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Abstract

This paper asks three explicit questions, where the first one concerns the impact of a firm's choice of innovation strategy and knowledge resources. The study aims at confirming that firms with a strategy with R&D persistency have a markedly higher productivity, profitability and wage level than other firms. The second question is focused on the location of firms, with a distinction between firms dwelling in a metropolitan region and other firms. The hypothesis is that a metropolitan knowledge milieu may augment the performance of firms. The third question concerns knowledge exchange in regional and global networks that pertain to multinational affiliates. Applying Swedish data on individual firms and their location, the paper shows that firm performance is significantly higher when the three factors R&D persistency, metropolitan location and affiliation to a multinational group are combined.

Keywords: R&D, knowledge, productivity, profitability, regional milieu
JEL-Codes: F23, L25, O31, O33, R11

1. INTRODUCTION

The effects of firms' R&D spending can be studied with regard to private and social return to R&D. There is a long tradition, saying that social returns are considerably higher than private returns (Nelson 1959, and Arrow, 1962). The reason is that there a public dimensions of knowledge and spillover of R&D results from a firm's environment to the firm. Thus, a firm's return to R&D efforts must consider both the individual attributes of a firm and the flow of knowledge and commercialisation opportunities that are present in the firm's environment. One side of the coin is that R&D investors do not appropriate all of the benefits from their investments. The other side is that there are positive spillovers generated by other firms' efforts.

To take the above type of issues into account, the present paper considers three categories of influence on the firm-level impact from own R&D spending. These are (i) the firm's R&D and innovation efforts, (ii) attributes of the firm including its history and its network to other actors, and (iii) influence from the regional milieu of the firm. Factors (ii) and (iii) may be thought of as preconditions for innovation.

The present paper introduces the hypothesis that firms can be distinguished by the R&D strategy they chose. As a first choice, they can select an approach with R&D investments that are persistent over time. A second major choice is to abstain from systematically organised R&D efforts, including occasional R&D attempts. A persistent R&D strategy may reveal itself in accumulated R&D results, often referred to as R&D stock. However, it also implies a learning process, in which the firm develops routines for performing R&D as well as experience in how to commercialise R&D results. This idea about a firm's R&D strategy has been investigated in Hall (2007), where she studies steady state R&D investments, while at the same time considering the development of the value of the firm as a performance variable, where the value refers to the present value of the firm's all future earnings.

A second assumption introduced in this paper is that the regional milieu influences the impact of a firm's R&D strategy. In this context, region refers to a functional urban region, which signifies an area in which the likelihood for face-to-face contacts is much higher than inter-regional contacts (Johansson and Lööf, 2008). Functional regions are frequently proxied by labour market regions (Johansson and Klaesson, 2007).

As observed earlier in the literature, the R&D intensity and performance is influenced by innovation interaction in networks that connect individual firms and influence firms interaction with private and public research institutions (Etzkowitz and Leyersdorf, 2000; Antonelli and Marchionatti, 2003). While retaining this assumption the present paper also considers that the regional milieu has consequences for the development of entrepreneurial knowledge and experience in commercialisation of R&D results. In view of this, the study focus on both R&D impacts on productivity and profits of the individual firm, employing observations on firms in the manufacturing industries.

A third issue considered in the paper concerns long distance knowledge flows which are often assumed to be more frequent and well organised for MNE-firms that can make use of the internal interaction network of a multinational company group.

In this study, we use both the firm's productivity and its profit to reflect the outcome of its R&D investment. In addition, we investigate the impact of R&D on firms' wages. The Schumpeter tradition implies that profit should be the basic performance variable, since the Schumpeter framework puts into focus a firm's expectation to gain temporary monopoly profits, perceived as the reward for bringing innovations to the market. Indeed, one may also argue that it is from gross profits that the firm cover the costs associated with R&D investments. Moreover, in the Schumpeter tradition a firm's incentive to carry out R&D activities is related to expected rewards in the form of profits above the "normal" level. In addition to productivity and profitability, we also use wages as dependent variable in order to test the theoretical model specification

In the subsequent analysis, we consider the role of agglomeration economies in firms' economic performances. In Sweden an urban region with more than one million inhabitants is classified as a metropolitan region. With this definition there are three metropolitan regions; Malmö, Göteborg and Stockholm. Also in this context, there is a motivation to study the profit outcome. In the theory of agglomeration economies, firms benefit productivity advantages that stem from the regional milieu. In equilibrium, the profits based on these advantages are predicted to increase the land rent and hence accumulate among landowners. This would imply that benefits from the regional milieu materialise in the form of higher wages and land values (Fujita and Thisse, 2002).

The paper contributes to the literature on modelling the impact of R&D on value added profitability and wages.. In addition, the following analysis shows that the regional milieu can add to the impacts of R&D on firm performance. Finally, the triple combination of R&D persistency, metropolitan location and multinational affiliation is tested.

The empirical observations are from a Swedish CIS census from year 2004, covering 1767 manufacturing firms. For these firms we consider a production function, with basic inputs such as capital, ordinary labour, and knowledge-intensive labour. Based on such a formulation, we formulate equations for estimating labour productivity and profit per employee, while adding factors describing each firm's preconditions for innovation. The latter include each firm's R&D strategy during the past 3 years, the economic milieu surrounding the firm in the form of localisation and urbanisation phenomena and four categories of ownership classification: domestic non-affiliate, domestic uninational, domestic multinational and foreign multinational.

2. THEORETICAL FRAMEWORK

In this section, we outline the theoretical background for an analysis of how R&D efforts and the regional milieu relate to firm performance. We consider three alternative performance measures: labour productivity, gross profit per employee and wage. The implicit background for the model discussions is profit-maximising firms in an environment of imperfect competition, where each firm perceive a negatively sloping demand. The paper asks two explicit questions, where the first one concerns the impact of a firm's choice of innovation strategy and its associated knowledge resources. The paper aims at confirming that firms with a strategy with R&D persistency have a markedly higher productivity than other firms. The second question is focused on the location of firms, where a distinction is made between firms dwelling in a metropolitan region and firms located in other regions. The hypothesis is that a metropolitan knowledge milieu may augment the productivity of firms.

2.1 Labour Productivity

The productivity of R&D may be analysed by formulating a production function, where the input variables include tangible capital, labour and R&D knowledge. This approach has been promoted by Griliches and leads to "theoretically plausible" estimations of the relation between R&D and a firm's output (and productivity). A standard formulation of a production function for our purposes would be

$$Q = F(z)L^{\alpha_L} C^{\alpha_C} K^{\alpha_K} \qquad (1)$$

where *Q* represents output, recorded as value added, and where *F*(*z*) is a shift function, *L* is labour input, *C* input of tangible capital and *K* input of knowledge capital (Mairesse and Mohnen, 1990). Our empirical analysis is constrained to use cross-section information from one year, and there is no direct information about knowledge assets, *K*, of each firm. However, the data set includes information about each firm's R&D strategy as conducted during the past three years. This makes it possible to identify firms that follow a strategy with persistent R&D investments over a sequence of years. Moreover, the labour force, *L*, can be separated into ordinary labour, *M*, and knowledge-intensive labour, *N*, where the latter category can be associated with a firm's R&D efforts. In order to consider these two aspects, we formulate our production function as follows:

$$Q = F(z)M^{\alpha_M} N^{\alpha_N} C^{\alpha_C} \exp\{\alpha_O D_O + \alpha_P D_P\} \qquad (2)$$

where *N*+*M* =*L*, and D_O and D_P are two dummy variables such that

$$D_O = \begin{cases} 1 & \text{for firms with occasional R \& D} \\ 0 & \text{otherwise} \end{cases}$$

(3)

$$D_P = \begin{cases} 1 \text{ for firms with persistent R \& D} \\ 0 \text{ otherwise} \end{cases}$$

Equation (2) excludes the variable R&D spending to allow for a focus on the target dimension, which is the difference between firms with persistent R&D versus other firms. The latter consists of firms with occasional R&D and firms that do not report any R&D at all during the past three years, although the non-reporting firms may make occasional R&D efforts at other points in time. We should also note that the value-added variable in (2) is influenced by the selected R&D strategy, which affects both physical output and output price.

In order to make the estimation of equation (2) tractable we can replace the variable Q by the normalised variable $q = Q/L$, i.e., labour productivity. An alternative discussed by Griliches and Mairesse (1984) is to consider the variable *Q*/*M*, as a way to separate labour involved in knowledge production, *N*, from other labour, *M*. However, in our framework the selection of a persistent R&D strategy implies that output and R&D activities are complementary parts of an overall firm routine.

A second normalisation is made with regard to capital, where C/L is used as the capital proxy in a re-specified version of equation (2). Observing that $\ln q = \ln Q - \ln L$, we can specify the following linear function for estimation of labour productivity:

$$\ln q = h_q + f(z) + \alpha_M \ln M + \alpha_N \ln N + \alpha_C \ln C + \alpha_O D_O + \alpha_P D_P \qquad (3)$$

where $f(z) = \ln F(z)$, which reflects shift effects related to the regional milieu of each individual firm. These effects are presented and discussed in subsection 2.4. For $\alpha_P > 0$, we can conclude that a persistent R&D strategy yields a higher productivity than in other cases. Moreover, the equation in (3) represents the logarithm of (2) when $h_q = \ln L$.

There is also a complementing way to interpret equation (3). First we observe that for most firms in our sample, $M \approx L$. In this case, we can establish the following approximate result:

$$\ln q = \hat{h}_q + f(z) + (\alpha_M - 1)\ln M + \alpha_N \ln N + \alpha_C \ln C + \alpha_O D_O + \alpha_P D_P \quad (4)$$

where we can expect that $(\alpha_M - 1)$ is negative, given that α_M represents the cost share of labour. Obviously, in (4) $\hat{h}_q$ is a small correction term to compensate for the difference between *M* and *L*.

2.2 Gross Profit and Wages

Value added, Q, represents sales value minus the cost of intermediaries, but can also be calculated as the sum of gross profit, π, and the wage sum, i.e., $Q = \pi + wL$. This means that labour productivity may be written as $Q/L = \pi/L + w$, implying that labour productivity is divided between wage level and gross profit per employee. Observe now that with the specification in (2) we have that

$$\pi = F(z)M^{\alpha_N} N^{\alpha_N} C^{\alpha_C} \exp\{\alpha_O D_O + \alpha_P D_P\} - wL \quad (5)$$

where π_1 may be influenced by R&D efforts that affect both physical productivity and output price. The specification in (5) implies that $\pi/L = Q/L - w$, which means that labour productivity is divided into wage level and profit per employee. Taking logs on both sides yields the linear equation $\ln(\pi/L) = \ln(Q/L - w)$, which is not tractable for direct comparisons with the expression for $\ln q = \ln(Q/L)$ in (5). However, we may consider the case when the wage is a fraction, ω, of the labour productivity so that $w = \omega Q/L$. In this case, $Q/L - w = (Q/L)(1-\omega)$, and we can write

$$\ln(\pi/L) = h_\pi + f(z) + \alpha_M \ln M + \alpha_N \ln N + \alpha_C \ln C + \alpha_O D_O + \alpha_P D_P \quad (6)$$

According to this formulation, profit per employee will be high in firms with a high labour productivity. For α_P>0, productivity is larger for firms with persistent R&D and high knowledge intensity. As we shall argue, such firms have a larger amount of knowledge capital per output than have other firms. We also observe that equation (6) approximates the equation in (2.2) when h_π = $\ln L$ + $\ln(1-\omega)$, which implies that $h_q >$ h_π.

Consider now the approximation applied in formula (4). A similar approximation for the gross profit equation in (7) yields

$$\ln(\pi/L) = \hat{h}_\pi + f(z) + (\alpha_M - 1)\ln M + \alpha_N \ln N + \alpha_C \ln C + \alpha_O D_O + \alpha_P D_P \quad (7)$$

As a final step, let us recall the approximation above, where we assume that $w = \omega Q/L$. We can of course use this assumption to formulate a wage equation as specified in (8):

$$\ln w = \hat{h}_w + f(z) + (\alpha_M - 1)\ln M + \alpha_N \ln N + \alpha_C \ln C + \alpha_O D_O + \alpha_P D_P \quad (8)$$

where $\hat{h}_w =$ $\hat{h}_q + \ln\omega$, which means that $\hat{h}_q > \hat{h}_w > \hat{h}_\pi$, since $\omega > (1-\omega)$, which means that $\ln(1-\omega) < \ln\omega < 0$. We may also define h_w = $\hat{h}_w + \ln L$, to conclude that $h_q > h_w > h_\pi$. The relations (i) $\hat{h}_q > \hat{h}_w > \hat{h}_\pi$ and (ii) $\alpha_M - 1 < 0$ will be tested in the regression analysis (Table 3).

2.3 Metropolitan Regions versus other Regions

In contemporary affluent economics, economic activities take place primarily in urban space, reflecting the importance of agglomeration. This idea can be traced back both to Adam Smith (1977, 1776) in his emphasis on the size of a local economy and Alfred Marshall (1920) in his discussions of external economies of scale. Smith's discussion is about the size of local demand and suggests a "modern" version of the home-market effect for service supply, whereas Marshall indicates the importance of local knowledge flows between interacting entrepreneurs.

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 improves 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 the present paper we first observe that firms have three types of cost advantages in large urban regions. First, proximity reduces the cost of deliveries to customers (where customers include other firms). Second, proximity reduces the cost of firms in their recruiting of employees. Third, proximity reduces cost of information and knowledge exchange. The larger accessibility in various dimensions also brings about positive productivity effects, such that the individual firm (i) gets greater accessibility to alternative and differentiated inputs, (ii) gets greater accessibility to a varied set of customers, (iii) gets greater accessibility to a labour supply that contains a variety of specialist, and (iv) gets greater accessibility to knowledge sources and flows of ideas.

In addition, a metropolitan region has a large labour market with diversified job opportunities and a labour supply with multiple competencies. An intense labour mobility of persons switching from one employer to another, includes also persons that change from being employed to starting a new firm.

The literature argues that the intensity of knowledge and information flows are a particularly relevant location characteristic in the context of innovation (Feldman 1999, Glaeser 1994). This type of flows provides firms with knowledge and information of novel products, designs, technologies and technical solutions, and can constitute the basis for a firm's innovation ideas (Andersson and Johansson 2008). Several studies using proxies for the potential of spatial knowledge and information flows find results that are consistent with such a hypothesis. Innovation activities are for example more concentrated in space than standard production activities (Audretsch and Feldman 1996), patent citations are geographically localized (Jaffe et al. 1993) and innovations tend to diffuse faster within clusters (Baptista 2000).

Geographic proximity and density are frequently shown to be positively related to innovation and productivity (Ciccone and Hall 1996, Rauch 1993). Dense urban regions with diverse industries and knowledge sources offer rich opportunities to interact with customers, knowledge intensive business services, universities and other 'knowledge-handlers'. Another diffusion factor is the flow of labour and technical personnel between firms, which is greater and more frequent in dense locations (Almeida and Kogut 1999, Moen 2005, Fallick et al. 2006).

The arguments put forward about the regional economic milieu form the basis for the specification of the shift factor, $F(z)$, which is introduced in the production function in formula (1). In the specification the following explanatory variables are introduced as arguments of the shift function $F(z_1, z_2, z_3) = \exp\{\beta_1 D_2 + \beta_2 D_2 + \beta_3 D_3\}$, where D_1 = 1 for locations in the Stockholm metropolitan region, D_2 = 1 for locations in the Göteborg metropolitan region, and D_3 = 1 for locations in the Malmö metropolitan region.

2.4 Knowledge transfer and corporate ownership structure

Knowledge transfers provide a potential to increase the revenues from firms' investment in research and development by acquiring access to technological assets of other firms locally and globally. The justification for incorporating ownership structure in the present study can be traced back to the literature on globalization of R&D as well as the literature on innovation systems. Both suggest that multinational enterprises, MNEs, are in a special position to handle global knowledge transfer.

This paper asks what ownership can add to the importance of internal knowledge accumulation through a persistent R&D- strategy and location in a metropolitan region with a larger local market, with proximity externalities relating to customers, suppliers, universities and knowledge service providers as well as a greater share of knowledge-intensive labour and knowledge-intensive service firms than elsewhere. A priori, it can be assumed that the effect of network activities between multiple affiliates as well as a verity of local and global cooperation partners in formal and non-formal collaboration arrangements, linked together by complex organizations within and across regions and nations will show up in firms' balance sheet.

3. DECRIPTIVE STATISTICS AND ECONOMETRIC FRAMEWORK

3.1 Economic statistics for three Categories of firms

We base our econometric analysis on observations from a set of manufacturing firms in Sweden, with 10 or more employees in a representative sample from Community Innovation Survey (CIS) IV. The survey 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 it covers both manufacturing and service sectors. However, in this paper, the analysis is constrained to manufacturing firms.

To obtain the full data set we have merged the survey data with information from a Statistics Sweden, which contains information about all firms in Sweden including sales, profitability, value added, capital structure, intermediates, gross investment, educational data, corporate ownership structure information, trade statistics, patent data, as well as location characteristics. In addition, the database has information on the local milieu of the firms such as spatial labour market and population statistics by industry across all urban areas (municipalities).

The total number of manufacturing firms in the data set is 1767, and all these observations are used in regression equations for productivity. All these observations contain only firms with a positive value added, a result from removing 29 original observations. When estimating equations for gross profit per employee, firms with below-zero gross profit have been excluded, and this reduces the number of observations in this case to 1712.

In order to ensure that the data are suitable for our estimation purposes, we have imposed additional restrictions on the sample. A first restriction was the censoring of value added to be less than 80% of sales (18 changes made). Second, profitability was censored to 80% of sales (1 change made). Finally, gross investment was forced to be less than 2 times sales (8 changes)

As already mentioned, we have added information about a set of economic variables for each firm. Some of this information is presented in Tables 1 and 2. The information about mean values is reported for the three categories of firms, separated with regard to the R&D strategy employed by each firm. The tables inform that around 40 percent of the population consists of firms that do not report any R&D, whereas more than 30 percent report occasional R&D, and just below 30 percent have persistent R&D spending.

Table 1 reveals that value added and wages as a fraction of sales are slightly larger among non-R&D firms as compared to R&D firms while the opposite is found for profitability and physical investments. This information has to consider that sales per input factors (such as labour force or capital) are larger for firms with persistent R&D. Thus, the major difference between the three categories is that the third type of firms on average has larger R&D spending and higher values of intermediary inputs.

In the empirical analysis, we have exploited three categories of information on the CIS firms, namely: (i) R&D-status, (ii) firm characteristics and (iii) conditions in the regional milieu that can be associated to external knowledge relevant for each individual firm. Table 2 presents three variables, which will appear as dependent performance indicators in regression equations. These are value added and gross profit and wages per employee, and for each of these variables, the values are consistently highest for firms with a persistent R&D strategy and lowest for non-R&D firms. A persistent R&D strategy is associated with more than 20 percent higher labour productivity and more than 40 percent larger gross profits per employee than what applies for non-R&D firms. Another message is the similarity between non-R&D firms and those that carry out R&D investments occasionally.

Compared with other categories of firms, those with a persistent R&D strategy distinguish themselves by a clear orientation towards utilizing knowledge resources and making development efforts. In particular, we observe that they have higher (i) R&D intensity, (ii) knowledge intensity, and (iii) share of firms in industries classified High-technology and Medium-High-technology. On average, these firms have larger sales and intermediate inputs per employee, and the firm size (number of employees) is larger than for other categories of firms. Consequently, their pre-conditions for designing an R&D strategy are more favourable than for other firms.

Table 2 also presents descriptive statistics with regard to (i) corporate ownership and structure, (ii) financial structure, (iii) agglomeration economies, and (iv) metropolitan effects. There are four categories of corporate structure, where non-affiliate firms do not belong to a company group, uninational firms belong to a company groups with all units located in Sweden. The two remaining categories are multinational company groups, with foreign and domestic ownership, respectively. The table shows that more than 70 percent of all firms with R&D persistency are multinational firms. Obviously, it is especially these firms which have enough resources to afford the formation of a persistent R&D strategy. Therefore, we find it necessary to investigate if our regression results remain intact when we control also for corporate structure.

3.2 Metropolitan regions

In order to examine the impact of metropolitan economies of the described type for innovating firms, the present study considers Sweden’s three metropolitan regions which all are integrated labour market regions and mutually separated by long distances. According to the delineation of Sweden into 81 labour market regions there are three metropolitan regions, where the Stockholm region is the largest, the Gothenburg region is the second largest, and the Malmö region is the smallest.

The impact from a location in each of these three regions is estimated with reference to 20 medium-sized regions and 58 small regions. The three metropolitan regions are separated by long distances. Moreover, an overwhelming majority of the medium-sized and small regions are in turn separated by long distances from any of the metropolitan regions.

The design of the study does only allow one link of spatial autocorrelation, namely the influence on the performance level that firms in a small or medium-sized region could get because of a close distance to one of the metropolitan regions. In the few cases where such proximity links could be identified, these cases would reduce the difference in performance between firms in a metropolitan environment and other firms.

An important issue is that there may be serious spatial dependence between firms inside each of the three metropolitan regions. We do not argue against this possibility. In fact, the hypothesis that metropolitan regions offer a milieu that affects firm productivity upwards is indeed compatible with the presence of such spatial dependence.

A second and related issue is how representative the subpopulations of firms in each of the metropolitan regions are. The answer is that the samples from each of the three regions are large enough to allow the comparison we make between the three largest regions and all other regions. At the same time the sample from each of the medium-sized regions is small. In this way, the available data set does not allow any finer spatial resolution than the one applied in the study. However, the data allows for a reliable comparison of metropolitan and non-metropolitan firm performance.

3.2 Econometric framework

Econometrically we will estimate equation (1) by ordinary least squares techniques, which in matrix form, can be expressed as

$$y = x\beta + \varepsilon \tag{3.1}$$

where variable *y* is log labour productivity and log profitability per employee respectively. The productivity equation and the profitability equation have both three different specifications: (i) basic, (ii) basic added with metropolitan variables (iii) basic added with corporate ownership variables. For the *basic specification*, the following exogenous variables, x_{Bi} , are used for firm *i*:

$$x_{Bi} = \{\ln M_i, \ln N_i, \ln C_i, D_{0i}, D_{Pi}, T_{1i}, T_{2i}, T_{3i}\} \tag{3.2}$$

where M_i, N_i and C_i denote firm *i*'s ordinary labour, knowledge-intensive labour and machinery investment. The second category of labour has at least three years university education. We also note that capital is replaced by machinery investment, assuming proportionality between these investments and physical capital. Moreover, D_{Oi}, D_{Pi}, T_{1i}, T_{2i} and T_{3i} are dummy variables for occasional R&D

firms, persistent R&D firms, and three industry sectors, classified as High-technology, Medium-high-technology and low technology, respectively.

The second group of regression equations applies the *metropolitan specification*, which recognises the importance of a firm's location in a metropolitan area. This is investigated in the third specification by including three dummy variables V_{1i}, V_{2i}, V_{3i}, which refer to the Stockholm, Göteborg and Malmö regions, respectively. The assumption is that the metropolitan economic milieu may influence productivity and profitability in a positive way.

We also present results for the basic specification and controlling for corporate ownership structure. The question in this case is the following: are the regression results robust, so that they remain the same also when corporate structure and ownership are included as additional explanatory factors. This control is motivated by the fact that firms belonging to a multinational group have a high frequency of R&D persistency.

4. EMPIRICAL RESULTS

The aim of this paper is twofold. First, it investigates the hypothesis that there is a systematic difference in the effect on a firm's performance when the firm follows a persistent R&D strategy and when it does not. Thus, the impact on productivity and profitability should be different when we compare the effect of new knowledge created through persistently repeated and occasional R&D engagements. The second aim is focused on the location of firms, where a distinction is made between firms dwelling in a metropolitan region and firms located in other regions. The hypothesis is that a metropolitan knowledge milieu may augment the productivity of firms. In addition we investigates the importance of spillovers due to the ownership structure, assuming that multinational firms are in an advantageously position.

Table 3 reports productivity and profitability estimates using the two basic equations 4 and 7. Table 4 includes the effect of location in three different metropolitan areas in the basic model, while Table 5 considers corporate ownership structure in the two equations. The final Table builds on the results from Table 3-5 and investigates the influence from metropolitan areas, persistent R&D and the ownership structure in a common framework.

4.1 The Effects of a Firm's R&D Strategy

The results shown in Table 3 are based on equations 4, 7 and 8. The profit equation presented in column 2 contains 1,712 observations, which means that 55 firms have been dropped from the original sample. This is a consequence of 55 negative figures for profitability, which we cannot combine with the log transformation used in the model specification. Therefore, in the regression analysis the elasticity of profitability with respect to its determinants will be somewhat overestimated. The other two equations, labour productivity (column 1) and wages (column 3) observe 1,767 firms.

From the theory discussion in Section 2, we expect a similar outcome of the profitability and wage equations as with our productivity equation, with the additional remark that the intercept should be higher for the productivity equation. This is confirmed by Table 3 which shows that the coefficient estimates are consistent between log of value added per employee, log of profitability per employee and log wage per employee.

First, we see that firms conducting R&D on occasional basis are not different from non-R&D firms. These results support Klette and Kortum (2002) who argue that many firms engage in R&D only when the market attraction of their main product(s) decreases and it generates less value to the balance sheet. Such firms temporarily invest in R&D in order to upgrade their obsolete products and routines. For the typical occasional R&D-firm, the coefficient is negative in all three equations, but just outside the lowest acceptable degree of significance (10%) in the case of productivity, not significant in the productivity equation and within the 10% level.

Let us now turn to persistent R&D-performers. Geroski et al (1993) suggest that this category of firms creates two kinds of outcomes. The first is the innovation itself. The other is a culture of learning processes, which has a profound impact on the efficiency of the firm. Such a culture establishes routines for repeated renewal activities. The estimates for the average firm shows that conducting R&D regularly is associated with productivity and profitability performance superior to other firms. Moreover, controlling for level of education, firm size, sector and R&D-strategy, the wage level are significantly higher. Interpretation of the order of magnitude of the dummy variables D with 100× (e^{Di}-1) % it is shown that firms with persistent R&D create about 9% higher value added per employee than other firms. This is transformed into both higher profitability and higher wages. In particular, the profitability differs considerably, although the reported 15% is overestimated.

Notable is that the size of the estimated coefficients and the degree of significance as well, indicate that the association between wages and R&D strategy is somewhat weaker than that between productivity and R&D strategy and profitability and R&D strategy. Our interpretation is that this reflects the centralized wage bargaining system in Sweden.

In our analysis we separate employees with at least three years university education from other employees and label the first category as “knowledge-intensive labour”, while the remaining part of the labour force is classified as “ordinary labour”. In the sample, the pertinent human capital corresponds to 6% percent of the work force among both non-R&D and occasional R&D firms, whereas it is considerable higher for persistent R&D firms (13%). The regression results show that, among labour inputs, only knowledge-intensive labour (human capital) correlates significantly and positively with productivity.

But how can we understand that the coefficient estimate for employment other than university graduated in fact is negative and weakly significant for the median and the high productive firm? The reader should recall that the theory discussion in Section 2 predicts a negative coefficient for ordinary labour inputs. Moreover, the effect of ordinary labour is partly captured in the coefficient estimate for (log) investment in machinery and equipment. Removing physical capital from the productivity equation, the estimated effect for ordinary labour is positive and significant for firms with a low level of productivity and positive but not significant for other categories of firm. The interpretation is that the size of investments partly reflects the size of the firm. When we remove investments, then ordinary labour take over this role.

The sign and size of the highly significant physical capital estimate is in accordance with the suggestions in the literature on production functions. The bottom of Table 3 report that productivity is closely associated with the technology level of firms. Notable is that the superior productivity performance among high technology firms are not transformed into superior profitability. Probably, this reflects higher cost for R&D and skilled employees compared to other firms.

The next step is to examine a firm’s R&D strategy with regard to the individual firm’s gross profit per employee. From the theory discussion in Section 2, we expect a similar outcome as with our productivity equation, with the additional remark that the intercept should be lower for the profit equation. Moreover, also with the profit equation, theory predicts a negative coefficient for ordinary labour.

In accordance with our theoretical prediction, a comparison of the three empirical results presented in Table 3 shows that the intercepts is highest for the productivity equation, followed by the intercepts for the wage equation, and with the lowest for the profit equation.

In the proceeding discussion, we narrow down the discussion to the productivity and profitability equations and focus on the roles of localization and ownership, controlling for R&D-strategy.

4.2 The regional milieu

In an earlier study (Johansson, Lööf and Rader Olsson, 2005), using Swedish CIS-data for year 2000 have shown that firms located in the largest Swedish metropolitan region exhibits a superior return to R&D investments than firms located elsewhere in the country. With the same data Johansson and Lööf (2008) also show that the probability of finding innovative firms was higher for the Stockholm region than elsewhere in the country. With the help of more extensive and detailed data we now examine the importance of external knowledge on firm performance expressed as labour productivity and profits per employee. The estimated effects are displayed in Table 4.

As noted by previous literature, dense urban regions with richness in sectors and knowledge sources offer interaction opportunities with different actors embodying relevant knowledge, such as customers, knowledge intensive business services, universities and other ‘knowledge-handlers’. Moreover, flows of labour and technical personnel between firms tend to be greater in dense locations, which stimulate the diffusion of competencies and knowledge embodied in people (Almeida and Kogut 1999, Moen 2005, Fallick et al. 2006). As suggested in Section 2, such features can be related to the regional milieu offered by metropolitan regions.

While column 1 examines the influence from a location in each of Sweden’s three metropolitan regions on labour productivity of firms, the effect on profitability are investigated in column 2. The results in the table indicate strongly that Stockholm, the largest metropolitan region, has the effect of augmenting the labour productivity of manufacturing firms located in the region. The estimated Stockholm-effect is quite sizeable (12%) and highly significant. For the second largest metropolitan region, Göteborg, we also find that there is a positive metropolitan effect for the average firm. The coefficient size is around 7%. The estimate for Malmö is not different from firms located in the reference group, Rest of Sweden.

Taking into account that we have dropped firms with negative profitability, we expect higher coefficient estimates for the profitability equation concerning the return on investments in R&D, knowledge and physical capital. However, this is not the case for the metropolitan variables. Localization to Stockholm or Göteborg is more closely associated with productivity than profitability. This observation may be associated with the theory of agglomeration economies (Fujita and Thisse, 2002), which suggest that higher productivity in urban agglomerations are not translated to higher profits in equilibrium. The explanation is that parts of or all productivity benefits are transferred into higher wages and land rents.

Tables 3 and 4 analyse the value added and the gross profits per employee. We find in both cases that firms, which report that they apply a persistent R&D strategy have higher productivity and larger profits per employee. However, in Section 3 we reported that more than 70 percent of all firms with R&D persistency are multinational firms. In order to check that our results is not a purely MNE-phenomenon. In Table 5, we provide strong evidence that the findings on R&D-strategy remain robust also when controlling for corporate ownership structure.

The positive and significant coefficients associated with persistent R&D-strategy, the two largest metropolitan areas in Sweden and corporate ownership structure presented in Tables 4 and 5, are tested in an integrated framework in Table 6. In order to reduce the space, only labour productivity is considered . Column 1 shows that labour productivity is, on average, about 10 percent higher among firms in Stockholm or Göteborg, controlling for firm size, human capital and physical capital and manufacturing sector. In a sensitivity test, we find that the result is almost the same when we also control for equity and presence on export markets.

Column 2 investigates the composite effect of both metropolitan area (the two largest metropolitan regions in Sweden) and persistent R&D. It appears that a regional environment characterized by proximity between firms and a higher intensity of knowledge flows has a positive and significant effect on firms conducting R&D-investments on a regular basis. The size of the estimate is substantial indicating that the agglomeration advantages for persistent R&D firms corresponds to more than 20 percent higher level of labour productivity. The reference group is non R&D firms and occasional R&D firms located in the rest of Sweden.

Column 3 analyzes the interaction between metropolitan region, persistent R&D-strategy and MNE ownership. Thus, it considers the composite effect of three categories of knowledge influence on firms' economic performance. The reference group is non MNE-firms in the rest of Sweden with no or only occasional R&D-activities. The results with respect to the control variables suggest that persistent R&D firms located in one of the two largest metropolitan regions have an additional productivity premium from being part of global network.

5. CONCLUSIONS

There is a stylized fact that R&D-spending has a significantly positive effect on the level of productivity and profitability. In the present paper the above issue is illuminated from a new angle, by disregarding the annual spending on R&D and instead classifying each firm in accordance with the innovation strategy it applies: with no, occasional or persistent R&D efforts. We assume that a firm's choice of strategy (specified by these three categories) is a lasting or endurable choice, where firms that engage in persistent R&D efforts develop a resource base with a larger share of knowledge workers, while maintaining the R&D skills of the labor force and the R&D routines of the firm.

The empirical observations are from a Swedish CIS census from year 2004, covering 1767 manufacturing firms. For these firms we consider a production function, with basic inputs such as capital, ordinary labour, and knowledge-intensive labour. Based on such a formulation, we introduce equations for estimating labour productivity and profit per employee, while adding factors describing each firm's preconditions for innovation. The latter include each firm's R&D strategy during the past 3 years, the economic milieu surrounding the firm in the form of localisation and urbanisation phenomena as well as its network to other actors, and the firm's affiliation to a multinational company group.

First, the paper theoretically models the consequences of R&D on value added and profit per employee. Given this the analysis answers three questions. First, does the qualitative information about firms' R&D persistency predict better performance among such firms compared to other firms? Second, when controlling for R&D-persistency, is it possible to detect an additional positive influence on firm performance from location in a metropolitan region. This latter factor is assumed to reflect local knowledge flows. The third question concerns long distance knowledge flows which are often assumed to be more frequent and well organised for MNE-firms that can make use of the internal interaction network of a multinational company group. Thus, we examine to what extent MNE-firms have superior performance than other firms, controlling for R&D persistency and multinational affiliation.

The econometric analysis provides confirmative evidence implying that there are positive impacts on economic performance from (i) R&D persistency, (ii) metropolitan location and (iii) and MNE affiliation. As a second step to clarify the importance of these three factors, the statistical analysis provides evidence to the hypothesis that the combination of metropolitan location and R&D persistency augments firm performance more than just R&D persistency, and that the triple combination of R&D persistency, metropolitan location and multinational affiliation has the strongest impact on firm performance.

In summary: Applying Swedish data on individual firms, their location, and their corporate ownership, the paper shows that firms that follow a strategy with persistent R&D efforts have a distinctly higher level of productivity and profitability than other firms do. If these firms in addition have a metropolitan location, the productivity is further increased. Finally, the productivity is lifted further upwards for those firms that combine MNE-affiliation, R&D persistency and location in Sweden's two largest metropolitan regions.

It should be observed that including the persistency variable in our regressions, implies that we are able to capture a temporal phenomenon also with cross-section methods. Having said this, it is evident that an extension of the approach by employing time series information about the observed firms would allow for an even sharper analysis. Another extension would be to combine information on the size and the permanency of R&D spending. Again, this would be more appropriate in a model with time series information.

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Table 1
Economic statistics, expressed as fraction of sales and fraction of capital

	Non R&D firms		R&D-firms			
			R&D Occasionally		R&D Continously	
	N=762		N=535		N=470	
	Mean	Std. Dev	Mean	Std. Dev	Mean	Std. Dev
Value added	0.384	*0.162*	0.368	*0.142*	0.344	*0.141*
Gross profit	0.158	*0.110*	0.160	*0.097*	0.162	*0.120*
Wages	0.228	*0.115*	0.210	*0.098*	0.184	*0.118*
Intermediates	0.613	*0.166*	0.630	*0.146*	0.645	*0.145*
Physical invest.[a]	0.104	*0.139*	0.119	*0.143*	0.132	*0.152*
R&D-investment	0.000	*0.000*	0.057	*0.172*	0.067	*0.134*

(a) Machinery and equipment investments

Table 2

Summary statistics

	Non R&D firms		R&D-firms			
			R&D Occasionally		R&D Continously	
	N=762		N=535		N=470	
	Mean	Std. Dev	Mean	Std. Dev	Mean	Std. Dev
R&D investments [a]	0	*0*	70	*181*	111	*151*
Value added [a]	514	*323*	525	*279*	664	*354*
Gross profit [a]	239	*300*	250	*253*	353	*333*
Wages [a]	275	*77*	275	*59*	310	*77*
Stockholm[b]	0.157	*0.364*	0.108	*0.311*	0.148	*0.356*
Goteborg[b]	0.106	*0.308*	0.069	*0.253*	0.117	*0.321*
Malmo	0.061	*0.240*	0.063	*0.244*	0.061	*0.240*
Rest of Sweden	0.674	*0.468*	0.758	*0.428*	0.672	*0.469*
Firm size, employment	93	*772*	85	*156*	466	*1,559*
Physical invest. [a]	1,171	*1,332*	1,113	*856*	1,624	*1,992*
Ordinary labour	87	*753*	80	*146*	385	*1,181*
Knowledge labour	7	*37*	6	*18*	84	*455*
Non Affiliate [b]	0.378	*0.485*	0.287	*0.452*	0.143	*0.350*
Uninational [b]	0.329	*0.470*	0.305	*0.461*	0.170	*0.376*
Domestic MNE [b]	0.147	*0.354*	0.185	*0.388*	0.364	*0.481*
Foreign MNE [b]	0.144	*0.351*	0.287	*0.452*	0.321	*0.467*
High technology [b]	0.066	*0.249*	0.076	*0.265*	0.145	*0.352*
High medium tech [b]	0.228	*0.419*	0.249	*0.433*	0.357	*0.479*
Low medium tech [b]	0.260	*0.439*	0.271	*0.455*	0.221	*0.415*
Low technology [b]	0.444	*0.497*	0.402	*0.490*	0.275	*0.447*

Notes: (a) Per employee, in 1000 Swedish Crowns. (c) as a fraction of all firms.

Table 3

Log value added per employee as dependent variable in the basic equation

	Value added	Profitability	Wages
R&D Occasion. [a]	-0.038	-0.006	-0.021
	(1.54)	(0.16)	(1.73)
R&D Persist [a]	0.088	0.143	0.027
	(3.09)***	(3.24)***	(1.97)
Log Investment	0.057	0.108	0.014
	(10.04)***	(12.43)***	(5.22)***
Log Knowl. labor	0.031	0.044	0.027
	(6.81)***	(6.24)***	(12.07)***
Log Ord. labor	-0.068	-0.111	-0.030
	(5.68)**	(5.97)***	(5.17)***
High technology [b]	0.112	0.069	0.098
	(2.85)***	(1.12)	(5.13)***
High med. tech. [b]	0.078	0.078	0.052
	(2.97)***	(1.94)	(4.06)***
Low med. tech [b]	0.046	0.054	0.009
	(1.74)	(1.32)	(0.74)
Constant	5.972	4.887	5.601
	(123.69)***	(65.61)***	(238.37)***
Observations	1767	1712	1767

Notes:

Only firms with positive profit are considered. Absolute value of t statistics in parentheses,

** significant at 5%; *** significant at 1%

(a) Reference is Non-R&D firms, (b) Reference is low technology firms

Interpretation of the dummy variables , D is $100\times(e^{D_i}-1)\%$

Table 4

Influence from a metropolitan milieu

	Value added	Profitability
R&D Occasion. [a]	-0.029	0.001
	(1.15)	(0.02)
R&D Persist [a]	0.093	0.147
	(3.26)***	(3.31)***
Log Investment	0.058	0.109
	(10.28)***	(12.53)***
Log Knowl. labor.	0.029	0.042
	(6.12)***	(5.80)***
Log Ord. labor	-0.066	-0.109
	(5.52)***	(5.85)***
High technology [b]	0.102	0.060
	(2.60)***	(0.98)
High med. tech. [b]	0.080	0.081
	(3.05)***	(2.00)**
Low med. tech [b]	0.050	0.056
	(1.89)	(1.38)
Stockholm [c]	0.111	0.106
	(3.59)***	(2.23)**
Goteborg [c]	0.069	0.029
	(1.96)**	(0.53)
Malmo [c]	-0.034	-0.056
	(0.79)	(0.82)
Constant	5.927	4.850
	(117.77)***	(62.12)***
Observations	1767	1712

Notes:

Only firms with positive profit are considered. Absolute value of t statistics in parentheses,
** significant at 5%; *** significant at 1%

(a) Reference is Non-R&D firms, (b) Reference is low technology firms, (c) Reference is Rest of Sweden

Interpretation of the dummy variables , D is $100\times(e^{D_i}-1)\%$

Table 5
Influence from the corporate ownership structure

	Value added	Profitability
R&D Occasion. [a]	-0.042	-0.015
	(1.73)	(0.39)
R&D Persist [a]	0.079	0.127
	(2.76)***	(2.89)***
Log Invest	0.054	0.104
	(9.61)***	(12.01)***
Log Human cap.	0.025	0.035
	(5.33)***	(4.84)***
Log Labour	-0.085	-0.138
	(6.93)***	(7.22)***
High technology [b]	0.108	0.062
	(2.78)***	(1.03)
High med. tech. [b]	0.066	0.059
	(2.51)***	(1.46)
Low med. tech [b]	0.039	0.043
	(1.47)	(1.06)
Domestic MNE	0.089	0.146
	(2.78)***	(2.94)***
Foreign MNE	0.133	0.194
	(3.95)***	(3.71)***
Non affiliate	-0.064	-0.095
	(2.33)**	(2.27)**
Constant	6.034	4.985
	(120.01)***	(64.21)***
Observations	1767	1712

Notes:

Only firms with positive profit are considered. Absolute value of t statistics in parentheses,

** significant at 5%; *** significant at 1%

(a) Reference is Non-R&D firms, (b) Reference is low technology firms, (c) Reference is Domestic non-affiliate firms.

Interpretation of the dummy variables , D is $100\times(e^{D_i}-1)\%$

Table 6

Influence from metropolitan areas, persistent R&D and the corporate ownership structure

	1	2	3
Metro [a]	0.099	-	-
	(4.03)***		
Metro [a] and persistent R&D	-	0.202	-
		(4.85)***-	
Metro [a] and persistent R&D and MNE	-		0.244
			(4.96)***
Log Invest	0.059	0.058	0.057
	(10.60)***	(10.34)***	(10.23)***
Log Human cap.	0.031	0.031	0.032
	(6.98)***	(6.95)***	(7.14)***
Log Labour	-0.061	-0.066	-0.069
	(-5.19)***	(-5.57)***	(-5.83)***
High technology [b]	0.118	0.103	0.108
	(3.02)***	(2.63)***	(2.56)**
High med. tech. [b]	0.091	0.079	0.079
	(3.49)***	(3.06)***	(3.06)***
Low med. tech [b]	0.054	0.046	0.046
	(2.06)***	(1.75)	(1.75)
Constant	5.907	5.907	5.907
	(121.04)***	(125.55)***	(125.55)***
Observations	1,767	1,767	1,767

Notes:

Only firms with positive profit are considered. Absolute value of t statistics in parentheses,
** significant at 5%; *** significant at 1%

(a) The two largest metropolitan areas in Sweden

(b) Reference is low technology firms
Interpretation of the dummy variables , D is $100\times(e^{D_i}-1)\%$