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The Impact of Firm's R&D Strategy on Profit and Productivity

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Abstract

This paper investigates how a firm's R&D strategy influences the firm performance as measured by productivity and profitability. A formal production model is introduced to define and interpret alternative ways of measuring the impact of R&D. Studying 1,767 randomly selected firms from the Swedish manufacturing sector, the main findings are: (i) firms which apply persistent R&D perform better than firms with occasional as well as no R&D, (ii) occasional R&D is associated with lower performance than no R&D, and (iii) in quantile regressions the positive effect from R&D persistency is lacking for low productivity firms (lowest quartile) indicating a non-linear response. Moreover, the analysis recognises the different roles of ordinary and knowledge labour in production when specifying alternative performance measures and when identifying knowledge labour as a firm's R&D capacity, which has a highly significant impact on firm performance. Introducing a formal production model in order to define and interpret alternative ways of measuring the impact of R&D, we apply simple ordinary OLS and quantile regressions on the economic model for analyzing the importance for a particular R&D strategy on firms' productivity and profitability. To the best of our knowledge, we believe that the main findings of the analysis make contributions to the R&D literature.

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1. INTRODUCTION

The economic literature on R&D spending and productivity continues to exhibit a phenomenal growth. The principle tool in this research has been a production function, in which cumulative R&D efforts represent the firm's input of knowledge capital (Griliches, 2000). The literature has convincingly shown that the impact of current R&D on current productivity depends crucially on past R&D (Griliches , 1979). An important feature of using the firm's R&D stock is that it functions as an indicator of both current knowledge of the firm and its past experience with R&D efforts and commercialization of the R&D results

There is an issue of accumulation and depreciation of firms' knowledge capital (Nadiri and Prucha, 1996; Klette and Johansen, 1998). In principle, the accumulation of knowledge capital should be treated in the same way as that of physical capital, using the "perpetual inventory" process as a common framework. When constructing the knowledge stock variable it is desirable to have a long history of each firm's R&D expenditure, while micro data series typically are characterised by "short T and large N".

The present paper focuses on the experience aspect by introducing a variable that reflects a firm's R&D efforts during a three-year period preceding the year when the firm's inputs and output are observed. When a firm develops knowledge by following a strategy of persistent R&D efforts it is less evident why this innovation skill should depreciate over time, in contradistinction to the R&D-stock (Hall, 2007). The innovation experience is the result of "learning by doing", establishing R&D routines.

An R&D strategy represents a sustainable feature of a firm's behaviour that we can detect also in a cross section analysis where the data inform about past history. Our approach can be linked to observations made by Scott (1984) who examines US firms over a long time period and finds that a large share of the variance in individual firms' R&D intensity is captured by firm specific effects, reflecting the R&D strategy of individual firms (see also Klette and Kortum, 2004).

In our case, the basic idiosyncrasy is between firms' that follow a persistent R&D strategy and those that do not. Persistent R&D efforts also imply that current observations of the pertinent firm's R&D capacity indicates a durable or slowly changing asset. The idea that firms can be classified with regard to their time-invariant decisions on R&D investment can be found also in Hall 2007, and it is recognised as a firm's R&D policy in Klette and Kortum (2004). It also relates to the distinction between innovators and non-innovators in Geroski, Machin and Van Reenen (1993).

1.1 Firm Performance and R&D Strategy

In view of the above discussion, we ask the following questions: why do firms in an industry choose different R&D strategies, and what is the impact on firm performance of different strategic choices? When posing these questions, we consider three strategic options. The first is to spend nothing on R&D, leaving the generation of new ideas to imitation and other forms of knowledge spillovers. The second type of strategy is to carry out R&D projects occasionally, while the third strategy is to follow a plan of persistent R&D efforts. These distinctions are transformed into a prime research question: Is there an observable impact of a firm's R&D strategy and its performance, measured by its labour productivity or gross profit per employee?

A second issue in the paper relates to what the literature refers to as double counting of R&D inputs, which implies that part of a firm's R&D spending is included in its labour costs, and hence it is recorded as input twice, and thereby forcing parameter estimates downwards. To examine this problem, our study divides labour input into two categories: ordinary labour and knowledge labour, each with a separate role in the estimated production function. The basic task in this case is to show that knowledge labour (or knowledge-intensive labour) has a significant impact on performance.

The major performance variable in the study is labour productivity, and two alternative specifications are introduced. The first is calculated as value added divided by ordinary labour. This measure represents an approach where the R&D efforts are separated from the production process, in which ordinary labour and capital are the inputs. The efficiency of these inputs is then assumed to be influenced by R&D results. An alternative view is that firm integrates its knowledge creation and production, which may imply that performance should be measured as value added per total labour, being the sum of ordinary and knowledge labour. On the basis of the same production function a regression equation is derived for each of the measures, and a similar approach is applied when the firm's performance is reflected by its gross profit.

1.2 Performance, Causality and Control Variables

This paper sheds additional light on the link between R&D and a firm's economic performance. The literature deliberates on several basic issues in this context. First, cross-section studies bring the robust message that the productivity of a firm is affected by the level of R&D spending. Studies by Griliches (1958, 1986, 1996), Mansfield (1961, 1965), Nelson (1962), Schmookler (1966), Hall and Mairesse (1995), Cohen and Klepper (1996), Sutton (1998), Lööf and Heshmati (2006) and others demonstrate that productivity differentials can be attributed to differences in the R&D levels. Second, panel data studies of firm performance and R&D investments are particular in the sense that they better can distinguish between correlation and causality and allows for influence from endogenous and

predetermined variables. However, in longitudinal studies and in contrast to the level dimension, productivity growth is not found to be strongly related to firm R&D (Klette and Kortum, 2004).

Our contribution is that we show that permanent features of a firm's R&D behaviour has an influence on its productivity also when the size of R&D expenditures is disregarded and replaced by R&D capacity. In the empirical analysis a firm's productivity level is determined by its R&D-strategy in combination with its capacity to perform R&D. The R&D strategy is captured by information about firms' R&D activities back in time while R&D capacity is reflected by the number of knowledge labours of the firm.

The contribution of this paper may also be recognised in view of the statement that there is no microeconomic consensus about how to model a firm's R&D and innovation decisions (Griliches 1979, 1995). This paper suggests that a microeconomic model of R&D behaviour should distinguish slowly changing strategic decisions from less slow market adjustments. In this context, the selection of an R&D strategy is a lasting property of firms, and we suggest that our approach therefore will reveal a causal relation between R&D strategy and firm performance.

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 the choice to make 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 similar approach is also followed by Eklund and Wiberg (2007), in a paper where they examine firms with a value above normal profits and relate such performance with the persistence of R&D efforts of the individual firm. The assumption is that the size of R&D investments is one dimension of an R&D strategy, while the persistence in the efforts is a second dimension.

In this paper, we use both the firm's productivity and its profit as primary performance indicators to reflect the outcome of its R&D investment. 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 covers 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 an ambition to obtain profits above the "normal" level.

Two contributions of the paper should be emphasised. First, the production function of each firm is specified to separate ordinary and knowledge labour as different inputs to production output. Second, firms are distinguished with regard to the R&D strategy that they have adopted, with the assumption that firms that make persistent R&D efforts are assumed to be rewarded with higher labour productivity and larger gross profits per employee than firms with occasional or no R&D spending at all. In this way the impact on performance comes from the size of knowledge-intensive labour in combination with the R&D strategy that the firm has selected. For firms with a persistent R&D strategy, the amount of knowledge labour will in fact reflect the knowledge assets of the firm.

The empirical observations are from a Swedish CIS census in 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. In addition the production function is also characterised by the R&D strategy that the firm follows. The production function is formulated as an extension of a structural model suggested by Mairesse and Mohnen (1990), for which parameter values can be interpreted in a microeconomic framework. It may be argued that a firm's choice of R&D strategy is influenced by its ownership structure. We examine this by making an additional regression where we control for this, by distinguishing between firms that belong to a domestic multinational group, a foreign multinational graoup, a uninational group, and non-affiliated firms.

1.3 Outline of the Paper

Section 2 provides a theoretical framework, within which regression equations are designed for estimating how a firm's R&D strategy and firm attributes can influence labour productivity and profit per employee. Section 3 presents descriptive statistics and the econometric approach. The regression results are presented and discussed in Section 4, while Section 5 concludes and points at several extensions of the present study.

2. THEORETICAL FRAMEWORK

In this section, we outline the theoretical background for an analysis of how a firm's R&D strategy and knowledge labour influence the firm's output and related performance variables. We consider two alternative performance measures: labour productivity and gross profit per employee. The implicit background for the model discussions is profit-maximising firms in an environment where R&D can affect input efficiency and/or the output price, and where a firm may perceive a negatively sloping demand.

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:

$$Q = F(z)L^{\alpha_L}C^{\alpha_C}K^{\alpha_K} \tag{2.1}$$

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 core production function in the following two alternative ways:

$$Q = F(z)\Omega = F(z)M^{\alpha_M}N^{\alpha_N}C^{\alpha_C}\exp\{\bar{\alpha} + \alpha_1 D_1 + \alpha_2 D_2\} \tag{2.2a}$$

$$Q = F(z)\hat{\Omega} = F(z)L^{\alpha_L}C^{\alpha_C}\exp\{\bar{\alpha} + \alpha_1 D_1 + \alpha_2 D_2\}\exp\{\alpha_3 N/L\} \tag{2.2b}$$

where $N+M=L$, and D_1 and D_2 are two category variables, where D_1 refers to firms with occasional R&D and D_2 to firms with a persistent R&D strategy, such that α_1 represents the additional effect of having occasional R&D in comparison with firms whose strategy is no R&D, while α_2 represents the effect of a persistent R&D strategy in comparison with the no-R&D strategy, where the latter is recognised as $\bar{\alpha}$. In view of this, there are three R&D strategies (i) no R&D, (ii) occasional R&D, and (iii) persistent R&D. Thus, D_1 and D_2 satisfy:

$$D_1 = \begin{cases} 1 & \text{for firms with occasional R\&D} \\ 0 & \text{otherwise} \end{cases} \tag{2.3a}$$

$$D_2 = \begin{cases} 1 & \text{for firms with persistent R\&D} \\ 0 & \text{otherwise} \end{cases} \tag{2.3b}$$

Equation (2.2a), which is our basic equation, differs in three ways from equation (2.1). It excludes the variable *K*, while it instead includes the variable *N* and the strategy variables D_1 and D_2. *K* refers to knowledge capital, which reflects the cumulated R&D spending over a sequence of years. The amount of knowledge labour, *N*, reflects the R&D capacity of a firm. For a firm with persistent R&D, *N* refers to a long-term capacity. If a major part of a firm's R&D expenditures relate to in-house R&D, the variable *N* will also reflect the size of *K*. Moreover, a large value of *K* would normally correspond to a persistent R&D strategy, and the importance of the latter is given by the parameter α_2. In conclusion, firms with large knowledge assets (R&D capacity) will have a large *N* and $D_2 = 1$, whereas firms with small knowledge assets will have a small *N* and $D_2 = 0$. The target is to provide evidence that firms with persistent R&D spending are rewarded by a higher labour productivity.

Firms that do not have a persistent R&D strategy, include 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. In view of this, one of our ambitions is to find out if the no-R&D firms and the occasional-R&D firms in all essence are the same type of firms. We should also note that the value-added variable in (2.2) is influenced by the selected R&D strategy, which affects both physical output and output price, which means that the functions in (2.2) could both be called "revenue function" (Hall, 2007).

Given the setting in (2.2), how should labour productivity be measured? There are two options. The first is based on arguments put forward in Griliches and Mairesse (1984), and it considers the results of R&D efforts as an input to the basic production process, which implies that the return to R&D is reflected by its effect on the productivity of ordinary labour, i.e., its effect on $q = Q / M$, where *M* = $L - N$. This approach considers the distinction between the production of knowledge and the returns to its use (Geroski, Machin and van Reenen, 1993), where the latter aspect is reflected by the knowledge impact on *q*. Of course, at each point in time *N* reflects inputs to future knowledge. However, for firms with a persistent R&D strategy, *N* will also indicate both the firm's R&D capacity and the size of its past R&D efforts.

We shall refer to the variable $q = Q / M$ as labour productivity in the *narrow sense*, in contradistinction to labour productivity in the *broad sense*, which is measure by the variable $\hat{q} = Q / L$. In this latter case each firm is perceived as an operation that integrates knowledge production and output production.

Using $q = Q/M$ as a productivity indicator implies that the focus is on output per production worker, which in (2.2) can be augmented by increasing *N* and by choosing a persistent R&D policy. Observing

that $\ln q = \ln Q - \ln M$, we can specify the following linear function for estimation of labour productivity in the narrow sense:

$$\ln q = f(z) + (\alpha_M - 1)\ln M + \alpha_N \ln N + \alpha_C \ln C + \bar{\alpha} + \alpha_1 D_1 + \alpha_2 D_2 \qquad (2.4a)$$

where $f(z) = \ln F(z)$, which reflects shift effects that may be specified to reflect various exogenous pre-conditions for each firm, such as the regional milieu, the technology classification and the corporate ownership structure of each individual firm. In section 2.3 we discuss the latter two pre-conditions. For $\alpha_2 > 0$, the model predicts that a persistent R&D strategy yields a higher productivity than a no-R&D strategy. Moreover, $\alpha_1 \leq 0$ means that occasional R&D is a reflection of R&D spending as a method to restore productivity to the same level as for firms with a no-R&D strategy.

Referring to the definition of a production function, basic requirements of estimated parameters in (2.3) are that (i) $(\alpha_M - 1) < 0$, and (ii) $0 < \alpha_M, \alpha_N, \alpha_C < 1$.

The results from our estimations of (2.3) will be compared with estimations of productivity in the broad sense. In this case $\hat{q} = Q/L$ is the dependent variable, where $L = M+N$. To retain a strict relation between estimated parameters and parameters in the production function, we use the specification in (2.2b), which yields

$$\ln \hat{q} = f(z) + (\alpha_L - 1)\ln L + \alpha_C \ln C + \bar{\alpha} + \alpha_1 D_1 + \alpha_2 D_2 + \alpha_3 (N/L) \qquad (2.4b)$$

where the share of knowledge-intensive labour is included to reflect the influence on productivity of the R&D and absorption capacity of the firm's labour force.

2.2 Gross Profit and R&D Efforts

Section 2.1 introduces a framework for investigating the impact of R&D strategy and R&D capacity (knowledge resources) on labour productivity. To the extent that such an influence is present in a systematic way, we should also expect a similar effect on gross profit of the individual firm. In this effort, we want to use the same production function as given by formula (2.2a). In order to accomplish this, the present sub section introduces an assumption which allows us to retain the formulation in (2.2a). In this way we can use the same variables as in the basic equation in (2.4a) and estimate how they influence gross profit per ordinary labour. This will make it possible to assess how much "a pure production firm" would be willing to pay for the knowledge generated by knowledge labour and a persistent R&D strategy.

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., $Q = \Pi + wL$. Now, we have two types of labour and hence two wage levels, w_M for ordinary labour and w_N for knowledge labour. This means that we can express gross profit as

$$\Pi = F(z)\Omega - w_M M - w_N N \qquad (2.5)$$

where $\Omega = M^{\alpha_M} N^{\alpha_N} C^{\alpha_C} \exp\{\bar{\alpha} + \alpha_1 D_1 + \alpha_2 D_2\}$, referred to as the core production function. In order to estimate $\pi = \Pi / M$ with the same type of equation as the one employed for *Q*/*M* in (2.4a), we make the following approximation: $w_M M + w_N N \approx \omega Q$, which says that the sum of labour costs is proportional to output. Inserting this into (2.5) yields $\Pi = (1-\omega)Q$. Introducing $\pi = \Pi / M$, we can specify the following profitability equation:

$$\ln \pi = \ln(1-\omega) + \ln(Q/M) \qquad (2.5)$$

which differs from (2.4a) only with regard to the term $\ln(1-\omega)$, which is a small negative number. Disregarding this small bias, the following specification approximates (2.5):

$$\ln \pi \approx f(z) + (\alpha_M - 1)\ln M + \alpha_N \ln N + \alpha_C \ln C + \bar{\alpha} + \alpha_1 D_1 + \alpha_1 D_2 \qquad (2.6)$$

which is exactly the same formulation as in (2.4a), but now with π replacing *q* on the left hand side. Our motive for using this formulation is to examine how the effects of a persistent R&D strategy on labour productivity (in the narrow sense) carry over to similar effects in terms of profitability, defined as gross profit per input of ordinary labour.

2.3 Controlling for Technology and Corporate Ownership

In the theoretical framework of this paper we assume that the individual firm has to choose an R&D strategy. Such a choice can be assumed to be more vital for firms in certain industries than in others, because industries differ significantly with regard their technological opportunities, and this is also revealed by clear differences in the R&D intensity of different industries. This implies that the production functions in (2.2a) and (2.2b) will be different for firms in different industries. The assumption introduced here is that all industries have the same basic parameters, but differ with regard to the value of the shift function *F*(*z*). This is accomplished by applying a technology classification of all industries into the following four categories: (1) denotes High technology, (2) denotes Medium-

high technology, (3) denotes low-medium technology, and (4) denotes the remaining reference group of industries.

In all specifications we employ three shift variables, z_1, z_2 and z_3, introduced as arguments of the shift function $F(z_1, z_2, z_3) = \exp\{\beta_1 z_1 + \beta_2 z_1 + \beta_3 z_3\}$, where z_1 = 1 for industries classified as category 1, and zero otherwise, where z_2 = 1 for industries classified as category 2, and zero otherwise , and where z_3 = 1 for industries classified as category 3, and zero otherwise.

The major novelty in this study is an examination of how a firm's R&D strategy affects the performance of the firm's production, indicated either by its labour productivity or by its gross profit per employee (profitability). The hypothesis is that firms with a persistent R&D strategy are able to improve their productivity and profitability. It then comes natural to ask: which firms are more likely to be capable of selecting a persistent R&D behaviour? A series of our own previous studies indicate that multinational firms might differ systematically in this regard (e.g. Johansson and Lööf, 2008; Ebersberger, Johansson and Lööf, 2007). In order to examine this possible effect, we control in two regressions for ownership structure, such that we identify firms belonging to a domestically owned multinational group as well as firms belonging to a foreign-owned multinational group. The properties being examined are the following: (i) are MNEs more likely to have persistent R&D so that the persistency variable just reflects an MNE influence, and (ii) do domestic MNEs (DMNEs) and foreign MNEs (FMNEs) differ in their impact on firm performance?

To examine the above properties, we introduce three dummy variables, represented by the vector $s = (s_1, s_2, s_3)$, where $s_1 = 1$ if the firm belongs to a DMNE group, and zero otherwise, where $s_2 = 1$ if the firm belongs to an FMNE group, and zero otherwise, where $s_3 = 1$ if the firm is non-affiliated, and zero otherwise, and where the reference group is uninational firms, i.e., firms with several units – all located inside the country. The *s*-vector is then inserted into the shift function, which becomes $\bar{F}(z, s) = \exp\{\beta z + \gamma s\}$, for $\gamma = (\gamma_1, \gamma_2, \gamma_3)$. With the help of this new shift function, the following two regression equations are defined

$$\ln q = \bar{f}(z, s) + \ln \Omega / M \tag{2.7}$$

$$\ln \pi = \bar{f}(z, s) + \ln \Omega / M \tag{2.8}$$

where $\Omega = M^{\alpha_M} N^{\alpha_N} C^{\alpha_C} \exp\{\bar{\alpha} + \alpha_1 D_1 + \alpha_2 D_2\}$, as specified in (2.2a), and where $\bar{f} = \ln \bar{F}$.

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 the CESIS[1] database, 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.

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 1710.

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 Table 3.1. 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 table shows 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.

[1] CESIS (Centre of Excellence for Science and Innovation Studies) is a research centre at the Royal Institute of Technology in Stockholm with the mission to organise and carry out studies of innovation systems and with a specific focus on Sweden. The ambition is to provide a deeper understanding of the interdependencies between innovations and economic development. Special attention is paid to how R&D influences economic growth, and to develop models and methods designed to examine such influences

Table 3.1: Economic statistics, expressed as a fraction of sales

	Non R&D firms		R&D-firms			
			Occasional R&D		Persistent R&D	
	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 investments[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

The table reveals that no-R&D and occasional-R&D firms can be distinguished from persistent-R&D firms. The latter have larger intermediary inputs and gross profits and lower value added and wage sum per sales value. 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.

3.2 Firm Attributes for Econometric Analysis

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) corporate ownership for each individual firm. Table 3.2 presents the variables which are included in the two alternative specifications in (2.2) of the production function of firms. In addition, the table informs about R&D investments per employee and firm size, measured by the number of employees.

Table 3.2: Descriptive statistics for performance variables and covariates.

	No-R&D firms N=762		R&D-firms Occasional R&D N=535		Persistent R&D N=470	
	Mean	Std. Dev	Mean	Std. Dev	Mean	Std. Dev
R&D investments[a]	0	*0*	70	*181*	110	*151*
Firm size, employment	91	*780*	84	*164*	435	*1,445*
Dependent variables						
Value added [a]	520	*315*	528	*276*	673	*347*
Value added[b]	583	*544*	581	*355*	820	*560*
Gross profit [a]	246	*287*	254	*247*	363	*319*
Gross profit[b]	277	*443*	280	*289*	440	*480*
Wages [a]	275	*77*	275	*59*	310	*77*
Covariates						
Physical investments [a]	1,171	*1,332*	1,113	*856*	1,624	*1,992*
Ordinary labour	84	*757*	78	*151*	351	*1,074*
Knowledge labour	7	*37*	6	*18*	84	*455*
Non Affiliate [c]	0.378	*0.485*	0.287	*0.452*	0.143	*0.350*
Uninational [c]	0.329	*0.470*	0.305	*0.461*	0.170	*0.376*
Domestic MNE [c]	0.147	*0.354*	0.185	*0.388*	0.364	*0.481*
Foreign MNE	0.144	*0.351*	0.287	*0.452*	0.321	*0.467*
High technology [c]	0.066	*0.249*	0.076	*0.265*	0.145	*0.352*
High medium tech. [c]	0.228	*0.419*	0.249	*0.433*	0.357	*0.479*
Low medium tech [c]	0.260	*0.439*	0.271	*0.455*	0.221	*0.415*
Low technology [c]	0.444	*0.497*	0.402	*0.490*	0.275	*0.447*

Notes: (a) Per employee, in 1000 Swedish Crowns, (b) Per ordinary labour, in 1000 Swedish Crowns, (c) As a fraction of all firms.

The table reports separate information for the three categories: no-R&D, occasional-R&D, and persistent-R&D firms. The performance variables in the table comprise value added per total labour and per ordinary labour, and gross profits per total labour and per ordinary labour, and wages per total labour. For all these variables, we can conclude that firms with persistent R&D have the highest and the no-R&D firms have the lowest values. 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 no-R&D firms. When these both performance measures are expressed per ordinary labour, the difference between persistent R&D firms and other firms is even more pronounced. Another observation is that there is a clear similarity between no-R&D firms and those that carry out R&D investments occasionally. These two groups may in fact represent the same firm population.

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

Table 3.2 also presents descriptive statistics with regard to corporate ownership and structure, divided into four categories : (i) non-affiliate firms which do not belong to a company group, (ii) uninational firms which belong to a company groups with all units located in Sweden, (iii) domestic multinationals (DMNEs), and (iv) foreign multinationals (FMNEs). 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.

3.3 Econometric framework

The empirical analysis is based on five different regression equations, presented in Table 3.3. Two of these have labour productivity in the narrow sense as dependent variable, specified as $\ln q = f(z) + \ln \Omega / M + \varepsilon$ in (2.4a) and $\ln q = \overline{f}(z,s) + \ln \Omega / M + \varepsilon$ in (2.7), where Ω is the core part of the production function as introduced in (2.2a), and where ε is a normally distributed error term. A third regression uses labour productivity in the broad sense as dependent variable, specified in (2.4b) as $\ln \hat{q} = f(z) + \ln \hat{\Omega} / L + \varepsilon$, where $\hat{\Omega}$ is defined in (2.2b).

The three labour productivity equations are contrasted by two regression equations, in which gross profit per ordinary labour is the dependent variable, given by $\ln \pi = f(z) + \ln \Omega / M + \varepsilon$ in (2.6), and $\ln \pi = \overline{f}(z,s) + \ln \Omega / M + \varepsilon$ in (2.8)[2]. We may then observe that the five equations in Table 3.3 are alternative ways to estimate the parameters of the core production function, Ω, together with alternative shift functions. For each specification, four regressions are made, comprising an ordinary OLS (called mean regression) and three quantile regressions to detect heterogeneity across the population of firms. The three quantile regressions are (i) lower quartile, (ii) median, and (iii) upper

[2] Although the results are not reported here, we have also estimated $\ln \hat{\pi} = f(z) + \ln \hat{\Omega} / L + \varepsilon$, where the profitability, $\hat{\pi}$, is defined as gross profit per total labour force, with only small changes in parameter estimates, compared to those of equation (2.6).

quartile. In these latter three cases, bootstrapping is applied to ascertain robustness of estimates and their significance levels. The independent variables are defined in Table D of the appendix.

Table 3.3: Five regression equations

1. Productivity equations	2. Profitability equations
(I) $\ln q = f(z) + \ln \Omega / M + \varepsilon$ in (2.4a)	3. (IV) $\ln \pi = f(z) + \ln \Omega / M + \varepsilon$ in (2.6)
(II) $\ln \hat{q} = f(z) + \ln \hat{\Omega} / L + \varepsilon$ in (2.4b),	4. (V) $\ln \pi = \bar{f}(z,s) + \ln \Omega / M + \varepsilon$ in (2.8)
(III) $\ln q = \bar{f}(z,s) + \ln \Omega / M + \varepsilon$ in (2.7)	5.

4. RESULTS FROM THE REGRESSIONS

Results from the regression exercises are presented in sub sections 4.1 and 4.2.. The first group of regressions uses labour productivity as dependent performance variable, and the second group has gross profitability as performance indicator. In all regressions that are presented, we control for industry effects with the help of three sector dummies.

4.1 Labour Productivity, R&D Strategy and R&D Capacity of the Firm

The basic hypothesis of this paper is that a firm's R&D strategy in combination with its R&D capacity has a robust influence on the labour productivity of the firm. The starting point is the basic equation as specified in (2.4a). In this specification labour productivity is defined in the narrow sense, which means that value added is divided by ordinary labour, i.e., $q = Q / M$. The parameter estimates with this basic equation are assessed against the assumed properties of the production function, specified in (2.2a).

Referring to Table 3.3, we compare the results from estimation (I) with those from estimations (II) and (III), where $\hat{q} = Q / L$ is performance variable in (II) , and $q = Q / M$ is performance variable in (III), where we control for a possible influence of corporate ownership. For example, it is evident from the descriptive statistics that multinationals dominate the group of firms which manage to follow a strategy of persistent R&D. In this way we can discuss the robustness of parameter estimates.

The basic equation is estimated as an ordinary mean regression (OLS). In addition, we use a median and two quartile regressions: the lowest quartile (25 percentile) and the highest quartile (75 percentile), while using bootstrapping. These results are presented in Table 4.1.

The table shows that parameters come out with the expected signs, where we note that $(\alpha_M - 1) < 0$, which means that the output elasticity of ordinary labour is positive and smaller than one. To see this, one can inspect the mean regression where $\alpha_M - 1$ equals -0.185, which gives α_M the value 0.815

Moreover, the productivity is significantly higher for the High-technology and High-medium-technology industries compared with low technology industries (reference group). With regard to a firm's R&D strategy, the parameter estimates imply that (i) firms with occasional R&D differ significantly from firms that report no R&D in all cases except the 75 percentile regression, (ii) the labour productivity is positively influenced by a persistent R&D strategy for the mean regression as well as the median and the 75 percentile regressions. Thus, the R&D strategy matters indeed, although not in a significant way for the lowest quartile. To a large extent this result corresponds to the fact that the employment of a persistent R&D strategy is a rare event among firms in the lowest quartile. We also conjecture that the group of firms with occasional R&D consists of firms that do not carry out R&D on a regular basis, but turn to R&D (as a rescue initiative) in situations when the productivity level falls below the level of competitors. We also observe that the impact of a persistent R&D strategy is especially high for firms with the largest productivity (upper quartile).

The R&D capacity is reflected by the number of knowledge workers, and this variable is highly significant with a positive parameter in all four regressions. The same conclusion applies for the variable investment in physical capital, which is used as a capital proxy.

Table 4.1: Value added per ordinary labour($\ln q$) as dependent variable in the basic equation (2.4a) – regression I

	Mean	25 Percentile[c]	Median[c]	75 Percentile[c]
Occasion. R&D [a]	-0.049*	-0.033*	-0.055***	-0.0060
	(0.025)	(0.018)	(0.018)	(0.025)
Persistent R&D [a]	0.077***	0.047	0.074**	0.12***
	(0.029)	(0.031)	(0.030)	(0.034)
Log Investment	0.058***	0.096***	0.085***	0.061***
	(0.006)	(0.013)	(0.013)	(0.012)
Log Knowl. labor	0.136***	0.084***	0.111***	0.142***
	(0.007)	(0.005)	(0.006)	(0.011)
Log Ord. labor	-0.185***	-0.162***	-0.187***	-0.190***
	(0.014)	(0.020)	(0.013)	(0.023)
High technology [b]	0.138***	0.152**	0.149***	0.163**
	(0.040)	(0.060)	(0.045)	(0.075)
High med. tech. [b]	0.088***	0.123***	0.083***	0.074
	(0.027)	(0.028)	(0.025)	(0.046)
Low med. tech [b]	0.055**	0.060**	0.063***	0.029
	(0.027)	(0.029)	(0.019)	(0.033)
Constant	6.410***	5.819***	6.175***	6.584***
	(0.051)	(0.061)	(0.073)	(0.096)
Observations	1767	1767	1767	1767

Notes: Absolute value of t statistics in parentheses, * significant at 10%; ** significant at 5%; and *** significant at the 1% level. (a) Reference is No-R&D firms, (b) Reference is low technology firms, (c) Bootstrapped errors in parentheses

Our next task is to examine if the results discussed apply also when equation II is estimated. This latter equation differs from I by having productivity in the broad sense as dependent variable and by using knowledge intensity instead of the number of knowledge workers. The result from the pertaining model estimations is presented in Table 4.2.

The major results with regression II are twofold just as before: The choice of R&D strategy matters for all firms except low productivity firms .With the mean regression the impact of a persistent R&D strategy is significant on the 5 percent level. For the lowest quartile, where very few firms apply a strategy of persistent R&D, the corresponding parameter is not significant. In association with this, we note that with regression II , only the median regression displays significant differences between firms employing a strategy of no R&D and those carrying out R&D on an occasional basis. But the image remains: occasional R&D is a firm's response to low productivity. Moreover, the knowledge-intensity variable (R&D capacity) is strongly significant in all four regressions.

Table 4.2: Value added per employee ($\ln \hat{q}$) as dependent variable in equation (2.4b) – regression II

	Mean	25 Percentile[c]	Median[c]	75 Percentile[c]
Occasion. R&D. [a]	-0.038	-0.031	-0.041**	-0.003
	(0.024)	(0.022)	(0.019)	(0.027)
Persistent R&D [a]	0.069**	0.029	0.063***	0.126***
	(0.028)	(0.026)	(0.022)	(0.031)
Log Investment	0.056***	0.091***	0.078***	0.061***
	(0.005)	(0.004)	(0.004)	(0.009)
Log Total labor.	-0.097***	-0.099***	-0.119***	-0.103***
	(0.014)	(0.013)	(0.011)	(0.018)
Knowl. Intensity	0.068***	0.041***	0.062***	0.071***
	(0.008)	(0.007)	(0.006)	(0.009)
High technology [b]	0.102***	0.098***	0.118***	0.108**
	(0.039)	(0.036)	(0.030)	(0.043)
High med. tech. [b]	0.078***	0.104***	0.074***	0.065**
	(0.026)	(0.023)	(0.020)	(0.029)
Low med. tech [b]	0.055**	0.055**	0.054***	0.022
	(0.026)	(0.024)	(0.020)	(0.029)
Constant	6.057***	5.594***	5.942***	6.204***
	(0.052)	(0.047)	(0.040)	(0.063)
Observations	1767	1767	1767	1767

Notes: Absolute value of t statistics in parentheses, * significant at 10%; ** significant at 5%; and ***significant at the 1% level. (a) Reference is no-R&D firms, (b) Reference is low technology firms, (c) Bootstrapped errors in parenthesis.

By definition we have that $q > \hat{q}$, which means that value added per ordinary labour is larger than value added per total labour inputs. Taking this into consideration it is possible to conclude that there is a strong correspondence between equations (2.4a) and (2.4b) as regards

(i) the size of the four parameter estimates of α_2, where α_2 is the coefficient describing the impact of a persistent R&D strategy ,

(ii) the size of the four parameter estimates of α_C, where α_C is the coefficient describing the elasticity of physical capital (investment in physical capital).

(iii) the elasticity parameter for total labour, α_L in regression II, which satisfies that $\alpha_L \approx \alpha_M + \alpha_N$, where the last two parameters refer to ordinary and knowledge labour, respectively in regression I.

Thus, the observations (i) – (iii) above suggest that the results are fairly similar when we regress labour productivity in the broad and the narrow sense. It also seems reasonable to conclude that R&D strategy and R&D capacity have a clear impact on a firm's productivity both in the narrow and the broad sense. It then remains to discuss the possible impact from ownership structure on labour productivity in the narrow sense.

The parameter values pertaining to the estimation in regression III are presented in Table A of the appendix. Two major results can be observed in Table A. The first is that the dummy variables for DMNEs (domestic multinationals) and FMNEs (foreign multinationals) are clearly significant in all four regressions. Hence, everything else equal, MNEs have a positive effect on the level of productivity in the narrow sense. The reference group is the set of firms belonging to uninationals.

The next question is: do the effects of the R&D strategy remain unchanged when ownership category is included in the estimated equations? The answer is that the picture remains unchanged. First, the influence from persistent R&D on productivity remains positive and significant for the median and 75 percentile regressions. In the mean regression, the influence is significant on the 5 percent level. Second, in the new specification there is a negative significant impact on the productivity in firms with occasional R&D. This observation strengthens our previous suggestion that no-R&D firms make use of occasional R&D in situations when their productivity has fallen below critical values.

The remaining issue is to what extent the R&D capacity – as represented by the number of knowledge labour – continues to have an impact on labour productivity in the narrow sense. Table A informs us that this variable remains highly significant and that the pertinent coefficients in the four regressions are at least as large as in the regression specification I, referring to equation (2.4a). Moreover, the parameter estimates associated with the capital proxy, investment, and with ordinary labour remain roughly unchanged in comparison with their values in regression I. In view of this, the results in Table 4.1 can be considered as robust when the regression controls for ownership category – as in Table A.

4.2 Profitability, R&D Strategy and R&D Capacity of the Firm

When a firm increases its labour productivity, does that mean that the wage sum of the firm is allowed to expand or does it mean that the profit level is augmented? If we want to remain consistent with the Schumpeterian tradition, this question is important, since the Schumpeter (1934) assumption is that the opportunity of making larger profits is the prime driving force in the stimulation of R&D efforts and innovation activities. We have in the preceding sub section seen that a firm's R&D strategy has an impact on its productivity level. The follow up question is whether it has a similar impact on the firms' profitability, represented by the firms' gross profit per ordinary labour. The answer is provided in regression IV in Table 4.3.

Table 4.3: Gross profit per ordinary labour ($\ln \pi$) as dependent variable in the basic equation in (2.6) – regression IV

	Mean	25 Percentile[c]	Median[c]	75 Percentile[c]
Occasion. R&D [a]	-0.014	-0.031	-0.072***	0.009
	(0.038)	(0.031)	(0.026)	(0.048)
R&D Persist [a]	0.121***	0.071*	0.113***	0.132***
	(0.045)	(0.036)	(0.037)	(0.046)
Log Investment	0.108***	0.169***	0.157***	0.131***
	(0.009)	(0.016)	(0.026)	(0.027)
Log Knowl. labor.	0.158***	0.122***	0.135***	0.174***
	(0.012)	(0.009)	(0.013)	(0.013)
Log Ordin. labor	-0.229***	-0.272***	-0.263***	-0.284***
	(0.022)	(0.025)	(0.042)	(0.050)
High technology [b]	0.088	0.234***	0.186***	0.173*
	(0.062)	(0.037)	(0.059)	(0.094)
High med. tech. [b]	0.086**	0.144***	0.125***	0.129**
	(0.041)	(0.034)	(0.044)	(0.063)
Low med. tech [b]	0.067	0.124***	0.105***	0.033
	(0.041)	(0.029)	(0.037)	(0.052)
Constant	5.321***	4.655***	5.039***	5.671***
	(0.078)	(0.086)	(0.128)	(0.122)
Observations	1712	1712	1712	1712

Notes: Absolute value of t statistics in parentheses, * significant at 10%; ** significant at 5%; and *** significant at the 1% level. (a) Reference is Non-R&D firms, (b) Reference is low technology firms, (c) Bootstrapped errors in parentheses

The first set of regressions (mean, lower quartile, median and upper quartile) are based on regression formulation IV, which is the same as regression formulation I, except that profitability has replaced labour productivity in the narrow sense as performance variable. This also means that we do not control for ownership category. The results from the estimations are presented in Table 4.3, in which we also observe that the number of observations is reduced, since the regression does not contain firms with a negative profit.

Table 4.3 informs that R&D strategy has an impact on profitability. The conclusions about a firm's profitability can be summarised as follows:

(i) Occasional R&D is statistically different from no R&D, only for the median regression.

(ii) Persistent R&D has clearly significant impact in the mean, median and upper quartile regressions. It is significant on the 10 percent level in the lowest quartile regression.

(iii) For the persistent R&D variable, the parameter values are higher than in the equations which have labour productivity as dependent variable.

(iv) The impact of knowledge labour (R&D capacity) is highly significant, positive and systematically larger than for the comparable labour productivity estimations.

(v) The impact of physical capital (investment) is significant, positive and has a systematically larger parameter, α_C, than for the comparable labour productivity estimations. This demonstrates a consistency between the profitability and the productivity regressions.

(vi) The impact of ordinary labour is highly significant and the parameter α_M is systematically lower than in the comparable labour productivity estimations.

First, the above observations imply that R&D strategy and R&D capacity play a similar role for the level of profitability and labour productivity. These result partly support the approximation introduced in formulas (2.5) and (2.6), while indicating that the variables R&D strategy, R&D capacity and physical capital all impact gross profitability slightly stronger than they impact labour productivity. Finally, the estimations with specification V in Table B of the appendix show that our conclusions remain unchanged we control for ownership structure

5. CONCLUSIONS

This paper presents "structural equations" for production of the individual firm, with a core production function, Ω, specified in (2.2). Referring to equations (2.4a) and (2.6), the elasticities of capital, ordinary labour and knowledge labour satisfy that $\alpha_M + \alpha_N + \alpha_C$ is greater than unity and smaller than 1.04, which indicates mild increasing returns to scale.

When interpreting results from the empirical analyses we have argued that the number of knowledge labours reflect the R&D capacity. As this variable is highly significant in all regressions, it seems important to find out to what extent knowledge labour represents both R&D capacity and other productivity enhancing skills, such as ordinary renewal capacity and commercialisation capabilities. These questions suggest extended approaches in future research.

A clear finding from the entire set of regressions presented in the paper is that occasional R&D is not associated with any positive R&D effect, which indicates that occasional R&D is chosen by firms that have productivity problems. Whether the occasional R&D efforts have any future impacts on productivity cannot be examined with the data set employed. However, occasional R&D efforts contrast the strategy labelled persistent R&D. With the exception of firms in the lower quartile, we can conclude that everything else equal, persistent R&D associates with higher (i) productivity level and (ii) profitability level. Thus, by dividing firms' R&D strategies into three groups, we extend the results in Klette (1996), where the distinction is between R&D and no R&D. This is further emphasised by our conjecture that no-R&D firms and occasional-R&D firms form one population with similar

innovation characteristics. In addition, our result strongly advices against combining firms with persistent and occasional R&D into one group.

Another finding is that the cross-section impact of employing a strategy with persistent R&D becomes stronger when the regressions control for corporate ownership structure. This suggests that the effects on productivity and profitability are especially strong for multinationals with persistent R&D. In all regressions of type III and V, the coefficients referring to DMNEs and FMNEs are quite similar, but systematically higher for the latter.

Among unresolved issues for further research we should first mention the interpretation of knowledge workers (knowledge-intensive labour) as an indicator of a firm's R&D capacity. When this capacity is utilised for R&D and other innovation activities, it is at least partly included in the firm's R&D expenditures. In view of this, a more elaborate model would include both (i) R&D capacity and (ii) R&D expenditures other than knowledge labour costs, i.e., without counting expenditures twice[3]. To do this, it seems necessary to observe firms over a sequence of periods.

Future research along the suggestions in this paper includes (i) a distinction between R&D and other innovation activities, (ii) a development of the idea about R&D strategies that combine spending and persistency, and (iii) an inter-temporal model in which firms are classified with regard to their innovation strategy.

[3] Recent research at CESIS, indicate that a considerable share of firm's R&D spending may not be in-house (Andersson, et.al., 2008). Moreover, Knowledge workers may to a considerable extent have tasks that associate with commercialization rather than R&D (Andersson and Johansson, 2008).

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APPENDIX

Table A: Value added per ordinary labour ($\ln q$) as dependent variable in equation (2.7), including corporate ownership categories. Regressions with specification III.

	Mean	25 Percentile[c]	Median[c]	75 Percentile[c]
Occasion. R&D [a]	-0.055**	-0.044**	-0.058***	-0.023
	(0.025)	(0.021)	(0.017)	(0.031)
Persistent R&D [a]	0.066**	0.043	0.060**	0.090**
	(0.029)	(0.036)	(0.029)	(0.041)
Log Invest/emp	0.056***	0.090***	0.078***	0.061***
	(0.006)	(0.013)	(0.010)	(0.015)
Log Knowl. labor	0.127***	0.0830***	0.099***	0.129***
	(0.007)	(0.007)	(0.004)	(0.011)
Log Ord. labor	-0.203***	-0.179***	-0.196***	-0.212***
	(0.014)	(0.023)	(0.020)	(0.029)
High technology [b]	0.136***	0.164***	0.141***	0.142**
	(0.040)	(0.047)	(0.026)	(0.065)
High med. tech. [b]	0.078***	0.117***	0.079***	0.074**
	(0.027)	(0.030)	(0.027)	(0.035)
Low med. tech [b]	0.049*	0.068**	0.045**	0.025
	(0.027)	(0.027)	(0.018)	(0.024)
Domestic MNE	0.097***	0.076**	0.100***	0.143***
	(0.033)	(0.036)	(0.030)	(0.037)
Foreign MNE	0.134***	0.085***	0.103***	0.181***
	(0.035)	(0.030)	(0.026)	(0.041)
Non affiliate	-0.069**	-0.049**	-0.057***	-0.083***
	(0.028)	(0.025)	(0.018)	(0.029)
Constant	6.474***	5.917***	6.256***	6.644***
	(0.053)	(0.066)	(0.042)	(0.101)
Observations	1767	1767	1767	1767

Notes: Absolute value of t statistics in parentheses, * significant at 10%; ** significant at 5%; and significant at the 1% level. (a) Reference is No-R&D firms, (b) Reference is low technology firms, (c) Bootstrapped errors in parentheses

Table B: Log profitability per ordinary labour ($\ln \pi$), as dependent variable in equation (2.8), including corporate ownership structure. Regressions with specification V.

	Mean	25 Percentile[c]	Median[c]	75 Percentile[c]
Occasion.R&D [a]	-0.025	-0.038	-0.097***	0.0046
	(0.038)	(0.027)	(0.033)	(0.034)
Persistant R&D [a]	0.104**	0.064*	0.091*	0.168***
	(0.045)	(0.036)	(0.050)	(0.052)
Log Investment	0.106***	0.168***	0.153***	0.114***
	(0.009)	(0.019)	(0.016)	(0.027)
Log Knowl. labor.	0.145***	0.120***	0.126***	0.162***
	(0.012)	(0.013)	(0.011)	(0.013)
Log Ordin. labor	-0.256***	-0.305***	-0.305***	-0.300***
	(0.022)	(0.028)	(0.030)	(0.045)
High technology [b]	0.086	0.226***	0.180***	0.078
	(0.062)	(0.049)	(0.048)	(0.077)
High med. tech. [b]	0.071*	0.138***	0.120***	0.101
	(0.0413)	(0.0339)	(0.0288)	(0.0647)
Low med. tech [b]	0.0584	0.112***	0.0895**	0.0573
	(0.041)	(0.030)	(0.035)	(0.046)
Domestic MNE	0.148***	0.122***	0.159***	0.182***
	(0.050)	(0.030)	(0.038)	(0.050)
Foreign MNE	0.184***	0.124***	0.188***	0.209***
	(0.053)	(0.042)	(0.057)	(0.054)
Non affiliate	-0.100**	-0.0334	-0.0922***	-0.147**
	(0.042)	(0.040)	(0.035)	(0.058)
Constant	5.419***	4.767***	5.206***	5.828***
	(0.081)	(0.122)	(0.087)	(0.139)
Observations	1712	1712	1712	1712

Notes: Absolute value of t statistics in parentheses, * significant at 10%; ** significant at 5%; and significant at the 1% level. (a) Reference is Non-R&D firms, (b) Reference is low technology firms, (c) Bootstrapped errors in parentheses

Table C: Definition of variables used in the regressions analyses

Variable	Definition
Log value added per ordinary employee	Value added per employee with less than 3 years university education
Log value added per employee	Value added per employee
Gross profit	Sales – value added
Wage sum	Total wage cost of the firm
Physical investment (as capital proxy)	Gross investments in machinery and equipment
Ordinary labour	Employees with less than 3 years university education
Knowledge labour	Employees with at least 3 years university education
Non-affiliate firms	Domestically owned firms not belonging to any group
Uninational firms	Domestically owned firms belonging to a group with only domestic affiliates
Domestic multinational firms	A multinational company with its headquarter in Sweden
Foreign multinational firms	A multinational company with its headquarter outside Sweden
High-technology firms	ISIC: 2423, 30, 32, 33, 353
High-medium-technology firms	ISIC: 24 excl 2423, 29, 31, 34, 352, 359
Low-medium-technology firms	ISIC: 23, 25, 26, 27, 28, 351, 354
Low-technology firms	ISIC: 15, 16, 17, 18, 19, 20, 21, 22, 36, 37
Persistent-R&D firms	Firms conducting R&D annually
Occasional-R&D firms	Firms not conducting R&D annually
Non R&D firms	Firms not conducting R&D