	0.070	0.051	0.033	0.032
	(0.030)**	(0.028)*	(0.032)	(0.035)
MR5 [a]	0.081	0.071	0.048	0.070
	(0.022)***	(0.022)***	(0.022)**	(0.029)**
MR6 [a]	0.157	0.143	0.099	0.130
	(0.041)***	(0.040)***	(0.044)**	(0.056)**
Equality of means [b]				
MR6=MR5	0.030**	0.029**	0.143	0.149
MR6=MR4	0.037**	0.019**	0.124	0.091*
MR6=MR3	0.000***	0.000***	0.029**	0.025**
MR6=MR2	0.001***	0.004***	0.054*	0.046**
MR5=MR4	0.713	0.482	0.598	0.345
MR5=MR3	0.000***	0.000***	0.037**	0.020**
MR5=MR2	0.255	0.215	0.344	0.205
Instruments				
First diff equ.	L(3/.).	L(3/5).	L(4/6).	L(5/7).
	(L.y h k l e x)	(L.y h k l e x)	(L.y h k l e x)	(L.y h k l e x)
Levels equ.	DL2.	DL2.	DL3.	DL4.
	(L.y h k l e x)	(L.y h k l e x)	(L.y h k l e x)	(L.y h k l e x)
Observations	17,539	17,539	17,539	17,539
AR (2)	0.225	0.165	139	0.478
Instruments	215	163	0.472	115
Hansen overid	0.217	0.173	0.592	0.721

Notes: Estimating equation 5. Only key variables reported.

* significant at 10%; ** significant at 5%; *** significant at 1%. Windmeijer corrected standard error within parentheses.

(a) Reference:MR1= Non Metro&Non R&D. (c) Reference: Independet domestic firms.

(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:

M2: City Stockholm versus Rest of Sweden. City Gothenburg and city Malmö not included.

Endogenous and predetermined variables: y L.y L2.y L(0/1).(h k l e x)

Interpretation of the *laglimits* command ( ): Laglimits (a b) requests lag (a) through (b) of the levels of the instruments for the first difference equation and (a-1) of the difference of the instruments for the levels equation.

Table IV:

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

	(M3:A)	(M3:B)	(M3:C)	(M3:D)
Laglimits	(3 .)	(3 5)	(4 6)	(5 7)
Key-variables				
MR2 [a]	0.012	0.008	0.012	-0.001
	(0.012)	(0.021)	(0.013)	(0.017)
MR3 [a]	0.014	0.015	0.014	0.016
	(0.012)	(0.011)	(0.012)	(0.014)
MR4 [a]	0.042	0.034	0.035	0.015
	(0.017)**	(0.017)*	(0.020)*	(0.023)
MR5 [a]	0.082	0.082	0.074	0.082
	(0.022)***	(0.023)***	(0.029)**	(0.035)**
MR6 [a]	0.109	0.103	0.085	0.090
	(0.024)***	(0.025)***	(0.030)***	(0.036)**
Equality of means [b]				
MR6=MR5	0.105	0.216	0.548	0.654
MR6=MR4	0.002***	0.001***	0.048**	0.019**
MR6=MR3	0.000***	0.000***	0.011**	0.020**
MR6=MR2	0.000***	0.000***	0.011**	0.015**
MR5=MR4	0.073*	0.028**	0.127	0.055*
MR5=MR3	0.000***	0.001***	0.022**	0.032**
MR5=MR2	0.002***	0.001***	0.030**	0.032**
Instruments				
First diff equ.	L(3/.).	L(3/5).	L(4/6).	L(5/7).
	(L.y h k l e x)	(L.y h k l e x)	(L.y h k l e x)	(L.y h k l e x)
Levels equ.	DL2.	DL2.	DL3.	DL4.
	(L.y h k l e x)	(L.y h k l e x)	(L.y h k l e x)	(L.y h k l e x)
Observations	19,551	19,551	19,551	19,551
AR (2)	0.082	0.085	0.878	0.455
Instruments	215	163	139	115
Hansen overid	0.097	0.105	0.393	0.422

Notes: Estimating equation 5. Only key variables reported.

* significant at 10%; ** significant at 5%; *** significant at 1%. Windmeijer corrected standard error within parentheses.

(a) Reference:MR1= Non Metro&Non R&D. (c) Reference: Independet domestic firms.

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

Unbalanced data. Dynamic GMM, two-step.

M3: Region Stockholm, Gothenburg and Malmö versus Rest of Sweden.

Endogenous and predetermined variables: y L.y L2.y L(0/1).(h k l e x)

Interpretation of the *laglimits* command ( ): Laglimits (a b) requests lag (a) through (b) of the levels of the instruments for the first difference equation and (a-1) of the difference of the instruments for the levels equation.

Table V:

Dependent variable is log value added per ordinary labor (y).
Robustness test of results displayed in Table 4, column 4, by changing laglimits. Model M4

	(M4:A)	(M4:B)	(M4:C)	(M4:D)
Laglimits	(3 .)	(3 5)	(4 6)	(5 7)
Key-variables				
MR2 [a]	0.026*	0.019	0.015	0.004
	(0.015)	(0.016)*	(0.017)	(0.020)
MR3 [a]	0.016	0.016	0.015	0.014
	(0.011)	(0.010)	(0.011)	(0.013)
MR4 [a]	0.064	0.050	0.043	0.027
	(0.025)**	(0.024)**	(0.027)	(0.029)
MR5 [a]	0.084	0.082	0.074	0.080
	(0.021)***	(0.022)***	(0.028)***	(0.035)**
MR6 [a]	0.133	0.124	0.091	0.108
	(0.030)***	(0.031)***	(0.037)**	(0.046)**
Equality of means [b]				
MR6=MR5	0.032**	0.065*	0.473	0.315
MR6=MR4	0.021**	0.011**	0.135	0.061*
MR6=MR3	0.000***	0.000***	0.025**	0.024**
MR6=MR2	0.000***	0.000***	0.020**	0.019**
MR5=MR4	0.452	0.190	0.246	0.138
MR5=MR3	0.000***	0.000***	0.015**	0.021**
MR5=MR2	0.010**	0.004***	0.024**	0.034**
Instruments				
First diff equ.	L(3/.).	L(3/5).	L(4/6).	L(5/7).
	(L.y h k l e x)	(L.y h k l e x)	(L.y h k l e x)	(L.y h k l e x)
Levels equ.	DL2.	DL2.	DL3.	DL4.
	(L.y h k l e x)	(L.y h k l e x)	(L.y h k l e x)	(L.y h k l e x)
Observations	19,551	19,551	19,551	19,551
AR (2)	0.081	0.165	0.882	0.441
Instruments	215	163	139	115
Hansen overid	0.091	0.173	0.402	0.423

Notes: Estimating equation 5. Only key variables reported.

* significant at 10%; ** significant at 5%; *** significant at 1%. Windmeijer corrected standard error within parentheses. (a) .

Reference:MR1= Non Metro&Non R&D. (c) Reference: Independet domestic firms. Unbalanced data. Dynamic GMM, two-step.

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

M4: City Stockholm, Gothenburg and Malmö versus Rest of Sweden.

Endogenous and predetermined variables: y L.y L2.y L(0/1).(h k l e x)

Interpretation of the *laglimits* command ( ): Laglimits (a b) requests lag (a) through (b) of the levels of the instruments for the first difference equation and (a-1) of the difference of the instruments for the levels equation.

Table VI

Sample Size by Year, Manufacturing and Service firms with 10 or more employees reported in the 2004 Community Innovation Survey

Year	Unbalanced Panel	Balanced Panel
1997	2,220	1,975
1998	2,286	1,975
1999	2,411	1,975
2000	2,529	1,975
2001	2,638	1,975
2002	2,711	1,975
2003	2,808	1,975
2004	2,898	1,975
2005	2,847	1,975
2006	2,749	1,975

Table VII

Distribution of firms after sector classification, percent

	Sweden		M1		M2		M3		M4	
	NP	P	NP	P	NP	P	NP	P	NP	P
Manu HT	4.0	5.0	4.3	12.1	3.1	5.5	4.7	11.5	4.4	7.4
Manu HMT	13.1	19.7	7.0	13.8	3.3	6.8	8.8	17.7	6.5	12.1
Manu LMT	15.3	20.9	5.8	6.3	4.0	3.9	7.6	8.9	5.9	4.6
Manu LT	23.9	24.7	17.2	8.6	21.2	8.7	17.8	9.4	18.3	8.1
Know serv	15.8	13.4	32.4	41.8	39.4	61.2	26.1	34.9	32.4	49.8
Other serv	27.9	16.3	33.4	17.3	28.9	14.0	34.9	17.6	32.2	18.0
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.

M1: Region Stockholm,
M2: City Stockholm
M3: region Stockholm, Large Gothenburg and Large Malmö,
M4: Core Stockholm, Core Gothenburg and Core Malmö,

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