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Investment and Performance of Firms: Correlation or Causality?

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Abstract

The purpose of this paper is to provide empirical analysis of the two-way causal relationship between some important investment and performance indicators at the firm level, in particular controlling for differences in these relationships between two cohorts of small and middle-sized firms and large firms respectively. Investigated performance variables include sales, value added, profit, cash flow, capital structure and employment. A multivariate vector autoregressive approach is applied to a panel of Swedish firms observed between 1992 and 2000. In particular, an attempt is made to investigate whether causal relationships between R&D and firm performance are of a transitory nature and whether the causal relationships are similar for small and medium-sized and large firms. Results show evidence of some two way causal relationships, which are mainly transitory in character. Significant heterogeneity is observed in the firms' investment and performance behavior by their size.

Keywords: R&D investment, productivity growth, financial constraints, panel data

JEL Classification: C23, C33, G32, L19, O33

1. INTRODUCTION

In the past, researchers have documented a significant positive relationship between R&D and productivity (Cohen and Klepper 1996, Griliches, 1998, Sutton, 1998).[1] However, the relationship is only robust across firms. In their survey of the literature, Klette and Kortum (2004) report a fragile and typically insignificant relationship between firms' R&D and their productivity growth. This suggests that the issue of causality is of a great importance to economists in their evaluation as well as for policymakers in their decisions. In fact, the relationship between investment and performance can be relevantly studied in both directions. A priori it can be assumed that better sales and profit performance of firms exert a positive influence on their R&D investments through retained profits. High performance also improves access to external resources through securities for investments in general and for investments in R&D in particular (Baumol and Wolff 1983; Pakes and Griliches, 1984). However, the innovation and growth literature still lack robust empirical evidence on a possible reverse link from productivity to investments in R&D activities.

The purpose of this paper is to provide empirical analysis of the possible two-way causal relationship between investment and performance at the firm level. We examine the interaction between a set of financial indicators represented by investments in R&D and physical capital and a set of performance variables including sales, value added, profit, cash flow, capital structure and employment. The analysis starts from three successive innovation-surveys in Sweden conducted between 1996 and 2000. For the richest of them, the 1998-survey, we extend the stratified sample by using annual account data for the period from 1992 to 2000 for firms with 50 or more employees. This threshold censoring of the data is explained by the fact that annual R&D-figures for the smallest firms not are available in the Swedish register data.

In the first part of the empirical exercise, we investigate the Swedish innovation surveys by using an identical multi-step innovation model. The results show a robust pattern of a significant and positive elasticity of productivity with respect to human capital, physical capital and knowledge capital. Knowledge capital is defined as innovation output generated from R&D-investments. Next we conduct a descriptive

[1] Productivity here refers to set of indicators such as value added or sales per employee.

data analysis for the firms observed in the 1998-innovation survey by following up the firms for the period 1992 to 2000. The results suggest that the cross-sectional relationship between investment variables and firm performance is prevailing also in the time-series dimension. Finally, a Granger causality test is applied on the data and we compare the two-way causal relationships between R&D and capital investments and firm performance while testing whether the effects are temporary or permanent. In the causality analysis part we compare results between small and medium-sized firms (50-250 employees) and large firms (250 and more) using Vector Auto Regressive (VAR) methodology.

The findings on the issues of causality and its uni- or bidirectional nature adds to empirical findings presented in Mairesse and Hall (1996), Hall et al. (1998), Bond, Harhoff and Van Reenen (1999), Levine, Loayza and Beck (2000), Gholami, Tom-Lee and Heshmati (2006) and other studies. Our approach is an improvement of the approaches employed in these previous studies in that it applies a multivariate approach on an extensive data set. Thereby, it strengthens the evidence on the dynamic relationship between finance, investment and growth at the firm level while accounting for size class heterogeneity.

The paper proceeds as follows. A theoretical background and some empirical findings from recent literature are summarized in section 2. In section 3, the data used is described, and results from cross-sectional regressions and preliminary findings from the descriptive statistics are reported. The econometric model is presented in section 4. Results from empirical analysis of causality relationship are presented in Section 5. The final section concludes this study and provides guidelines for future studies of causal relationship between performance and investment.

2. THEORETICAL ASPECTS AND PREVIOUS STUDIES

In this section we provide a brief review of the literature dealing with studies of the link between R&D and productivity growth, the relationships between firm size, investments and performance and the nature of the relationship between investment and performance. Are relationships to be understood as correlation or causality? If causal effects can be found, are they of a transitory or a permanent nature?

2.1 R&D and growth relationships

It is a commonly held view that R&D makes a vital contribution to firms' sales performance, productivity and profit (Griliches, 1988; Romer, 1990; Geroski, Machin and Van Reenen, 1993; Jones, 1995; Van Reenen, 1997). Firms invest in R&D in order to enhance their competitiveness and capability to earn profits. Ericsson and Pakes (1995) show that the stochastic outcome of a firm's own investments in R&D, physical capital, human capital, marketing and the competitive pressure from other firms within or outside the industry determine the sales performance, profitability and growth of the firm.

The relation between R&D and productivity has recently been discussed in numerous theoretical and empirical studies. However, despite significant progress made, the literature still lacks evidence on certain important relationships. Compared to the influence that R&D intensity, among other determinants, exerts on firms' economic performance, very little attention has been paid to the reverse relationship. In general, the existing empirical results are not conclusive and there is not much evidence on neither the complex nature of the relationship, nor on effects of firm performance to the R&D activity. Yet is it clear that such a relationship with a high probability exists. Variables such as cash flow, productivity and profit affect the quantity of resources available for physical investment and for investment in R&D (Baumol and Wolff, 1983).

The importance of the reverse link between firm performance and R&D is also connected to recent empirical findings suggesting that R&D activities are difficult to finance through external funding sources. An extensive literature within corporate finance, industrial organization and different strands of the Neo-Schumpetrian research has explored the presence of "liquidity" constraints and the importance of cash-flow and retained profit for R&D-investments (See for example Himmelsberg and Petersen 1994; Kaplan and Zingales, 1997; Brown, 1997; Harhoff, 1998 and Cincera, 2002).

2.2 Firm size, investments and performance relationships

In this paper we will compare the two-way causal relationship between investment and firm performance for two size groups; firms with 250 or less employees, and firms with more than 250 employees. The threshold censoring level of 50 employees is due to limitations in the available register panel dataset. It should be noted that only few small firms are involved in R&D activities.

From the literature, we know that Gibrat's law postulates that firm size has no systematic effect on the rate of growth of firms. Not necessarily inconsistent with this law of proportional effect, the Schumpeterian strand of the innovation literature suggests that bigger firms have an advantage in the R&D process due to access to financial, skill and organization resources, economy of scale in R&D and a superior ability to exploit results of research. Moreover, several researchers report that the capital structure of R&D-intensive firms exhibits less leverage than that of other firms. For the American economy, Hall (2002) finds that banks and other debt holders prefer to use physical assets as collateral and are reluctant to lend when projects involve substantial R&D-investments. Taken all together, smaller firms with less physical assets to secure loans and lower economies of scale in R&D can be expected to have a different relationship between investments and firm performance than their larger counterparts.

2.3 Correlation or causality?

Partly due to increased data availability and partly due to developments of methods, there has been a surge in the analysis of firm level panel data over the last couple of decades. Time series of cross sectional firm observations are, however, typically quite short which brings about the issue of efficient estimators and estimation of individual heterogeneity effects. Consistent estimation of model parameters requires a sufficient number of time period observations for each firm.

While overwhelming evidence show that R&D is a good predictor of productivity, at least in the level dimension, most results do not take the issue of causality into account.

However, in recent years significant improvements in econometric modeling of causal relationships have been made. These include studies by Granger (1969), Sims (1972), Holz-Eakin, Newey and Rosen (1988), Arellano and Bond (1991), Arelleano and Bover (1995) and Blundell and Bond (1998) who offer new approaches for systematic testing and determination of causal directions among different indicators of interest.

Geroski, Machin and Van Reenen (1993) employ the Arellano and Bond estimator to evaluate effects of corporate profitability from major innovations. They find positive direct effects spread over a period of seven years for a sample of 721 large, quoted U.K. firms and indirect effects up to three times larger than the direct effects.

Hall et al. (1999) apply the Newly and Rosen (1988) methodology on cross-country data sets in evaluating whether cash flow and sales cause physical investment and R&D. The main findings show that the direction of causality differs between the investigated countries, suggesting important institutional differences between the "market based" Anglo-Saxon countries (United States, United Kingdom and Canada) and the "bank-based" financial systems of France, Germany and Japan.

Bond, Harhoff and Van Reenen (1999) test for the importance of cash flow on investment in fixed capital and R&D using data on German and British firm and a system of GMM estimators developed by Arelleano and Bover (1995) and Blundell and Bond (1998). They find that financial constraints affect the decision to engage in R&D rather than the level of R&D-spending.

A serious drawback of the traditional Granger model is that it requires long time series (Colombo and Garrone, 1996). The introduction of a time dimension in the data will reduce the problem, since it allows using both cross-sectional and time-series information to test the causality relationship. In particular, it gives the researcher a large number of observations, increases the degree of freedom, and reduces the collinearity among explanatory variables. So, at the cost of strong assumption of homogeneous causal relationship across firms, it noticeably improves the efficiency of a Granger causality test.

Applying a simple method of estimating VAR-equations with panel data, Holz-Eakin, Newey and Rosen (1989) study dynamic relationship between local government revenues and expenditures. They find that lags of one or two years are sufficient to summarize the dynamic interrelationship in local public finance, but they also emphasize the importance of testing for appropriate lag length before testing causality.

The current paper uses a recently proposed model for panel data to analyze the Granger causality (Granger, 1969) relationships between a firm's investment variables and the firm performance. The analysis relies on a sample of Swedish firms observed during the period 1992 to 2000. As Baltagi (2001) points out, the interpretations of vector Autoregressions (VAR) in terms of causal relationship is still a controversial issue. Most researchers would agree that VAR are useful means of summarizing dynamic relationships, such as the dynamic relationship between firms' R&D expenditures and sales income. In this study we have tested the causal relationships between the investment and performance variables by using one, two and three lags. Taking the short time series into account, models with a lag length of two lags were preferred.

2.4 Transitory or permanent?

Investigating the correlation between innovation (innovative output) and profitability, Geroski, Machin, and Van Reenen (1993) attempt to distinguish between transitory and permanent effects. If the dominating effects of R&D investments are new products on the market, we can expect a larger likelihood of a transitory effect. The introduction of new products may lead to increased profits, which remain high only until rivals successfully imitate and begin to drain the innovator's rent. On the contrary, if the dominating effect is the process of innovation, having a generic impact on the firm's core competence, the probability of permanent effects will increase.

The present paper will touch upon the issue of transitory and permanent effects. If the possible causal impact of R&D or physical investments on firm performance will cease after only one period, we will regard this as an indication of transitory effects.

3. DATA AND PRELIMINARY FINDINGS

3.1 Data sources and data collection

This paper is based on two sources of data. First, we have three consecutive innovation surveys conducted in Sweden in 1996, 1998 and 2000: the National Innovation Survey

(NIS) and two Community Innovation Surveys (CIS). The criterion for including a firm in our sample is that the number of employees is 50 or more. This is a requirement to exploit the available R&D-information for the whole period 1992-2000 in the subsequent analyses. The censoring resulted in 480 observations in the year 1996-data (CIS II), 931 observations in the 1998-data (National innovation survey) and 519 firm observations in the 2000-data (CIS III). The share of firms with positive R&D investment varies in the interval 43% to 68% (see Table 1).[1]

Table 1: Firms with 50 or more employees in three consecutive innovation surveys.

Surveys	Number of firm observations	R&D Investors share
Community Innovation Survey (CIS II) 1996	480	68%
National Innovation Survey (NIS) 1998	931	43%
Community Innovation Survey (CIS III) 2000	519	51%

The second source of data is a panel covering the period 1992-2000. The data contains annual R&D investments and other information for firms included in the stratified sample used in the 1998 innovation survey. Table 2 summarizes the unbalanced and balanced versions of the panel data. The former data allows for exit and entry of firms and it consists of 12,082 observations. Since we use lag structure to establish the causal relationship between the variables of interest, the unbalanced panel is limited to firms observed at least 4 consecutive years. The unbalanced sample is reduced to 7751 observations (see Table A1 in the Appendix).

The unbalanced panel, despite its increased data management and estimation complications, it is of course preferred since it allows for both entry and exit of firms with different technology levels to the market. In addition it has the advantage that it also reduces sample selection and attrition biases.

[1] The first survey (CIS I) was collected in 1992, but only a minority of European countries participated. Since CIS I was not conducted in Sweden, it is not utilized in this study.

Table 2: Panel data sets. The observables are based of the stratified sample from the Swedish national Innovation Survey conducted in 1998.

	Unbalanced Panel Data			Balanced Panel Data		
Year	Frequency	Percentage	Cumulative Frequency	Frequency	Percentage	Cumulative Frequency
1992	1,070	8.8	1,070	776	11.1	776
1993	1,080	10.0	2,150	776	11.1	1,552
1994	1,170	8.8	3,320	776	11.1	2,328
1995	1,290	10.7	4,610	776	11.1	3,104
1996	1,390	11.5	6,000	776	11.1	3,880
1997	1,480	12.2	7,480	776	11.1	4,656
1998	**1,605**	**13.3**	**9,085**	**776**	**11.1**	**5,432**
1999	1,519	12.6	10,604	776	11.1	6,208
2000	1,478	12.2	12,082	776	11.1	6,984

Note: Number of firms with 50 or more employees is 1,605 in the stratified sample of which 931 responded to the innovation survey.

3.2 Variables and their definitions

The key variables in the panel data analysis, which is our main interest, are presented in Table 3. The financial performance variables include: sales (SALE), value added (VALA), research and development (R&D), flow of tangible investments (FTAN), gross profit (PROF) and cash flows (CASH). Other variables include employment (EMPL), stock of tangible investments (STAN), capital structure, (CAPS), human capital expressed as share of employment with a university degree (HCAP), knowledge intensive production technology (KNOW), debt (DEBT) and equity (EQUI).

Summary statistics of the data is presented in Table 3. Column 1 reveals summary statistics for all firms in the balanced sample. Columns 2 and 3 show corresponding data for small and medium-sized and large firms respectively. Small and medium-sized enterprises (SME)[2] are those with 50-250 employees. The category of large firms includes firms with more than 250 employees. The average size for the smaller firms is 113 employees compared to 896 employees for larger firms. The monetary values are transformed to 2000 fixed prices using producer price index.

[2] The definition used here is not a standard OECD definition. The SME group generally includes firms that have 10-300 employees, but the classification differs across sectors.

Table 3: Summary statistics of the variables, unbalanced panel data 1992-2000.

Size	All firms 50- employees 1,339 firms, 7,751 obs		Small and Medium firms 50-250 employees 990 firms, 5,590 obs		Large firms 251- employees 349 firms, 2,161 obs	
Variable	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev
SALE	1565.72	982.46	1462.50	937.72	1832.72	1043.57
VALA	488.13	221.22	460.96	192.53	558.41	270.59
R&D	37.28	1351.23	33.68	1589.68	46.59	109.34
FTAN	72.86	123.25	64.43	102.33	94.66	163.54
PROF	100.85	177.63	89.23	153.02	130.90	226.65
CASH	491.32	221.17	464.720	193.02	560.13	269.32
EMPL	331.36	820.64	112.90	52.95	896.46	1402.16
STAN	342.16	446.68	290.07	328.57	476.92	641.38
CAPS	0.70	0.20	0.69	0.20	0.71	0.19
HCAP	0.15	0.11	0.13	0.11	0.18	0.13
KNOW	0.30	-	0.27	-	0.40	-
DEBT	344498.12	1695696.79	61370.47	63664.17	1076882.92	3092281.76
EQUI	152937.06	757459.83	303582.69	56886.94	469956.46	1382311.76

Notes: Definition of the variables: SALE: Sales, VALA: Value added, R&D: R&D investments. FTAN: Flow of tangible investments, PROF: Gross profit, CASH: Gross cash flows, EMPL: employment, STAN: Stock of tangible investments, CAPS: Capital structure (DEBT/(DEBT+EQUI)), HCAP: Human capital, KNOW: Knowledge intensive production, DEBT: Debt, and EQUI: Equity.

3.3 Cross-sectional data analysis

In what follows we shall estimate models based on the three innovation samples using the CDM-model which in recent year has been frequently used for analyzing CIS data.

The first question we wish to ask is how internally generated capital (profit), debt and equity contributes to R&D-investments? All three variables are expressed in per employee-terms. Next we explore the relationship between R&D-investments and innovation sales per employee. Finally, we are interested in the elasticity of value added per employee with respect to innovation output.[3] In each equation of the model, we use the traditional control-variables (see Table 4) suggested in the Schumpeterian literature (Cohen and Klepper, 1996; Crepon et al., 1998; Janz, Lööf and Peters., 2004).

[3] The CDM model consists of four equations including: propensity to invest in innovation activities, innovation input, innovation output and productivity. The first two equations are estimated using a generalized tobit model, while the last two equations are estimated in a simultaneous equations system. The estimation procedure accounts for both selectivity and simultaneity biases. For details on the specification and estimation of the model, see Lööf and Heshmati (2002 and 2006).

Table 4: The three last equations of the four equation structural CDM-model

	Innovation Survey 1996 (CIS II) n=480		**Innovation Survey 1998 (NIS) n=931**		**Innovation Survey 2000 (CIS III) n=519**	
	Est coeff	Std error	Est coeff	Std error	Est coeff	Std error
Panel A: Dependent variable: R&D investments (log R&D investment per employee)						
Firm size	0.258***	(0.093)	0.128	(0.111)	0.302**	(0.126)
Equity	0.376***	(0.126)	0.335***	(0.071)	-0.064	(0.106)
Profit	0.080***	(0.030)	-0.005	(0.027)	-0.042	(0.032)
Long term debt	0.023	(0.044)	0.089***	(0.032)	0.021	(0.036)
Short term debt	0.193	(0.153)	0.683***	(0.115)	1.003***	(0.189)
Capital stock	-0.105	(0.092)	-0.112	(0.091)	-0.230**	(0.100)
Industry dummies	Included		Included		Included	
Panel B: Dependent variable: Innovation output (log innovation sales per employee)						
R&D(t-1)	0.826**	(0.364)	0.524***	(0.147)	0.496***	(0.189)
Firm size	0.128	(0.173)	-0.564	(0.451)	-0.174	(0.132)
Capital, flow	0.238	(0.043)	0.000	(0.071)	-0.034	(0.056)
Productivity	1.103	(0.679)	-0.182	(0.986)	1.312***	(0.480)
Mill's ratio	0.182	(0.502)	-2.178	(1.923)	-0.161	(0.405)
Industry dummies	Included		Included		Included	
Panel C: Dependent variable: Productivity (log value added per employee)						
Innovation output(t-1)	0.269***	(0.078)	0.185***	(0.067)	0.302***	(0.083)
Capital, stock	0.067***	(0.023)	0.138***	(0.024)	0.104**	(0.047)
Engineers	0.656*	(0.357)	0.949***	(0.286)	0.702**	(0.329)
Administrators	0.605	(0.773)	0.430	(0.874)	-0.018	(0.335)
Firm size	-0.088	(0.035)	-0.023	(0.020)	0.016	(0.040)
Industry dummies	Included		Included		Included	

Note: Asterics ***, ** and * indicate significance at the 1%, 5% and 10% levels of significance, respectively.

All three regressions reveal results consistent with our expectations regarding the estimates and elasticities of R&D investment, innovation output and productivity. The R&D intensity is an increasing function of size. The picture is clear when the very small firms are censored. Using cross sectional data from the three Swedish innovation surveys, but non-censored observations, Lööf and Heshmati (2002 and 2006) and Janz, Lööf and Peters (2004) find results similar to those presented in Table 4.

What is new in the present study compared to other analysis of the Swedish innovation data is that we introduce financial variables as determinants of firms' R&D-intensity. In contrast with the robust and positive relationship between R&D and innovation sales (See Panel B of Table 4) and between innovation sales and productivity (See Panel C), the results concerning the R&D-elasticity is somewhat mixed over the three data samples. R&D-intensity is an increasing function of equity (per employee) in the 1996 and 1998 data, but not in 2000. The point estimate for profit is significant only when we use the 1996 data. Short- term debt contributes positively and significantly to R&D in 1998 and 2000 but not for the 1996 sample. Long-term debt is significant only in the 1998-data. Table 4 shows that for firms with 50 or more employees, R&D is an increasing function of size measured as number of employment. It should be noted that the correlation between capital stock and R&D-intensity is only significant (and negative) in the CIS III data.

3.4 Descriptive analysis of the panel data

The cross-sectional analysis, presented in Table 4, Panel C, confirms the commonly held view in the Schumpeterian literature that physical capital and knowledge capital (the output from R&D), together with human capital are main determinants to productivity growth. In the following we will add the time-series dimension to the cross-sectional analysis in the previous section. Unfortunately, the three innovation surveys are only partly overlapping and less sufficient for our panel-data data analysis. As an alternative strategy, we use the richest of the three cross-sectional data sets, the 1998 innovation survey data, and merge it with time-series of cross sectional data for the period 1992-2000 obtained using Swedish firm register data. Since R&D is the key-variable in our study, and since the merged data contains R&D-information only for firm with 50 or more employees, we had to drop the smallest firms with less than 50 employees from the further investigation.

Table 5 provides an initial simple descriptive analysis of the resulting panel data. We report the annual growth rates for 1992-2000 by R&D-intensity, for the key variables in the study. The sample is divided into three subgroups distinguished by the size of R&D-investment including: zero investment, moderate investment rate (0.1-2.0% as a share of sales) and high investment rate (more than 2%). The label “A” here indicates growth rates during the next 8 years (1992-2000) after R&D-intensity measured in year

1992, and the label “B” indicates growth rates during the previous 8 years, measured by the year 2000 R&D-intensity.

It is shown that the future growth rate of sales (See label A), value added, profit, cash flows and employment is positively associated to the initial R&D-intensity. Moreover, for firms with 50 or more employees, the present level of R&D (See label B) is a fairly good predictor of the previous growth rate of four out of five of these variables. Only for employment no difference can be observed between non-R&D firms and other firms.

Table 5: Annual growth rate in 1992 to 2000 grouped by the ratio of R&D to sales.

R&D/Sales	**0.0 %**	**0.1-2.0 %**	**2.1 - %**	**Tendency**
Sales A	5.6	6.2	8.6	+
Sales B	5.9	6.4	8.0	+
Cash flow A	5.6	7.1	7.6	+
Cash flow B	6.0	6.9	7.7	+
Labor productivity A	4.9	6.5	7.0	+
Labor productivity B	5.2	6.4	6.9	+
Profit A[1]	10.5	17.7	18.6	+
Profit B	12.6	15.3	19.8	+
Employment A	0.3	0.6	1.3	+
Employment B	0.3	0.5	0.3	None
Debt A	5.0	5.2	1.8	-
Debt B	5.4	4.7	1.3	-
Equity A	9.4	9.4	8.5	-
Equity B	11.3	8.1	7.6	-
Observations used in A	349	279	158	
Observations used in B	407	239	140	

Note: (A): Growth rate of (R&D/Sales) year 1992, and (B); Growth rate of (R&D/Sales) year 2000.
(1) Only firms with positive profit in both 1992 and 2000 are included.

The four rows at the bottom of the table reveal growth rate of total debt (long-run and short-run) and equity. The results indicate that debt per employee in 1992 to 2000 is a decreasing function of the initial R&D-intensity as well as over R&D-intensity at the end of the period. The differences are small in the future growth rate of equity, with respect to initial R&D-effort. Looking at the backward perspective, firms with no R&D-investment in year 2000 had the largest growth of equity between 1992 and 2000.

Table 6 shows correlation between the key investment and performance variables in the balanced panel dataset. Panel A depicts 7,751 observations from the overall sample, Panel B 5,590 observation from the subgroup of small and medium-sized firms (50-250 employees), and Panel C shows the correlations among of large firms (2,161 observations from the subgroup of large firms with more than 250 employees).

The three panels revels a fairly stable pattern; there is a strong correlation between sales and value added, profitability and cash flows. The correlation coefficients between sales and value added, one the one hand side, and human capital, physical capital and R&D on the other are quite sizeable in the order of 0.3 to 0.5.

Starting with Panel A, we see that sales, value added and cash flows exhibit high correlation with R&D investment. The correlation between these three financial variables and investment is somewhat lower when we consider investment in tangible assets. Capital structure measured as the ratio of debt to sum of debt and equity is negatively associated to both types of investment. The correlation coefficients for all financial variables is measured in form of intensity, i.e. per employee. Human capital is measured as share of the employees with a university education, Knowledge intense industries corresponds to sectors with a high R&D/sales ratio or a high proportion of employees with a university education.

Table 6: Correlation of investment and performance variables.

Panel A: ALL firm sizes (50 and more employees)											
	SALE	VALA	FTAN	R&D	PROF	CASH	EMPL	STAN	CAPS	HCAP	KNOW
SALE	1.00										
VALA	0.61a	1.00									
FTAN	0.02	0.01	1.00								
R&D	0.26a	0.30a	-0.01	1.00							
PROF	0.47a	0.87a	0.01	0.17a	1.00						
CASH	0.60a	0.97a	0.01	0.28a	0.89a	1.00					
EMPL	0.19a	0.16a	002	0.07a	0.08a	0.14a	1.00				
STAN	0.37a	0.46a	-0.01	0.64a	0.24a	0.43a	0.11a	1.00			
CAPS	-0.01a	-0.15a	0.01	-0.01	-0.17a	-0.16a	0.06a	-0.05a	1.00		
HCAP	0.20a	0.29a	0.04a	0.06a	0.13a	0.31a	0.21a	0.04a	-0.01	1.00	
KNOW	-0.06a	-0.01	0.03a	-0.11a	-0.01	-0.01	0.13a	-0.21a	0.03a	0.22a	1.00
Panel B: Small and medium (SME) sized firms (50-250 employees)											
	SALE	VALA	FTAN	R&D	PROF	CASH	EMPL	STAN	CAPS	HCAP	KNOW
SALE	1.00										
VALA	0.58a	1.00									
FTAN	0.01	0.01	1.00								
R&D	0.25a	0.27a	-0.01	1.00							
PROF	0.44a	0.87a	0.01	0.15a	1.00						
CASH	0.58a	0.97a	0.01	0.26a	0.89a	1.00					
EMPL	0.01	0.07a	-0.01	0.01	0.03a	0.07a	1.00				
STAN	0.35a	0.36a	-0.01	0.63a	0.14a	0.34a	0.01	1.00			
CAPS	-0.01a	-0.17a	0.01	0.01	-0.18a	-0.19a	-0.01	-0.08	1.00		
HCAP	0.17a	0.27a	0.03	0.01	0.13a	0.30a	0.10a	-0.01	-0.04a	1.00	
KNOW	-0.08a	-0.01	0.02a	-0.10a	0.01	-0.01	0.03a	-0.20a	-0.01	0.17a	1.00
Panel C: Large sized firms (251 and more employees).											
	SALE	VALA	FTAN	R&D	PROF	CASH	EMPL	PCAP	CAPS	HCAP	KNOW
SALE	1.00										
VALA	0.63a	1.00									
FTAN	0.32a	0.24a	1.00								
R&D	0.24a	0.30a	0.01	1.00							
PROF	0.50a	0.87a	0.15a	0.17a	1.00						
CASH	0.62a	0.96a	0.24a	0-28a	0.91a	1.00					
EMPL	0.24a	0.12a	0.41a	0.04b	0.05a	0.10a	1.00				
PCAP	0.39a	0.53a	-0.07a	0.65a	0.31a	0.50a	0.04b	1.00			
STAN	0.03c	-0.15a	-0.05b	-0.02	-0.19a	-0.15a	0.09a	-0.10a	1.00		
HCAP	0.19a	0.24a	0.54a	0.08a	0.10a	0.26a	0.24a	0.02	0.05a	1.00	
KNOW	-0.10a	-0.08a	0.35a	-0.16a	-0.05b	-0.08a	0.16a	-0.31a	0.12a	0.26a	1.00

Notes: Significant at the less than 1% (a), 1-5% (b) and 6-10% (c) levels of significance.

Definition of the variables: SALE: Sales, VALA: Value added, R&D: R&D investments. FTAN: Flow of tangible investments, PROF: Gross profit, CASH: Gross cash flows, EMPL: employment, STAN: Stock of tangible investments, CAPS: Capital structure (DEBT/(DEBT+EQUI)), HCAP: Human capital, KNOW: Knowledge intensive production, DEBT: Debt, and EQUI: Equity.

3.5 Some preliminary findings

We conclude this section by summarizing the preliminary findings from the cross-sectional analysis and the descriptive analysis of the panel data. By using an identical specification of the multi-step CDM-model, the data suggest that R&D-investment is an increasing function of both internal (retained profit) and external (debt and equity) financial sources. The results give some evidence that external sources of capital are more important than internal funds, which is in contrast to the literature (see e.g. Hall, 2002). These results, however, are not robust across the three survey samples, which might be explained by business cycle factors. A commonly held view in the financial literature is that firms' adjustment of the degree of indebtedness is associated with the market valuation of the firm (Brealey, Mayers and Allen, 2006).

Although the CDM-model, by definition, is aimed at capturing the relationship between the decision to engage in R&D, and the size of R&D-investments, the output from R&D-investments, and finally productivity, the cross-sectional nature of the data doesn't allow us to draw any conclusion about causal relationships among the variables. We try to improve upon this limitation by tracing firms backward and forward. Our second preliminary finding comes from the panel data analysis. Here, we also introduce cash flow in the analysis. Both the "forward and backward" tests and the correlation analysis indicate that the R&D-investments are closely correlated with different measures of firms' performances.

In the following, we will explore the relationship between R&D and firm performance in more detail. In particular we will ask four questions: (i) Is there a causal relationship between R&D and firm performance? (ii) Is there a reverse causal dependence between R&D-investment and market success for a firm, measured as sales and profit? (iii) Is the causal association temporary or transitory? (iv) Does the pattern of causality and robustness differ between small and medium and large firms?

4. THE EMPIRICAL MODEL AND ESTIMATION PROCEDURES

In this section the empirical model is presented. Let us consider two variables y_{it} and x_{it}. The former is firm i's performance in time period t. The latter measures the firm's investment. The existence of a relationship between the two variables above does not prove presence of causality or the direction of influence between the variables. To explain the Granger test for causality, we will consider the question: Is it R&D that "causes" the increased sales $(x \rightarrow y)$ or is it the increased sales that causes R&D $(y \rightarrow x)$? A variable *x* is said to Granger cause a variable *y* if, given the past values of *y*, past values of *x* is useful in predicting *y*. The Granger causality (Granger 1969) test assumes that the information relevant to the prediction of the two variables, e.g. R&D and sales, is contained solely in the time dimension of the data.

A common method for testing Granger causality is to regress the variable *y* on its own lagged values and on lagged values of the *x* variable, and to test the null hypothesis that the estimated coefficients on the lagged values of *x* are jointly zero. It should be noted that in testing for causal relationship between two or more variables one could account for heterogeneity (labelled as conditional or *z*-variables) not reflected in the lag of variables of interest.

The following model will allow the study of whether x_{it} Granger causes y_{it}:

$$(1)\quad y_{it} = \alpha_{0t} + \sum_{l=1}^{m} \alpha_{lt} y_{i,t-1} + \sum_{l=1}^{m} \beta_{lt} x_{i,t-1} + u_{it}$$

where *m* is number of lags (m=2), *i* is number of firms in each year (1,070-1,605), *t* is time period (1992-2000) and u_{it} is a random error term. The error term follows a two-way error component structure (Baltagi, 2001) and can be broken down into an unobservable firm specific (μ_i), time specific (λ_t), and a random (ν_{it}) error term component written as:

$$(2)\quad u_{it} = \mu_i + \lambda_t + v_{it}$$

The error term ν_{it} represents measurement error in the dependent variable and omitted explanatory variables. The error random term is assumed to be independently and identically distributed with zero mean and constant variance, σ^2. The firm and time specific effects, μ_i and λ_t, are effects capturing firm heterogeneity and exogenous technological change respectively and are assumed to be independent of each other and of regressors.

Similarly, in order to study whether y_{it} Granger causes x_{it}, we will specify a fully analogous model as in (1):

(3) $$x_{it} = \gamma_{0t} + \sum_{l=1}^{m} \gamma_{lt} x_{i,t-1} + \sum_{l=1}^{m} \delta_{lt} y_{i,t-1} + u_{it}$$

In the results presented in Section 5, we use two lags. The choice of lags is empirical rather than theoretical (some firms are observed only 4 periods). Testing for different lag structures, we find that the impact is negligible on the estimated regression coefficients. It should be noted that a small number of lags increases the number of degrees of freedom, while a large number of lags decreases or rules out autocorrelation.

Finally, we specify two null hypotheses. First, x_{it} will Granger cause $y_{it,}$ if the following null hypothesis is rejected:

(4) $H_0 : \beta_{it} = 0 \forall m \in [1, 2]$ and $\forall t \in [1992, \ldots, 2000]$

and, similarly, y_{it} will Granger cause x_{it} if the following null hypothesis is rejected:

(5) $H_0 : \delta_{it} = 0 \forall m \in [1, 2]$ and $\forall t \in [1992, \ldots, 2000]$

The models in (1) and (3) can be estimated using pooled ordinary least squares (OLS), least square dummy variables (LSDV) or within estimation methods. In the pooled model, no account is made for unobservable firm and time specific effects in (2), while in the LSDV model firm and time effects are captured by dummy variables. These are transformed out in the within estimation method. The latter two types of estimations give identical slope (causality) parameter estimates. The OLS models and within model are nested and the significance of the unobserved firm and time effects can be tested jointly. In addition the lag length is tested and determined.

5. EMPIRICAL RESULTS

We begin by reporting the main result from the investigation of uni- and bidirectional causality between investment and performance and then discuss the complete multivariate equations. Tables 7.1-7.4 present the summary of results from the causality tests for three performance measures, namely sales, employment and profitability, and two investment measures of tangible and intangible assets. Tables 8.1 and 8.2 show detailed results from the causality test among these five indicators, conditioning on a few other key variables such as capital structure, human capital and knowledge intensive production technology.

One important issue is that we also ask if the possible causality effect is persistent or only transitory. Naturally, the short panel and the exploitation of only two lag variables reduce the potential to explore the persistency/transitory nature of the effect properly. We believe, however, that the results provide some indications on the characteristics of the effects. If the causal effect holds only for the first lag but not the second, we interpret the influence as transitory, whereas a causality effect for both lags is required for the presence of a persistent causal effect.

The models in (1) and (3) are estimated using pooled and within estimation methods. In the former no accounts is made for unobservable firm and time specific effects in (2), while in the later we accounts for such effects. The joint test results (see Table 6.1 and 6.2) indicate that the effects are highly statistically significantly different than zero and should be included in the model specification. The models are then estimated by within estimation method transforming out the effects and using 2 lags of the dependent and independent investment and performance variables and having controlled several conditional variables.

5.1 Causality between sales and investment variables

Panel A in Table 7.1 contains the empirical results of estimating equations (1) and (3) for the sample of small and medium sized firms (SME) and the sample of large firms (LARGE). For both samples the within-model indicate that the last years sales per employee is not correlated with the present year's R&D-investments per employee, suggesting low importance of internal financial sources for R&D expenditures. The causal relationship between sales and R&D, however, turns out to be fragile and statistically significant at low level only for LARGE firms. The sign of lag 2 changes from positive to negative for both samples, indicating that effect from sales on R&D is transitory. In stark contrast to the cross-sections results reported in Section 3, the reverse causality from R&D-intensity to sales per employee is insignificant for both lag values of R&D. Our results confirm the findings by Klette and Kortum (2004) on insignificant relationship between R&D and firm performance (productivity) in the longitudinal dimension. It should be noted that we here, in congruence with other studies, interpret sales per employee (gross labor productivity) as a proxy for value added per employee (net labor productivity).

Panel B of Table 7.1 reveals some similarity between intangible investments (R&D) and tangible investments (physical capital), namely a positive but insignificant influence from sales one year lagged. The coefficient of two years lag sales yields still insignificant estimate for SME firms, whereas the causal relationship between sales and investment is highly significant and positive for LARGE firms. Thus, increased sales performance is a good predictor of increased investment activity only for larger firms. One explanation may be that they to a larger degree can use physical assets as collateral when seeking external financing.

Table 7.1. Causality Tests: Sales and Investment variables

		SME with 50-250 employees			**Large firms with 251- employees**		
	LAGS	Sign	Significance	Effect	Sign	Significance	Effect
PANEL A		Sales → R&D			Sales → R&D		
SALE	L1	+		None	+	*	⇒
	L2	-		None	-	*	⇒
		R&D → Sales			R&D → Sales		
R&D	L1	-		None	+		None
	L2	-		None	-		None
PANEL B		Sales → Gross physical investment			Sales → Gross physical investment		
SALE	L1	+		None	+		None
	L2	-		None	+	***	⇒
		Gross physical investment → Sales			Gross physical investment → Sales		
GPINV	L1	-	*	⇒	-		None
	L2	-		None	-		None

Notes: Significant at the less than 1% (***), 1-5% (**) and 5-10% (*) levels of significance.
⇒ Indicate causal relationship.

5.2 Causality between profit and investment variables

The reported results from the Granger causality test between sales and investments are reported in Table 7.1. Table 5.2 addresses the issue of financial constraint more directly than the results reported in Table 7.1. Panel C of Table 7.2 shows the relationship between profitability and the two R&D and Gross Physical investment variables. The first striking result is that we find no influence from profitability to R&D, or any feedback effect from R&D on profits. Interestingly, the signs of the estimates are positive in both L1 and L2 dimension as well as in the two-way causality perspective for SME firms, indicating the presence of liquidity constraints. For LARGE firms the sign of the estimate is mainly negative. However, due to insignificant effects no inference can be made here.

Turning now to the results of causality test between profitability and physical capital, the panel 4 of Table 7.2 shows a two-way causal relationship for both SME and large firms, although the sign is positive when the influence from profit on tangible investments is considered, and negative in form of feedback from physical investment on profit. The causality test suggests that in SMEs, firms' financial assets (retained profit) causes physical investments, which means that performance success in period 1 is highly important for the firms' possibilities to develop a capacity to be successful also in period 2. However, the negative influence of increased physical investments on profitability in both the first and second years perspective informs us that there is a considerable time lag between investment, break-even and profit.

In the case of large firms, by contrast, the causal influence from profitability to physical investments (Table 7.2) is only transitory, that is, the effect is insignificant for the second lag. Finally, we find that it takes two years for physical investments to influence profitability negatively for large firms, whereas the impact is immediate for SMEs.

Table 7.2 Causality Tests: Profitability and Investment variables

	LAGS	SME with 50-250 employees: Sign	Significance	Effect	Large firms with 251- employees: Sign	Significance	Effect
PANEL C		Profitability → R&D			Profitability → R&D		
PROF	L1	+		None	-		None
	L2	+		None	-		None
		R&D → Profitability			R&D → Profitability		
R&D	L1	+		None	-		None
	L2	+		None	+		None
PANEL D		Profitability → Physical investment			Profitability → Physical investment		
PROF	L1	+	***	⇒	+	***	⇒
	L2	+	***	⇒	+		None
		Physical investment → Profitability			Physical investment → Profitability		
GPINV	L1	-	***	⇒	-	***	⇒
	L2	-	*	⇒	+		None

Notes: Significant at the less than 1% (***), 1-5% (**) and 5-10% (*) levels of significance.
⇒ Indicate causal relationship.
All variables are in per employee.

5.3 Causality between employment and investment variables

Table 7.3 summarizes the causality test between employment and investment intensity. Interesting differences between the two sample sizes are revealed. First, in Panel E it is shown that firm growth, as measured in terms of employment, has no impact on R&D-investment for SMEs. This is in contrast to LARGE firms, for which the results suggest that last year's employment growth has a highly significant causal influence on the present R&D activities. But the effect is only transitory and last only for one year. The sign for lag two is only weakly significant and moreover, it is negative.

Looking then at the reverse relationship, Panel E of Table 7.3 shows that increased R&D-investments predicts reduced employment for SMEs, and the effect is highly significant after two years. We don't find any corresponding result for the LARGE firms. On the contrary, the effect of higher R&D-intensity is positive, but only weakly significant and transitory lasting only one year.

The results presented in Panel F of Table 7.3 do not reject the null hypothesis that an increased employment does not cause increased physical investments in the L1-dimension for both samples. We observe that increased employment has a significant positive influence on physical investment for SMEs when the number of lags is two. The L2 estimate for the employment-investment relationship is insignificant for LARGE firms. Physical investment, on the other hand, affects employment for both types of firms in the short run.

Table 7.3 Causality Tests: Employment and Investment variables

	LAGS	SME with 50-250 employees			Large firms with 251- employees		
		Sign	Significance	Effect	Sign	Significance	Effect
PANEL E		Employment → R&D			Employment → R&D		
EMPL	L1	-		None	+	***	⇒
	L2	+		None	-	*	⇒
		R&D →Employment			R&D →Employment		
R&D	L1	-		None	+	*	⇒
	L2	-	***	⇒	-		None
PANEL F		Employment → Physical investment			Employment → Physical investment		
EMPL	L1	-		None	+		None
	L2	+	***	⇒	-		None
		Physical investment →Employment			Physical investment →Employment		
GPINV	L1	+	***	⇒	+	*	⇒
	L2	-		None	+		None

Notes: Significant at the less than 1% (***), 1-5% (**) and 5-10% (*) levels of significance.
⇒ Indicate causal relationship.

We then turn to the reverse causality between employment and physical investment. Panel F shows that the instant effect of increased physical investment on employment is positive and highly significant for SMEs, but the effect changes to negative and insignificant in the L2 dimension. In the case of LARGE firms, evidence is provided that physical capital Granger causes employment only in transitory form lasting one year. The transitory effect vanishes as the higher capital intensity is associated with lower employment rate.

5.4 Causality between investment variables

Finally, Table 7.4 provides causality tests for tangible and intangible capital investments. For the SMEs as well as for LARGE firms the results suggest a significant negative effect from gross physical capital investments to R&D. However, the nature of the effect differs by size in that it is transitory for SMEs while it is non-transitory for large firms. We do not find a feedback, that is a positive influence of R&D on the level of gross investment in physical capital

Table 7.4 Causality Tests: Gross physical investment and R&D Investment variables

		SME with 50-250 employees			Large firms with 251- employees		
	LAGS	Sign	Significance	Effect	LAGS	Sign	Effect
PANEL G		Physical investment → R&D			Physical investment → R&D		
GPINV	L1	-	**	⇒	-		None
	L2	+		None	-	***	⇒
		R&D → Physical investment			R&D → Physical investment		
R&D	L1	+		None	-		None
	L2	+		None	-		None

Notes: Significant at the less than 1% (***), 1-5% (**) and 5-10% (*) levels of significance.
⇒ Indicate causal relationship.
All variables are in per employee.

5.5 Causal relationship between performance and invest variables

In investigating the causal relationship between the two investment variables (R&D and Gross physical) and three performance variables (Sales, Employment and Profit) two lags are used due to short time period in the data. The five models are estimated using pooled OLS and within estimation methods. Test results indicate that within method, where firm and time effects are accounted for, is the preferred model specification and estimation method. The test results also suggest that the conditioning variables of capital structure, human capital and knowledge intensive production technology should be included in the model specifications. The results for firms grouped into small and medium and large size classes are presented in Tables 8.1 and 8.2, respectively. In all cases the variables are measured per employee.

Table 8.1 Within causality parameter estimates, SME firms, NT=5590 obs.

Explanatory variables	Models					
	LAGS	SALE	PROF	EMPL	R&D	GPINV
SALE	L1	0.326***	0.544***	0.091***	0.321	0.018
	L2	0.008	-0.535***	-0.020**	-0.274	-0.037
R&D	L1	-0.001	0.002	-0.001	0.249***	0.001
	L2	-0.001	0.005	0.002***	-0.039***	0.004
GPINV	L1	-0.003*	-0.038***	0.004***	-0.053**	-0.021
	L2	-0.002	-0.028*	-0.001	0.006	-0.074***
EMPL	L1	-0.038**	-0.085	0.732***	-0.073	-0.244
	L2	-0.007	-0.732***	-0.046***	0.298	-0.537***
PROF	L1	-0.005***	0.104***	0.007***	0.016	0.088***
	L2	-0.002	-0.059***	0.002**	0.011	0.041***
CAPS	-	0.032	-0.323***	0.016***	0.613*	0.862***
EDUC	-	0.088	-0.311***	-0.052	0.323***	1.758**
KNOW	-	-0.101	-0.338	0.004	0.059	-0.544***
R2 adj		0.102	0.057	0.481	0.059	0.026
F-test model	-	50.09***	26.86***	398.85***	28.07***	12.71***
F-test: OLS vs Within		3.091***	2.394***	2.623***	2.102**	2.233**

Note: Significant at the less than 1% (***), 1-5% (**) and 6-10% (*) levels of significance.

Definition of the variables: SALE: Sales, VALA: Value added, R&D: R&D investments. GPINV: Gross physical investments, PROF: Gross profit, CASH: Gross cash flows, EMPL: employment, PCAP: Physical capital, CAPS: Capital structure (DEBT/(DEBT+EQUI)), EDUC: education, KNOW: Knowledge intensive firm, DEBT: Debt, EQUI: Equity.

Results based on the SME sample data reported in Table 8.1 show evidence of different relationships between the investment and performance variables. Current values of all indicators are related to their own lags. In the case of R&D, employment and profit the sign changes between the two lags. For instance SALE is strongly related to profit and employment but not to R&D or gross physical investment. Profit, in turn, is strongly associated with physical investment but not with R&D investment. Despite short lag structure, differences are also found in the longevity of the effects. The conditional variables show stronger association with profit and physical investment and no association with sales. Some of the results are unexpected, such as the effects of human capital on profits or knowledge intensity on physical capital investment.

Our causality results based on the large sized sample reported in Table 8.2 differ in several respects to those of the SME size. Even here we see that different indicators show evidence of difference in determinant relationship among the variables.

Differences by size are observed not only by significance and sign but also by persistency of the effects. Similar results are found concerning the relationship between current values of the indicators and their lag structure. One exception is that of Gross physical investment which in similarity with R&D, employment and profit switches from a positive to a negative effect when going from one to two lags. The statistically significant conditional variables show similar relation with the five indicators. However, in some cases we see difference in the effects by size of firms.

Table 8.2 Within causality parameter estimates, LARGE firms, NT=2161 obs.

Explanatory variables	Models					
	LAGS	SALE	PROF	EMPL	R&D	GPINV
SALE	L1	0.408***	0.402	0.074***	0.757*	0.152
	L2	0.036*	0.114	0.025	-0.717*	0.312***
R&D	L1	0.001	-0.014	0.002*	0.284***	-0.001
	L2	-0.001	0.003	-0.001	-0.066***	-0.004
GPINV	L1	-0.001	-0.113***	0.029*	-0.103	0.043**
	L2	-0.005	0.037	0.003	-0.211***	-0.151***
EMPL	L1	-0.036*	-0.134	0.689***	1.220***	0.027
	L2	0.013	0.314	-0.046**	-0.616*	-0.149
PROF	L1	-0.005**	0.195***	0.006**	-0.009	0.060***
	L2	-0.005***	-0.153***	-0.004**	-0.015	0.008
CAPS	-	-0.009	-1.619***	0.307***	1.584***	0.733***
EDUC	-	0.708***	1.098	-0.447***	7.476***	2.479***
KNOW	-	-0.208	-0.463	0.157***	-0.361	0.229
R2 adj		0.207	0.073	0.495	0.092	0.069
F-test model	-	44.58***	14.11***	163.93***	17.75***	13.25***
F-test: OLS vs Within		3.855***	2.826***	3.347***	2.441***	3.109***

Note: Significant at the less than 1% (***), 1-5% (**) and 6-10% (*) levels of significance.
Definition of the variables: SALE: Sales, VALA: Value added, R&D: R&D investments. GPINV: Gross physical investments, PROF: Gross profit, CASH: Gross cash flows, EMPL: employment, PCAP: Physical capital, CAPS: Capital structure (DEBT/(DEBT+EQUI)), EDUC: education, KNOW: Knowledge intensive firm, DEBT: Debt, EQUI: Equity.

6. SUMMARY AND CONCLUSIONS

Does a better financial performance of firms exert a positive influence on their R&D investments? While previous research in this area have shown that the level of R&D is a good predictor of financial performance of firms, they are far from being able to establish the nature of causal relationships between the key investment and performance variables. Some studies document a fragile and typically insignificant relationship between firms' R&D and their productivity growth suggesting that issues of causality are important in evaluations of R&D effects as well as for various policy decisions.

This paper first examined the cross-sectional nature of the R&D and firm performance relationships. The empirical results are based on data from three consecutive Swedish innovation surveys. A common multi-step estimation approach which accounts for both simultaneity and selection biases was applied. As expected, the results showed evidence of a strong and highly significant relationship between R&D and productivity through innovation output, measured as share of sales associated with new product and processes at the firm level.

Next we conducted time dimension analysis by selecting the 1998 national innovation survey firms and performing a simple forward-backward analysis. We found that R&D is a good predictor of future growth in, foremost, profit and employment, but also in sales and value added. Moreover, no R&D or only moderate R&D intensity predicts growing debt. The backward analysis indicated that the growth rate of profit, value added and sales are fairly good predictors of future R&D-intensity, while the growth rates of both equity and debt are negatively related to future R&D-intensity. The capital stock was found to be neutral to R&D in simple descriptive statistical forward and backward analysis.

For the Granger causality analysis we conducted causality tests based on both pooled OLS and within estimation analysis. The test results indicated a necessity to account for unobservable firm and time effects, thereby suggesting within as the appropriate estimation method. We estimated two R&D and gross physical investment variables and the three sales, profit and employment performance variables. In each of the five models we used a lag length of 2 applied to each of the dependent and independent variables. Due to heterogeneity in causal relationship by size of firms revealed in the preliminary analysis, we conducted the test separately for the groups of small and medium and large enterprises. In addition, we controlled for a number of conditional variables including indebtedness, human capital and knowledge intensity in firms' production technology.

We investigated whether there is a causal relationship between investment and performance of firms and whether the relationship is two-way causal. In addition, we studied the persistency of the relationship and its differences across firm sizes. Results based on the SME sample showed evidence of different relationship between the investment and performance variables. Current values of all indicators were found to be related to their own lags. In the case of R&D, employment and profit the sign changed between the two lags. For instance; sales is strongly related to profit and employment but not to R&D or gross physical investment. There are differences among the two sizes concerning the feedback from profit to gross physical investment. This indicates presence of capital constraint among the lower profitable SME firms. SMEs finance their investment needs with internal funds. The difference is however not statistically strong. Profit, in turn, is strongly associated with physical investment but not with R&D investment. Despite short lag structure, differences are also found in the longevity of the effects.

Our causality results based on the sample of large firms differ in several respects to those of the SME size. Even here we see that different indicators show evidence of difference in determinant relationship among the variables. Differences by firm size are observed not only in differing significance and signs, but also by persistency of the effects. Similar results are found concerning the relationship between current values of the indicators and their lag structure. The statistically significant conditional variables show similar relation with the five indicators across the two size groups. However, in some cases we see difference in the effects by size of firms.

The effect of R&D on profit is fragile and statistically insignificant. This confirms the finding in the literature on the longitudinal relationship between R&D and productivity. R&D has a week positive effect on employment only for large firms. We do not find many examples of a two way causal relationship between the two sets of variables and the relationships are transitory. Surprisingly, R&D and gross physical investment has no positive co-variation for large firms.

In this paper, we have elaborated several important issues such as cross sectional and time series aspects of the relationship between investment and performance variables accounting for conditional variables. We explored the size heterogeneity and the persistency in the relationships among the variables. We find it important to conclude this study with a few suggestions for future research on the causality between R&D investment and performance. One important step is to extend the relatively short panel data to a longer time period covering different growth and recession periods. This will gives a better base for applying systems of equations and alternative estimation methods for dynamic panel data analysis. Another extension is to perform stationarity tests in the data sets prior to the causality tests. Unfortunately, none of these extensions are possible with the current data sets which have short time coverage.

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Appendix A1. Firms observed 4 or more consecutive years

Number of years	Frequency	Percentage	Cumulative Frequency	Cumulative Percent
4	222	2.9	222	2.9
5	294	38	516	6.7
6	412	5.3	928	12.0
7	650	8.4	1578	20.4
8	636	8.2	2214	28.6
9	5537	71.4	7751	100.0