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Is R&D Financially Restrained? Theory and Evidence from Irish Manufacturing

By S. Bougheas, H. Görg and E. Strobl

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Abstract

We re-examine the effects of liquidity constraints on R&D investment. In our theoretical section we extend the neoclassical framework of investment in physical capital by introducing R&D and liquidity constraints. We analyse this issue empirically using firm-level data for R&D active manufacturing firms in the Republic of Ireland. Our results provide evidence that R&D investment is financially constrained which is in line with previous studies of US firms.

Outline

Non-Technical Summary

It is commonly argued that firms are not able to attract external funds to finance R&D. However, the empirical evidence supporting this view is based mainly on US data, presumably because of a lack of data available for other countries. In this paper we use firm-level R&D data for manufacturing firms in the Republic of Ireland to re-examine the effect of liquidity constraints on firms investment in R&D.

Testing for the effect of liquidity constraints on investment in general amounts to looking for a positive correlation between investment and some measures of liquidity. However, such a correlation may be spurious due to the possible correlation of both variables with profitability. This problem has traditionally been addressed by comparing either different types of investment or different types of firms where it is expected that this relationship is stronger for those investments or firms that are more financially constrained. In our theoretical model we suggest that this problem might be less severe if the variability of payoffs is high. The intuition is that while optimal investment levels might be correlated with future profitability, this will not be the case for actual levels of investment if they cannot be financed externally.

In the empirical analysis we use firm-level data to examine the effect of liquidity constraints on R&D. Our dataset enables us to exclude R&D undertaken in the firm but financed by other firms or through government grants. A failure to make this distinction may bias the results since a firm that finances R&D through these sources may record high investments in R&D but may still be liquidity constrained. Previous studies of the relationship between liquidity and R&D do not seem to have made this distinction. Our empirical estimations provide strong evidence that R&D investments of Irish manufacturing firms are liquidity constrained. This result holds for a number of different specifications of the empirical model. In line with the previous empirical literature we compare our results for investment in R&D with investment in physical capital and we do not find evidence that the latter is financially constrained.

1 Introduction

It is widely accepted that internal finance is the most important funding source for investment in Research and Development (R&D). Although there have been a number of empirical studies addressing this issue, they have not been based on explicit models of R&D financing but have relied on theoretical arguments borrowed from the finance literature. These include papers by Leland and Pyle (1977) and Myers and Majluf (1984) which suggest that R&D projects, which face long and uncertain payoffs, are subject to high lemon's premia because of the inability of outside investors to distinguish their quality. External finance opportunities for inventive activities are also restricted by moral hazard arising from risk assessment problems, as suggested by Arrow (1962). Furthermore, R&D projects lack tangible assets that can be used as collateral which, as demonstrated by Bester (1985), can mitigate incentive problems. All of the above arguments offer potential explanations for the reluctance of outside investors to finance R&D. There is an additional argument, suggested by Bhattacharya and Ritter (1985), that stresses the reluctance of firms to finance their R&D externally because of the cost of revealing the quality of their innovation to the market.

The more recent empirical studies of the impact of financial constraints on R&D spending follow the methodology suggested by Fazzari, Hubbard and Petersen (1988).[1] For example Hall (1992) compares the behaviour of investment in physical capital and R&D spending assuming that the latter faces greater barriers to external finance while Hao and Jaffe (1993) split their sample in groups identified by the size of firms given that large firms have easier access to external finance. Both studies use data from the US and find support for the hypothesis that R&D is liquidity constrained, although Hao and Jaffe's (1993) results suggest that there is no liquidity effect for

[1] Fazzari, Hubbard and Petersen (1988) point out that one of the problems of testing the impact of financial constraints on current investments is that both the level of spending and measures of liquidity might be correlated with profitability. As a result, simple regressions might show a positive relationship between investment and such measures even if the capital markets are perfect. They suggest that this problem can be addressed by comparing the behaviour of firms that belong to different sectors of the economy. The idea is that it is likely that financial constraints are not equally severe for all types of investments and therefore the theory would predict that the relationship will be stronger for those investments that are more constrained by internal finance. This approach has been followed by Hoshi, Kashyap, and Scharfstein (1991) in an empirical study of the Japanese financial system.

large firms. Himmelberg and Petersen (1994) obtain similar results from a panel study of small US hi-tech manufacturing firms that do not have access to the venture capital market and Hall, Mairesse, Branstetter and Crepon (1999) offer further support from a comparative study of French, Japanese and US firms.

This paper contributes to the literature both theoretically and empirically. On the theoretical side we present a dynamic programming model of the firm's investment decision where both R&D and the financial constraints are explicitly considered. In addition to its physical capital investment decision, the firm each period decides its level of R&D. As in Aghion and Tirole (1994), R&D in our model increases the probabilty of success of the firm's project. We assume that the firm cannot finance R&D externally and capture this restriction by introducing a cash-in-advance type of constraint that limits each period's R&D expenditure to no more than the net profits earned in the previous period. In contrast, investment in physical capital can be financed externally.[2] The financial constraint implies that when past profits are sufficiently high, R&D spending will be set at its first-best level. Otherwise, the firm is constrained and there will be underinvestment in R&D. The conventional wisdom is that the returns of R&D projects are much more variable than the corresponding returns of other types of investment. If this is the case, both R&D spending and past profitability are only weakly correlated with expected future profitability although strongly correlated with each other. On the contrary, in our model investment in physical capital is not liquidity constrained and, therefore, it is predicted to have a much weaker correlation with past profits even if it is highly correlated with expected profitability.

On the empirical side, we re-examine the effect of liquidity constraints on R&D spending using data for the Republic of Ireland. Ireland provides an especially interesting case study given its recent economic growth experience particularly in high tech sectors (see, for example, Sachs, 1997). Furthermore, our dataset enables us to exclude R&D undertaken in the firm but financed by other firms or through government grants. A failure to make this distinction may bias the results since a firm that finances R&D through these sources can still be liquidity constrained. Previous studies of the relationship between liquidity and R&D expenditure do not seem to have been able to make this

[2]With only two types of investment, this distinction allows us to investigate the theoretical implications of financial constraints.

distinction.

The paper is structured as follows. The next section presents the model and draws out the hypotheses to be tested empirically. For ease of exposition, before we introduce the financial constraint, we first consider the case of perfect capital markets. Section 3 discusses the dataset, presents some summary statistics and the results of the empirical estimations. Section 4 concludes.

2 The Model

We consider a firm's physical capital and R&D investment decisions within a dynamic programming framework. We extend the neo-classical model of investment with internal adjustment costs under uncertainty by introducing R&D as a productivity enhancing input. Every period the firm's physical capital stock, K_t, and R&D investment, e_t, yield expected profits:

$$E_t[A_t; e_t]F(K_t) - I_t - e_t - C(I_t)$$

where E is the expectation operator, A_t is a random productivity parameter whose distribution depends on the level of R&D. We assume that $\frac{\partial}{\partial e_t}E_t[A_t; e_t] > 0$ and $\frac{\partial^2}{\partial e_t^2}E_t[A_t; e_t] < 0$. In other words, R&D improves expected profits at a decreasing rate. This method of modeling R&D follows Aghion and Tirole (1994) who postulate a Bernoulli distribution of returns and they assume that R&D increases the probability of success. $F(K_t)$ is a production function that also exhibits diminishing returns, I_t denotes investment in physical capital and $C(I_t)$ is an adjustment cost function with $C(0) = 0$, $C' > 0$ and $C'' > 0$.

The evolution of the firm's capital stock is given by:

$$K_t + I_t = K_{t+1}$$

where the initial level of capital stock K_0 is given.

Before we introduce in the model financial constraints, we will consider the case of perfect capital markets. In this benchmark case the firm can finance both types of investment externally; i.e. either by issuing new equity or bonds.

2.1 Perfect Capital Markets

The firm maximizes the present value of the stream of profits by choosing the two types of investment. The Lagrangian for this problem is given by:

$$\mathcal{L} = \sum_{t=0}^{\infty} \frac{1}{(1+r)^t} \{E_t[A_t; e_t]F(K_t) - I_t - e_t - C(I_t) + q_t (K_t + I_t - K_{t+1})\} \tag{1}$$

where r denotes the interest rate and q (the Langrangian multiplier) shows the value of an additional unit of capital. The first order condition for the investment in physical capital implies:

$$1 + C'(I_t) = q_t \tag{2}$$

the first order condition for R&D investment implies:

$$\frac{\partial}{\partial e_t} E_t[A_t; e_t]F(K_t) = 1 \tag{3}$$

and the corresponding condition for the capital stock implies:

$$E_t[A_t; e_t]F'(K_t) = (1+r)q_{t-1} - q_t \tag{4}$$

There is also a transversality condition stating that the value of the capital stock must approach zero. Equation (2) states that the firm invests to the point where the cost of one additional unit of capital is equal to the value of capital. Equation (3) states that the firm invests optimally in R&D when the expected marginal benefit of one additional unit of R&D expenditure is equal to its cost. Finally, equation (4) states that at the optimum the expected marginal revenue product of capital is equal to the opportunity cost of capital. Notice that letting $\Delta q_t = q_t - q_{t-1}$, the right-hand side of (4) can be written as $rq_{t-1} - \Delta q_t$, which shows that the opportunity cost of capital is equal to the forgone interest minus capital gains.

The dynamics of the neo-classical model of investment have not been significantly affected with the addition of R&D and, therefore, we will only briefly summarize them. Equation (2) implies that when $q_t = 1$, $I_t = 0$, and since $C'(I_t)$ is increasing in I_t, the latter is increasing in q_t. In addition, equation (4) implies that q_t is constant, i.e. capital gains are equal to zero, when the expected marginal revenue product of capital is equal to the forgone interest. These two equations and the transversality condition determine the transitional dynamics. When $q_t > 1$, q_t falls and K_t rises as both are approaching their steady-state values. Notice that R&D affects only current profits and equation (3) implies that it is complemetary to physical capital. If the firm's initial capital, K_0, is below its steady-state value, both K_t and e_t will increase over time. In the following section, we consider the optimal paths of investment in physical capital and R&D when the capital markets are imperfect.

2.2 Cash Flow Constraints and R&D

Suppose that the firm cannot finance R&D externally. The firm needs the funds for R&D at the beginning of each period and the only source of funds is last period's revenues. In this model, apart from R&D and capital there are no other inputs; e.g. labour and raw materials. Since, by assumption, investment in physical capital can be financed externally the firm can use last period's revenues to finance R&D.[3] For simplicity, it is assumed that at the end of each period the firm distributes all of its profits, net of next period's R&D, as dividends. Physical capital is financed by issuing new equity instead of debt.[4] The following set of inequalities captures this constraint:[5]

$$A_{t-1}F(K_{t-1}) \geq e_t, \forall t \tag{5}$$

[3]Of course, this is not quite correct because accounts receivable on the firm's balance sheet might be positive indicating that some sales are made on credit. As long as credit sales are a constant fraction of total sales this should not be too problematic.

[4]We can easily introduce debt in the model without affecting our results. To do so we need to add to the obsective function the net change of the stock of debt (positive for new loans and negative for repayments). In addition, we need some kind of constraint that limits the amount of total borrowing. Since we assume that there are no capital market imperfections with respect to physical capital investments bondholders and equityholders would be in agreement about this kind of limit.

[5]Notice that this constraint is similar to the cash-in-advance (Clower) constraint encounterd in monetary models.

The introduction of this constraint does not affect the first order condition for the investment in physical capital, however, the other two conditions need to be modified as:[6]

$$\left[\frac{\partial}{\partial e_t}E_t[A_t;e_t]+\frac{1}{1+r}\frac{\partial}{\partial e_t}E_t[m_{t+1}A_t;e_t]\right]F(K_t)=(1+m_t) \tag{3a}$$

$$\left[E_t[A_t;e_t]+\frac{1}{1+r}E_t[m_{t+1}A_t;e_t]\right]F'(K_t)-(1+r)q_{t-1}+q_t=0 \tag{4a}$$

where m_t is the multiplier associated with the cash flow constraint. The only new terms in the new conditions are the ones containing the multiplier. In condition (3a) the multiplier appears on both sides. An increase in R&D spending this period increases expected profits and, thus, relaxes next period's constraint. This effect is captured by the second term in the brackets on the left-hand side. The presence of the multiplier on the right-hand side depicts the effect of last-period's returns on current R&D spending. In condition (4a), the presence of the multiplier on the left-hand side captures the expected benefits from relaxing next period's constraint by increasing physical capital by one unit. Since investment in physical capital is not financially constrained the current multiplier is absent from condition (4a).

Investment in physical capital depends only on expected profits. Assuming that the firm's initial capital stock is low, investment will increase over time. If there is high profit variability then the correlation between investment and actual returns will be low. On the contrary, R&D expenditure depends directly on the realization of returns. When returns are low, the constraint binds and R&D spending next period will be low; otherwise, R&D spending will be at its optimal level. As a consequence, when there is high profit variability, R&D spending will be strongly correlated with returns.

3 Empirical Analysis

The main hypothesis to be tested from the model is that firms facing financial constraints have to rely on internal funds to finance R&D. In order to analyse

[6]Whether the constraint binds or not will depend on the realizations of A_t and, consequently, the analysis of the dynamics of the model is becoming more complicated. Nevertheless, in the mathematical appendix, using a two-period version of the model, we demonstrate how the complete solution can be derived recursively.

this issue we estimate an equation of the following form:

$$(r/k)_{it} = \beta_0 + \beta_1 (y/k)_{it-1} + \beta_2 (q/k)_{it-1} + \beta_3 (d/k)_{it} + e_{it} \tag{6}$$

where r is R&D expenditure of firm i, y is net profits (revenues minus current expenditures; i.e. labour costs, raw materials etc.), q is sales, d is long-term debt, k is capital and e is the error term. Such a specification is common in the literature; similar specifications were used by Hall (1992) and Himmelberg and Petersen (1994). In particular, dividing each variable by capital allows not only the comparison of R&D ratios over time and across firms but also minimises potential heteroskedasticity as all variables are normalised by a measure of firm size. Following Hall (1992) we use y as a measure of liquidity. In the theoretical model we have assumed that apart from R&D and physical capital there are no other inputs. For our empirical implementation we need to subtract these expenditures from revenues and therefore we use net profits as a proxy for liquidity. We include past sales q in order to capture expectations regarding future revenues.

We use a similar specification to estimate an equation for investment in physical capital:

$$(i/k)_{it} = \gamma_0 + \gamma_1 (y/k)_{it-1} + \gamma_2 (q/k)_{it-1} + \gamma_3 (d/k)_{it} + \varepsilon_{it} \tag{7}$$

If our hypotheses are correct we expect β_1 to be positive and statistically significant while γ_1, if statistically significant should be less than β_1.

3.1 Description of the Data

The data used are drawn from a dataset which combines three sources, the Forfas Irish Economy Expenditure Survey (FIEES), the Forfas Research and Development Survey (FRDS), and the Forfas Innovation Survey (FIS). All three surveys are undertaken by Forfas, the policy and advisory board for industrial development in Ireland. To the best of our knowledge, our paper is the first to combine data from the three surveys to create a unique dataset.

The main variable of interest is the R&D expenditure of a firm and data on this at the firm level is derived from the FRDS and FIS.[7] The FRDS is

[7] In the questionnaires, Forfas defines R&D as "creative work which is undertaken on

a bi-annually survey and has been collected for the years 1986, 1988, 1991, 1993, 1995, 1997. Amongst other things, this source provides information on the in-house R&D expenditure of a firm. For one of the years that is missed due to the bi-annual nature of the FRDS, namely, 1990, information from the FIS can be used, which is an intermittent survey on innovation that also provides data on in-house R&D.

Both of these data sources cover virtually all known R&D active firms of at least 10 employees in the Irish manufacturing sector, and hence for the covered firm sizes provide the in-house R&D expenditure of the entire R&D active plant population. The surveys distinguish in-house R&D expenditure financed through the firms' own funds from R&D funded by other companies (located in Ireland or abroad) or government funding (either Irish, EU or other). We utilise data on in-house R&D expenditure and exclude the other two categories. This allows us to focus in more detail on the constraints within a firm in order to determine how a firm raises funds to finance its own in-house R&D, whether through own liquidity or external sources. Table 1 shows that for our sample the percentage of R&D financed by either other firms or government grants was about 10 percent in all years covered in the survey.

[Insert Table 1 about here]

Information given in the FIEES is used to obtain other firm specific variables. The FIEES survey is undertaken annually since 1983 and includes detailed information on each firm's output, expenditure on labour and other inputs, capital and debt, although the information on the latter two variables is only available from 1990 onwards. The survey is sent out to all firms with twenty or more employees. Participation is not compulsory, but response rates are generally good; firms responding to the survey account for around 60-80 per cent of employment of the target population each year.

Given the unique firm identifier associated with each firm by Forfas it was possible to link these three data sources to create a sample of R&D active

a systematic basis in order to create new or improved products, processes, services or other applicatioins. R&D is distinguishable from other activities by the presence of an appreciable element of novelty and by the resolution of problems and uncertainties using scientific or technological means. Routine activities, such as routine software development or pre-production preparation, where there is no appreciable novelty or problem resolution, are not considered to be R&D for the purposes of this survey".

manufacturing firms for which information on output, inputs, employment, capital, debt, and R&D expenditure was available. The sample size was necessarily constrained by the coverage of the FIEES. Overall, this resulted in a sample of 573 R&D active firms of at least twenty employees spanning the years 1990, 1991, 1993, 1995 and 1997. However, for most firms we have only very short panels, for many even only one observation over the whole period. This is due to the merging of the three datasets which left us with many missing observations on some of the variables.

Table 2 presents some summary statistics on the variables included in the model as well as on employment size of firms in the sample. Note that the average employment size is 160 employees which, by international standards, is quite small. As Hao and Jaffe (1993) show, financial constraints in financing R&D can be expected to be more severe for small than for large firms.[8]

[*Insert Table 2 about here*]

3.2 Econometric Results

Table 3 presents the empirical results of estimating various specifications of the R&D equation and the investment equation. The sample used for these estimations includes only those firms for which we have data on both R&D and investment in physical capital. The equations are estimated using simple OLS allowing for clustering of the error terms by firm identifier. We use OLS rather than panel data techniques since we have only short panels for most firms, as pointed out above.[9]

[Insert Table 3 about here]

Examination of the estimation results in the upper panel of Table 3 shows that both past sales and past profits are statistically significant determinants of R&D expenditure while the coefficient on debt-to-capital ratio is statistically insignificant. The results on the profit variable are robust to the exclusion of either/both debt-to-capital or/and sales. On the other hand,

[8] The study by Himmelberg and Petersen (1994) also uses only data on small firms.

[9] We have also run the estimations allowing for firm specific time invariant effects using the random effects technique. The results were very similar to the OLS results and are therefore not reported.

past profits are not a statistically significant determinant of investment in physical capital as documented by the results in the lower panel of Table 3. These findings are in line with the empirical evidence provided for the US by Hall (1992), Himmelberg and Petersen (1994) and Hao and Jaffe (1993). They support our hypothesis that R&D spending has to be financed internally due to financial constraints. Investment in physical capital does not appear to be influenced by such constraints, however.

For a number of firms in our sample we have information on either only R&D or investment in physical capital. Therefore we re-estimated the R&D equation using data on all firms which reported R&D data (but not necessarily investment data). We also performed similar re-estimations for the investment equation, the results of which are reported in Table 4. Note that the coefficients remain very similar in terms of size and statistical significance for all variables.

[Insert Table 4 about here]

4 Conclusion

It is commonly argued that firms are not able to attract external funds to finance R&D. However, the empirical evidence supporting this view is based mainly on US data, presumably because of a lack of data availability for other countries. In this paper we use R&D data for the Republic of Ireland which have become available partly because the country's recent high growth experience has mainly been attributed to the expansion of R&D intensive high-tech sectors.

Testing for the effect of liquidity constraints on investment amounts to looking for a positive correlation between investment and some measures of liquidity. However, such a correlation may be spurious due to the possible correlation of both of these variables with profitability. This problem has traditionally been addressed by comparing either different types of investment or different types of firms where it is expected that this relationship is stronger for those investments or firms that are more financially constrained. In our theoretical model we suggest that this problem might be less severe if the variability of payoffs is high. The intuition is that while optimal investment levels might be correlated with future profitability, this will not be the case for actual levels of investment if they cannot be financed externally.

In our empirical estimations we find strong evidence that R&D investments of Irish manufacturing firms are liquidity constrained for a number of different specifications of the empirical model. In line with the previous empirical literature we compare our results for investment in R&D with investment in physical capital and we do not find evidence that the latter is financially constrained.

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A Appendix

We consider a two-period version of our model to demonstrate how the complete solution can be recursively derived. There are two periods, 1 and 2. The capital stock in period 1, K_1, is given. With only two periods we can ignore adjustment costs. The firm need to choose E_1, E_2 and K_2 to maximise expected profits. For simplicity, we assume that $A_t (t = 1, 2)$ has a Bernoulli distribution. More specifically,

$$A_t = \begin{matrix} A_h \\ A_l \end{matrix} \text{ with prob } \begin{matrix} p(E_t) \\ 1 - p(E_t) \end{matrix}$$

where $A_h > A_l$, $p' > 0$ and $p'' < 0$.

We begin with the second period optimization. Given the beginning of period physical capital stock, the firm maximizes:

$$\left[p\left(E_2\right) A_h + \left(1 - p\left(E_2\right)\right) A_l\right] F(K_2) - E_2$$

subject to:

$$A_1 F(K_1) \geq E_2$$

Notice that in the final period there is no additional investment in physical capital. The first order condition for second period R&D implies:

$$p'\left(E_2\right)\left(A_h - A_l\right) F(K_2) = 1$$

Using this expression we can derive the optimal choice of second period R&D, E_2^*, as a function of the second period capital stock:

$$E_2^* = p'^{-1}\left(\frac{1}{(A_h - A_l)F(K_2)}\right) \equiv g(K_2), \quad g' > 0$$

Suppose that

$$A_h F(K_1) > E_2^* > A_l F(K_1)$$

i.e. the constraint only binds when $A_1 = A_l$. Then in the first period the firm maximizes:

$$\begin{aligned}
&[p(E_1)A_h + (1-p(E_1))A_l]F(K_1) - K_2 + K_1 - E_1 + \\
&\frac{1}{1+r}\{p(E_1)[(p(g(K_2))A_h + (1-p(g(K_2)))A_l)F(K_2) - g(K_2)] + \\
&(1-p(E_1))[(p(A_lF(K_1))A_h + (1-p(A_lF(K_1)))A_l)F(K_2) - A_lF(K_1)]\}
\end{aligned}$$

where in the second period R&D will be set equal to its optimal value with probability $p(E_1)$ and to first year profits with probability $1-p(E_1)$. The first order conditions for E_1 and K_2 are:

$$\begin{aligned}
& p'(E_1)(A_h - A_l)F(K_1) - 1 + \\
& \frac{1}{1+r}p'(E_1)[(p(g(K_2))A_h + (1-p(g(K_2)))A_l)F(K_2) - g(K_2) \\
& -(p(A_lF(K_1))A_h - (1-p(A_lF(K_1)))A_l)F(K_2) + A_lF(K_1)] \\
= \; & 0
\end{aligned}$$

and

$$\begin{aligned}
& p(E_1)[(p'(g(K_2)g'(K_2)(A_h - A_l))F(K_2) + \\
& (p(g(K_2))A_h + (1-p(g(K_2)))A_l)F'(K_2) - g'(K_2)] + \\
& (1-p(E_1))[p(A_lF(K_1))A_h + (1-p(A_lF(K_1)))A_l]F'(K_2) \\
= \; & 0
\end{aligned}$$

The above two conditions are a system of two equations in two unknowns, E_1 and K_2.

Table 1: Percentage of R&D financed by other firms and government grants

Year	Percentage
1990	8.58
1991	14.64
1993	13.03
1995	9.41
1997	8.73

Table 2: Summary statistics

	mean	s.d.
r/k	6.998	111.318
i/k	3.654	73.300
y/k_{t-1}	4.897	71.359
q/k_{t-1}	24.287	333.271
d/k	0.119	0.352
Employment	160.340	438.503

Table 3: Econometric results for R&D and investment equation

	(i)	(ii)	(iii)	(iv)
Dependent variable: r/k				
y/k_{t-1}	0.024	0.024	0.033	0.033
	(0.004)**	(0.004)**	(0.004)**	(0.004)**
q/k_{t-1}	0.002	0.002	-	-
	(0.001)**	(0.001)**		
d/k	0.012	-	0.006	-
	(0.028)		(0.033)	
obs	872	873	872	873
R-sq.	0.81	0.81	0.77	0.77
Dependent variable: i/k				
y/k_{t-1}	-0.092	-0.092	0.177	0.177
	(0.153)	(0.153)	(0.115)	(0.115)
q/k_{t-1}	0.065	0.065	-	-
	(0.064)	(0.064)		
d/k	0.529	-	0.353	-
	(0.836)		(0.805)	
obs	872	873	872	873
R-sq.	0.22	0.22	0.09	0.09

Notes: All regressions include sector and time dummies.
**, * denote statistical significance at 1, 5 percent level respectively

Variables: dependent variables: r/k = internally financed R&D spend / capital, i/k = physical investment / capital
independent variables: y/k = profits / capital, q/k = sales / capital, d/k = longterm debt / capital

Table 4: Econometric results for estimations using all firms

	(i)	(ii)	(iii)	(iv)
Dependent variable: r/k				
y/k_{t-1}	0.021	0.021	0.037	0.036
	(0.005)**	(0.005)**	(0.004)**	(0.004)**
q/k_{t-1}	0.003	0.003	-	-
	(0.001)**	(0.001)**		
d/k	-0.002	-	-0.025	-
	(0.032)		(0.048)	
obs	916	917	916	917
R-sq.	0.84	0.84	0.75	0.75
Dependent variable: i/k				
y/k_{t-1}	0.147	0.147	0.210	0.210
	(0.172)	(0.172)	(0.118)	(0.118)
q/k_{t-1}	0.021	0.021	-	-
	(0.047)	(0.047)		
d/k	-1.070	-	-1.124	-
	(1.594)		(1.497)	
obs	1593	1597	1593	1597
R-sq.	0.06	0.06	0.06	0.06

Note: All regressions include sector and time dummies.
**, * denote statistical significance at 1, 5 percent level respectively