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Finance and R&D Investment:

Is there a Debt Overhang Effect on R&D Investment?

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Gustav Martinsson*

Abstract

The motivation of this paper is the rather naive approach to debt as a financing source of R&D investment in the empirical investment literature. I focus on long-term relational debt based on its appealing contractual properties and discover a debt overhang effect for the relationship between additional long-term debt and R&D investment. I augment an error correction accelerator-profit specification to include changes in long-term debt as a transitory determinant of R&D investment as has been done with internal finance previously. Firms with previous period debt levels around 0.60 display a positive relationship between additional long-term debt and R&D investment.

JEL Classification: C01, G0, O16, O30

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I Introduction

Schumpeter (1942) emphasized that investments such as in R&D is preferably financed internally due to agency problems and the discretion that it demands. There is also a so called wedge between the private rate of return on R&D investment and the cost of capital when finance is supplied by an external actor (see Arrow, 1962 for early contributions and Hall, 2002 for a more recent literature review).

Aghion et al. (2005, 2007a, 2007b) emphasize the potential problem of financing constraints and structural issues such as firm innovation. Their work provides strong theoretical contributions but they do not completely integrate their work with the frontier of econometric modeling. Aghion et al (2007a) conclude that firms with better access to external credit are able to maintain its R&D share over the business cycle unlike firms which are credit constrained.

In this paper I intend to bridge the gap between theoretical contributions on credit constraints for R&D investment and the state-of-the-art econometric modeling. Agency problems and the subsequent contractual issues make debt inappropriate as a financing source of R&D investment. However, the corporate governance literature (Boot, 2000 and David et al., 2008) presents compelling evidence in favor of long-term relational debt as a financing source for strategic investment such as R&D.

As David et al. (2008) point out; the difference in financial systems needs to be considered. Most empirical results on the relationship between financing sources and R&D investment are obtained from datasets comprising U.S. large corporations. They exclusively issue bonds as external debt. Bonds are so called transactional debt which is inappropriate for R&D investment even within a relationship or bank-based financial system. The U.S. financial market is a so called arms-length or market-based financial system (see Levine, 2005 or Rajan and Zingales, 2001 for important contributions on financial systems). The firms of this paper function in a bank-based financial system thus increasing the relevance of exploring the impact of long-term relational debt on firm R&D investment.

This paper augments the successfully applied error correction accelerator-profit model (Bond et al., 2003b and Mulkaly et al., 2001) with the one lag annual change of long-term debt as a transitory impact factor on firm R&D investment. The impact of long-term debt is interacted with the firm's previous period debt level thus capturing the potential debt overhang effect (as proposed by Myers, 1977). I estimate an error correction model which is consistent with neoclassical investment theory, i.e. the long-run determinant of investment is output.[2] The augmentation of the error correction model with variables capturing the impact of internal finance (liquidity constraints) and of debt (credit constraints) allows me to bridge the gap between theoretical contributions on debt financing and the frontier of econometric modeling.

The empirical analysis produces interesting results. Firms in the sample which are moderately levered, i.e. around 60 percent of its assets financed by debt, display a positive relationship between changes in long-term debt and R&D investment. This implies that for instance a 5 percentage point increase in long-term debt last year yields a 0.3 percent increase in contemporaneous R&D investment. Alongside this effect, there is a transitory cash flow effect with output as a permanent determinant.

[2] The empirical literature on financing and R&D investment evolved from the literature on financing and capital investment (see e.g. Mairesse et al., 1999 and Bond et al., 2003a).

Due to the purpose of this paper to be consistent with state-of-the-art econometric modeling in terms of firm investment the paper is rather econometrics heavy. The results discussed above are obtained by the efficient system generalized method of moment (GMM) estimator.

The approach of this paper to include annual changes in debt to an error correction setting alongside internal financing is a novel contribution. The explicit results of a debt overhang effect of this rather precise magnitude is also somewhat novel, even though both Aghion et al. (2004) and Casson et al. (2008) find evidence of an inverted U-curve relationship (the correlation of debt and R&D investment rising and then falling with R&D expenditure) between debt and R&D investment for U.K. firms.

This paper proceeds as follows. Section II comprises a rather extensive theoretical discussion resulting in the articulation of hypotheses ahead of the empirical analysis. Section III presents the error correction accelerator-profit specification and also a discussion on estimation. In section IV I present the data and provide some initial results. Section V tests the hypotheses proposed at the end of section II and discusses the results. Section VI concludes.

II Background

The impact of different financing sources and firm investment is not an uncontroversial research issue. Modigliani and Miller (1958) (from here on MM) argue in their seminal work that internal and external financing sources are perfect substitutes, implying that firms will invest if the net present value is positive. However, the MM result have been subject to great criticism, and it is now mostly viewed as a benchmark for evaluating financial frictions which cause the cost of raising external capital to be higher than that of internal finance (e.g. Schiantarelli, 1996).[3] Myers (1984) argues in favor of a so called pecking order of financing sources. The pecking order theory implies that firms try to fund investment with retained earnings. When retained earnings run out firms issue debt, and as a last resort they issue equity (which implies that the firm gives up ownership stake).

In the empirical literature there is no unanimous view of how to model firm investment. In section 1, I discuss the empirical literature on financing sources and investment by supplying a brief overview. In section 2 I discuss the literature on financing sources explicitly. Section 3 discusses the notion of the debt overhang effect, and section 4 makes explicit theoretical predictions.

1 Financing sources and R&D investment in the empirical literature

The empirical results on the link between firms financing sources and R&D investment evolved from the literature on capital investment. First of all, it is important to separate between structural investment models such as q-models and Euler-equation models and the reduced form models such as the accelerator profit model and the error correction model (this topic is

[3] Myers (1977) reject the Modigliani and Miller (1958) result by showing that firms that are partly debt financed may forego investments with a positive net present value.

discussed more in section III). The advocates of structural models argue that reduced form models do not capture the role of expectations. By expectations I mean a firm's investment opportunities. The approach of the structural model is closer to MM and the argument that the key determinant of firm investment is to have projects with a positive net present value. Reduced form models including financial variables without accounting for expectations may be difficult to interpret. A reported cash flow effect on investment may simply reflect the firm's future investment opportunities and not a sign of liquidity constraints. Gomes (2001) argues that reduced form investment models which have significant cash flow effects are simply miss-specified. Whited (1992) finds significant effects between financial variables and capital investment applying an Euler-equation specification. The structural models, though, have performed poorly empirically (Oliner et al., 1995). Therefore, additional specifications like the accelerator profit model and the error correction model have been applied. The major caveat of abandoning the structural models is the fact of not modeling expectations explicitly. Alti (2003) argues that the expectations-related problem is avoided by using lagged instruments of cash flow. The cash flow effect on investment is mostly established by reduced form models. Bernanke et al. (1996), Bond et al. (2003a), Chirinko and Schaller (1995), Devereux and Schiantarelli (1989), Fazzari et al. (1988)[4], Gertler and Hubbard (1989), Hoshi et al. (1991), Hubbard (1998), Mairesse et al. (1999), and Ughetto (2008) all find a positive relationship between cash flow (i.e. internal finance) and firm capital investment.

The literature presented above has been augmented to firm R&D investment. One first difficulty of simply augmenting the capital investment literature is the higher adjustment costs associated with R&D investment which is less severe for capital investment. The higher adjustment costs originate from the largest portion of R&D investments comprising salaries to the researchers. Thus, firms choose to smooth out R&D investments over time to avoid the high adjustment costs (see Hall, 2002 and Himmelberg and Petersen, 1994 for excellent discussions).

Early cross section results of financial sources and firm R&D investment fail to establish a statistically significant relationship (Elliot, 1971 and Scherer, 1965). More recently, there are numerous pieces of evidence of a correlation between cash flow and R&D investment (Aghion et al., 2004, Bougheas et al., 2003, Czarnitzki and Binz, 2008, Hall, 1992, Harhoff, 1997, Himmelberg and Petersen, 1994 and Mulkaly et al., 2001)[5]. These results are all reached utilizing reduced form models. The relationship of internal finance and R&D investment is stronger for smaller firms (Hao and Jaffe, 1993, Harhoff, 1997, Himmelberg and Petersen, 1994 and Czarnitzki and Binz, 2008). Brown et al. (2009) apply an Euler-equation model and find a strong relationship for younger firms whereas mature firms display a non-significant relationship.[6] Chiao (2002) separates between science and non-science based industries and finds a stronger relationship between internal finance and R&D investment for the science based firms. Himmelberg and Petersen (1994) and Brown et al. (2009) limit their analyses to high technology sectors which may induce bias in their results.

[4] Fazzari et al. (1988) apply q, neoclassical and accelerator models.

[5] Most results display a transitory impact of cash flow on R&D investment. The advocates of the error correction model tests this explicitly since the error correction model is derived from the neoclassical demand for capital which implies that the long run return of capital is proportional to output and the user cost of capital (this is augmented to R&D expenditure which in the long run is assumed to be proportional to output). Therefore, the cash flow effect is assumed to only pose transitory impact on R&D investment and a non-significant long-term effect, more on this in the econometrics section and the results section.

[6] A young firm implies a firm which has been public less than 15 years and a mature firm has been public for 15 years or more.

The empirical literature has mainly focused on the role of internal finance as a financing source of R&D investment. Debt financing is commonly viewed as inappropriate for R&D intensive firms. Hall (1992) includes long-term debt while estimating the role of cash flow, sales and q on R&D investment using U.S. firm level data. Applying ordinary least squares (OLS) estimation there is a contemporaneous inverse relationship between long-term debt and R&D investment and a positive relationship between cash flow and R&D investment. However, when Hall (1992) accounts for simultaneity by instrumentation only cash flow remains statistically significant. Chiao (2002) criticizes Hall (1992) for not accounting for the heterogeneity of firms explicitly and the simultaneous nature of investment and corporate debt. Therefore he separates firms based on if they belong to a science based[7] or a non-science based industry and applies general method of moments (GMM) to account for simultaneity. He concludes that the results of Hall (1992) apply to the science based firms, but for the non science based firms there is a positive relationship between long-term corporate debt and R&D investment.

2 The role of debt financing for the investing firm

The topic of this paper was born while contemplating how debt-financing is treated in the investment literature. The research field is huge and there exist different perspectives of how firms choose financing sources. The seminal paper by Jensen & Meckling (1976, p. 10) made me reflect the literature even more:"*The firm is not an individual. It is a legal fiction which serves as a focus for a complex process in which the conflicting objectives of individuals (some of whom may "represent" other organizations) are brought into equilibrium within a framework of contractual relations. In this sense the "behavior" of the firm is like the behavior of a market, that is, the outcome of a complex equilibrium process. We seldom fall into the trap of characterizing the wheat or stock market as an individual, but we often make this error by thinking about organizations as if they were persons with motivations and intentions"*.

How is it possible to categorically claim that debt-financing is inappropriate for R&D investment? The review of Hall (2002) clearly states that due to information asymmetries, adverse selection and moral hazard problems debt-financing of R&D investment is inappropriate (also Stiglitz and Weiss, 1981). The empirical literature on capital structure clearly reports an inverse relationship between intangible assets and leverage (see for instance Balakrishnan and Fox, 1993, Berger and Udell, 1990, Bradley et al., 1984, Hall et al., 2000, Harris and Raviv, 1990, 1991, Long and Malitz, 1983, Titman, 1984, and Titman and Wessels, 1988). I am not arguing in favor of debt-financing being the preferred source of financing for R&D, but I believe the empirical literature has tested debt-financing as a determinant of R&D investment naively. Chiao (2002) simply splits his sample by industry belonging and find that non science based firms display a positive relationship between debt and R&D. David et al. (2008) analyze debt as a determinant of R&D from a corporate governance perspective and conclude that relational debt, i.e. bank loans, are positively associated with R&D investment whereas transactional debt, i.e. debt contracts for which there is a secondary market (such as bonds), are inversely related to R&D investment.

I also think it is worth while contemplating the implication of correlations. The complex process comprising a firm (according to Jensen and Meckling, 1976) is difficult to capture empirically. A simple calculation exercise of the inverse relationship between leverage and

[7] Science based industries are chemicals and allied products (SIC 28), machinery (35), electrical equipment (36) and professional and scientific instruments (38) and all other industries are treated as non-science based (Chiao, 2002, p. 118).

intangible assets[8] hints that correlations of this kind should be interpreted with care. The positive impact of cash flow on the increase of intangible assets (e.g. R&D investment) is fairly grounded in the empirical literature. Consider a firm with $1,000,000 in assets. Assume this firm to be the average R&D performing firm of the sample of this paper (see table 2) implying a leverage ratio of 0.60. Then it has $400,000 worth of equity and subsequently $600,000 in debt. The inverse relationship of leverage and intangible assets is accentuated by the positive relationship of cash flow and intangible investment. Consider a year-to-year drop of cash flow of fifteen percent implying a reduction of firm equity from $400,000 to $340,000. Assume that the firm's debt level is unchanged. The average firm's leverage has now increased from 0.60 to 0.64, with no increase in the actual amount of debt. Thus declining R&D investment as a response to increases in leverage is rather a sign of the positive relationship between cash flow and R&D investment.

Rajan and Zingales (1995, p. 1457) conclude that profitability is inversely related to leverage from a cross country, cross-section, empirical analysis. But their results are not unanimous across firm size and country. For instance for France and Germany there is no observed statistical relationship. Larger firms display a considerably more negative relationship than smaller firms. Their theoretical prediction is that if debt is the primary source of external finance then profitability is expected to be inversely related to changes in leverage (in line with e.g. Harris and Raviv, 1991 and Myers and Majluf, 1984). However, if profitability increases more than the amount of external finance then the firm deleverages, implying that the amount of external finance may still increase even if leverage is inversely related to intangible assets. Jensen (1986) proposes that if corporate control is effective then he predicts a positive relationship between profitability and leverage.

This discussion aims to shed light on the complexity of the firm's financing choice and subsequently the difficulty to further predict its impact on firm investment.

2.1 Theory of the firm's choice of financing sources

Jensen and Meckling (1976) are cautious about how to refer to the firm's different sources of finance. They refrain from the term capital structure which to them stands for the relative quantities of bonds, equity etc. which make up the liabilities of the firm. They instead prefer to treat it as ownership structure. By ownership structure they imply the relative amount of ownership claims held by the insiders of the firm and outsiders. Financial contracting theory utilizes this same angle (see e.g. Aghion and Bolton, 1992, Fluck, 1998, Grossman and Hart, 1986, and Hart, 2001). Hart (2001) points to the principal missing ingredients of Modigliani and Miller (1958), namely taxes and incentive problems (the literature has mostly focused on the latter). Debt-financing has an advantage of being relieved of income tax and it is also deductible whereas internal funds are subject to corporate taxation. Jensen and Meckling (1976) discuss why we do not witness firms individually owned with just a very small fraction of its capital supplied by the individual owner and the predominant part supplied via debt. That way the owner can risk little of his own capital for almost the entire ownership stake. First, no lender would agree to lend to a firm which is not willing to share the risk. This is of course the extreme case. But there are severe issues of obtaining debt for high risk projects such as R&D investments. One intrinsic feature of why an investor agrees to fund a high risk project is of course the possibility of enjoying the return if the high risk project is successful. Debt-financing payments comprise a fixed set of payments which are unaffected by the potential success of the high risk project. Thus

[8] Tangible assets support debt, based on their ability to pose as collateral, since they are possible to liquidate in case of bankruptcy. See Binks and Ennew (1996) for a discussion on why it is important to differentiate among tangible assets also.

a lender prefers the low risk project since it is by definition more likely to succeed (see e.g. Stiglitz, 1985).

Myers and Majluf (1984) approach the problem from the firm insiders' point of view. Their argument is based on the fact that the insiders have superior information about the firm's investment opportunities. That implies that the firm is undervalued, and by attracting capital via external equity they sell ownership stake at a discount. In this case issuing debt is preferable since they only have to pay the market interest rate in return, thus avoiding the discount-problem and the dilution of ownership which punish the current shareholders.

The literature on capital and ownership structure does not really provide a clear answer. Jensen and Meckling (1976) argue that if there is an optimal tradeoff between debt and equity it is the point where the marginal benefit of keeping the managers from treating themselves to too excessive perks is offset by the marginal cost of conducting risky behavior. It is a matter of agency problems. Hart (2001, p. 1084) calls it the intrinsic incompleteness of contracts which makes it difficult to beforehand draw a covering contract. Instead the firm can tune their financial structure based on the 'state of the world'. Equity dilutes the ownership stake of the entrepreneur but do not come with a required payback plan. Debt does not dilute the ownership stake but it has an attached stream of payments to it which if the entrepreneur fails to payback gives the debtor the right to seize assets and finally the right to liquidate the firm. In this sense debt serves as a disciplinary device (Anderson and Prezas, 1999, Harris and Raviv, 1990 and Hart and Moore, 1998[9]). The returns on equity financing are first received by the entrepreneur who then, potentially, can act recklessly before the investors get any return. Whereas debt-financing is in a way a dilution of cash flow and then the entrepreneur cannot claim the cash flow first, and if he does so he of course jeopardizes the firm by risking bankruptcy.

There is another stream of research of firm's financing sources which criticizes certain elements of the above discussed literature.

2.2 Transaction cost economics and relationship banking

The seminal paper by Williamson (1988) concludes that equity allows more discretion which makes it a more suitable financing source than debt for funding R&D investment. The Williamson paper has received criticism. David et al. (2008) point to the problem of treating debt homogenously as mentioned in the introduction of this section. They separate between transactional debt and relational debt. Most empirical literature is based on U.S., and to some extent U.K., data. The debt structure of U.S. and U.K. firms almost exclusively comprises transactional debt because of their market based financial systems. Transactional debt does not provide the necessary disclosure of information which R&D projects require and it is not attached with the same flexibility as relational debt. Therefore transactional debt is inappropriate for funding strategic investments such as R&D.

Relational debt comprises bank loans where the firm and the bank have developed a relationship. The inappropriateness of transactional debt contracts do not apply to the same extent to relationship bank loans. Relationship banking can overcome, via monitoring; some of the agency problems associated with information asymmetries (see Diamond, 1984 and Bhattacharya and Thakor, 1993). Boot (2000) actually claims that one of the reasons for financial intermediaries such as banks for existing is to mitigate informational asymmetries. Banks have incentives to fund strategic investments of its clients (to whom they have an established

[9] This paper is a synthesis of two previous papers (Hart and Moore, 1989, 1996).

relationship with) which improve their clients long-term competitiveness. Therefore this mutual relationship may lead the client to reveal discretionary information which would never have been revealed if it was a transactional debt contract (Bhattacharya and Chiesa, 1995). Transactional debt contracts are restricted by rigid market regulations whereas relationship debt contracts are established between the bank and the firm it is lending to (Boot and Thakor, 2000). An important feature of relational debt is the possibility of relational lenders to exercise forbearance[10] (Hoshi et al., 1989 and Gilson et al., 1990) provides empirical evidence that relational lenders actually exercise their forbearance rights). This possibility makes it easier for relational lenders to support strategic investments. Berger and Udell (1995) and Petersen and Rajan (1994) show that firms with much relational debt can easier and cheaper access additional debt, implying that the fact that a firm obtains relational debt is a signal to other lenders of its high quality.

David et al. (2008) test the appropriateness of relational debt as financing source of R&D investment on a sample of Japanese[11] firms. They find a strong relationship between relational debt and R&D investment both statistically and economically. Transactional debt displays the expected inverse relationship with R&D investment.

3 The debt Overhang effect

Myers (1977) contributes with a theory on corporate borrowing. The amount of debt chosen by a firm has no direct relationship to the probability of the borrower defaulting, instead the amount of issued debt by the firm should be set to equal V_D^*. This implies the amount of debt which maximizes firm market value. The Myers (1977) theory suggests that V_D^* is inversely related to the ratio V_G/V, i.e. the fraction of the market value which comprises growth opportunities. This piece of evidence does not suggest that R&D firms should issue little debt. R&D performing firms are commonly established and profitable firms with relatively few investment opportunities. His theory establishes the notion of a debt overhang effect which possibly may depress future investment.

Consider a firm's investment opportunity as a call option which the firm has the option to exercise in period $t = 1$.[12] The objective of the firm's managers is to maximize firm market value V, V comprise $V_A + V_G$(market value of assets in place + market value of its growth opportunities). Initially the firm's liabilities comprise only equity (V_E). When the firm uses only equity financing firm value is set by:

$$V = \int_{s_a}^{\infty} q(s)[V(s) - I]ds \qquad (2.1)$$

[10] Forbearance is the act of the creditor who refrains from enforcing a debt when it falls due. Transactional creditors do not have the ability to exercise forbearance.

[11] Japan is a particularly suitable example. Japan began deregulating their financial markets in 1979. Before 1979 firms could only access relational bank debt. David et al. (2008)'s hypothesis is that early on in the deregulation period (1982-1992) firms have not adjusted to the new conditions where they could choose either bank or market-based debt. But in the second half of their sample period (1993-2001) firms are expected to have adjusted to the new conditions. According to expectations they find no relationship between relational debt in the early deregulation period whereas the strong relationship between relational debt and R&D investment is present in the later stage of deregulation.

[12] This model is described in detail in Myers (1977, pp. 149-155).

Where $q(s)$ is the equilibrium price of a dollar delivered at $t = 1$ only if 'state of the world', s, occurs, $V(s)$ denotes firm market value of 'state of the world', s and I, of course, denotes investments. The 'state of the world' s_a, which is the lower boundary of the integral, is the point where the decision to invest increases market value.

Consider instead that the firm needs to issue debt in order to finance its investment.[13] The debt comes with a promised payment P. As long as $V(s) - I \geq P$, then the firm is interested in repaying the debt. Subsequently, if $V(s) - I < P$ then the bondholders will be able to take over the firm. This leads to the equilibrium market value of the firm's debt to be set by:

$$V_D = \int_{s_a}^{\infty} q(s)[\min(V(s) - I, P)]ds \qquad (2.2)$$

Equation (2.2) implies that the firm may borrow the entire value of the firm. The objective of the firm is to maximize the value of its equity, $max[0, V(s) - P]$ (the 0 implies that the firm does not exercise its investment opportunity) and to minimize the value of its debt $[\min(V(s), P)]$. The debt repayments, P, inflict a debt overhang on the firm. The firm's payback decision, $V(s) - I \geq P$, can be rewritten to highlight the debt overhang effect on firm investment, $V(s) - P \geq I$. This implies that the market value for 'state of the world' s must exceed P in order for the firm to continue investing. Equation (2.2) establishes a so called debt ceiling. The firm specific debt ceiling is given by the equilibrium market value of its debt for which its market value is maximized.

Jensen and Meckling (1976) mention the debt overhang effect from a moral hazard perspective, arguing that high levels of debt induces firms to partake in too risky investment projects. Hart (2001) further emphasizes the risk of high debt levels in the face of agency problems, stating that debt becomes risky at high levels.

The features of a debt overhang and debt ceiling are corroborated in the empirical literature on both capital investment and R&D investment. Bo (2007) and Jaramillo et al. (1996) provide empirical evidence of a positive relationship between debt and capital investment up to a point when further increase of debt is inversely related to increases in capital investment, a so called inverted U-curve relationship. Aghion et al. (2004) and Casson et al. (2008) display a similar inverted U-curve relationship for increases of debt and R&D investment.

4 Theoretical predictions

The empirical literature on financial variables' impact on R&D investment has mostly focused on the conflicting agency problems which make debt-financing inappropriate. Further, the empirical literature has treated debt homogeneously which has given rise to an inverse empirical relationship between debt and R&D investment.

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[13] The Myers-model cannot allow the firm to simply issue debt in order to increase its cash base. Because then the firm could utilize the borrowed capital to acquire other assets which could collateralize more debt (Myers (1977, p. 152)). There are additional assumptions which I do not discuss here since I do not believe it is necessary for my overall purpose of the paper.

By decomposing the debt variable and designing an empirical model to capture the debt overhang and ceiling effects I intend to properly evaluate the relationship between debt and R&D investment. Based on the discussion in section 2.2 I focus on relational debt only. Gan (2007) concludes that most long-term debt comprises relational debt, why I will analyze the flow of long-term debt's impact on R&D investment. Based on the propositions of section 2.3 from Myers (1977) I expect that the impact of changes in long-term debt on R&D investment is conditioned on the firm's previous debt level. Basically firms with lower leverage the previous period are expected to have a positive relationship between debt changes and R&D investment compared to firms with higher leverage which are predicted to display an inverse relationship. The cash flow effect on R&D investment is also explored. Based on the literature there is expected to be a transitory cash flow effect on R&D investment, this is further discussed in the next section and in the results section.

The problem of the firm's financing decision being endogenous is accounted for by instrumentation within a system GMM setting.

III Econometrics

The exposition of the error corrected accelerator-profit model is in line with papers by Bond et al. (2003a, 2003b), Harhoff (1997), Mairesse et al. (1999) and Mulkaly et al. (2001). The starting point of the error correction approach for firm investment is Bean (1981) whose motive is the poor empirical results from using structural models such as q-models and Euler-equation models. The error correction accelerator-profit model is an augmentation of the traditional accelerator-profit specification of the investment equation; see e.g. Eisner (1978), Oudiz (1978), and Mairesse and Dormont (1985).[14] The major enhancement of adding the error correction characteristics is the inclusion of level information. Or in other words, the error-correction specification is preferred over the traditional accelerator model since it explicitly separates long-run (level values) and short-run (first-differenced values) effects.[15] It is also a parsimonious specification since the lagged level values of the error-correction term combined with the lagged dependent variable implies that the first-differenced explanatory variables need not be lagged too far back in time as in the traditional accelerator specification for firm investment.

In section 1 the error-correction accelerator-profit specification is presented in depth. I first derive the fix investment case and in 2 the derivation is extended to R&D investment (as in the papers cited in the beginning of this section). In section 3 long-term debt is included in the specification and this section concludes with a discussion on estimation.

1 The error correction accelerator-profit specification

The derivation of the error correction specification originates from the neoclassical demand for capital which implies that the long-run return of the capital stock is proportional to output and the user cost of capital.

[14] See Mairesse et al. (1999, pp. 3-7) for a comparison of the traditional accelerator-profit and the error corrected version, in particular their Appendix A where they derive the traditional accelerator model.

[15] The inclusion of level values is made possible due to exploiting the coinetegrated properties of economic firm-level variables, more on this in the estimation section.

The desired capital stock is denoted $k_{i,t}$ for firm *i* year *t*, and $y_{i,t}$ denotes output. They are both in log form. The user cost of capital is represented by $j_{i,t}$. So, the desired stock of capital is expressed as:

$$k_{i,t} = \alpha_t + \beta y_{i,t} - \varpi j_{i,t} \qquad (3.1)$$

Equation (3.1) assumes that adjustment costs are absent since the adjustment process is complex to capture econometrically. The user cost of capital, $j_{i,t}$, is also hard to model and therefore firm-specific and time-specific effects are included to control for adjustment costs and the user cost of capital. So, $\alpha_t - \varpi j_{i,t}$ are captured by $\alpha_t + \alpha_i$. (3.1) is consistent with a profit maximizing firm with a CES production function

As a next step in the specification an autoregressive distributed lags model is applied to capture the dynamics of this process. The literature uses 2 lags of both capital and output, yielding:

$$k_{i,t} = \alpha_i + \alpha_t + \omega_1 k_{i,t-1} + \omega_2 k_{i,t-2} + \beta_0 y_{i,t} + \beta_1 y_{i,t-1} + \beta_2 y_{i,t-2} + \varepsilon_{i,t} \qquad (3.2)$$

In order to obtain (3.2) in error correction form $k_{i,t-1}$ is subtracted from both sides:[16]

$$\Delta k_{i,t} = \alpha_i + \alpha_t + (\omega_1 - 1)k_{i,t-1} + \beta_0 \Delta y_{i,t} + (\beta_0 + \beta_1)\Delta y_{i,t-1} + (\omega_2 + \omega_1 - 1)\big(k_{i,t-2} - y_{i,t-2}\big) + (\beta_0 + \beta_1 + \beta_2 + \omega_1 + \omega_2 - 1)y_{i,t-2} + \varepsilon_{i,t} \qquad (3.3)$$

Equation (3.3) expresses the growth rate of the capital stock as a function of its own lagged growth rate, the growth rate of output, an error correction term (which is the log of the capital-output ratio), and a scale factor. (3.3) comprises some interesting properties. If $(\omega_2 + \omega_1) < 1$, meaning that the error correction term is negative, the necessary condition of stationarity is met. Also economically the error correction term needs to be negative, since a capital stock above its desired level is assumed to yield lower future investment, and the same goes the other way around.

The term in front of $y_{i,t-2}$ tests the restriction that the long-run elasticity of capital with respect to output is unity.[17] Omitting $y_{i,t-2}$ implies assuming constant returns to scale.

Previous papers include cash flow in the specification in order to explore the possibility of liquidity constraints hampering investment. However, the interpretation of the cash flow variable is ambiguous. A significant cash flow coefficient may simply reflect expectations of future

[16] See Bean (1981, pp. 106-108) for a step-by-step exposition of the step from (3.2) to (3.3).

[17] $y_{i,t-2}$ is not included in all the papers applying the error-correction specification. Mairesse et al. (1999) and Mulkaly et al. (2001) include it whereas Bond et al. (2003a, 2003b) omit it. The papers including $y_{i,t-2}$ do not focus on it particularly much, remember that $y_{i,t-2}$ is present in the error correction term anyway.

demand.[18] The previous papers estimating error-correction specifications compare different countries and therefore draw conclusions on liquidity constraints based on the comparison.

Cash flow is only included as to pose a short-run or transitory effect on investment; this enables the error-correction specification to remain consistent with simple neoclassical long-run equilibrium theory. The cash flow effect is denoted as $\pi_{i,t}$ and is defined as after-tax cash flow divided by the beginning of the period capital stock $k_{i,t-1}$.

In order to capture both the change in capital, $\Delta k_{i,t}$, and the firm specific depreciation of capital, δ_i, in the specification they are proxied by the net growth rate of the capital stock, $I_{i,t}/k_{i,t-1}$, i.e. $I_{i,t}/k_{i,t-1} = \Delta k_{i,t} + \delta_i$. By inserting the profit rate and the just mentioned proxy for capital growth and the depreciation of capital into (3.3) the error correction accelerator-profit specification is obtained:

$$\frac{I_{i,t}}{K_{i,t-1}} = \alpha_i + \alpha_t + \psi_1 \frac{I_{i,t-1}}{K_{i,t-2}} + \theta_0 \Delta y_{i,t} + \theta_1 \Delta y_{i,t-1} + \tau(k_{i,t-2} - y_{i,t-2}) + \varsigma y_{i,t-2} + \rho_0 \pi_{i,t} + \rho_1 \pi_{i,t-1} + \rho_2 \pi_{i,t-2} + \varepsilon_{i,t} \quad (3.4)$$

Translated from (3.3), $\psi_1 = \omega_1 - 1, \theta_0 = \beta_0, \theta_1 = \beta_0 + \beta_1,\ \tau = \omega_2 + \omega_1 - 1$ (the error correction mechanism), and $\varsigma = \beta_0 + \beta_1 + \beta_2 + \omega_2 + \omega_1 - 1$ (the long-run elasticity of capital estimate).

The cash flow coefficients can be tested for joint significance to see whether they pose a permanent or transitory effect on investment. This is conducted using the Wald test. The sales growth parameters are also tested with the Wald test. The joint sales effect is expected to be permanent for both capital and R&D investment. Whereas at least for capital investment is the cash flow effect is expected to be transitory. According to Mairesse et al. (1999) the insignificant joint cash flow effect is expected to capture the transitory effect of financial constraints on firm investment. However, a significant permanent sales growth effect is expected whereas the expectation of the joint significance is harder to predict.

2 R&D investment and the error correction accelerator-profit specification

This section derives the transition of model (3.4) from modeling capital investment to R&D investment. First, consider the underlying stock of accumulated R&D spending, referred to as the knowledge stock $G_{i,t}$. The knowledge stock $G_{i,t}$ is given conceptually by $G_{i,t} = (1 - \delta_i^{R\&D})G_{i,t-1} + R_{i,t}$ where $\delta_i^{R\&D}$ is the depreciation of research capital and $R_{i,t}$ is current R&D spending. Consider (3.3) from above and simply replace $k_{i,t}$ with $g_{i,t}$, with $g_{i,t}$ representing the log of the stock of accumulated R&D. However, there exists no measure of the so called R&D capital stock. For this reason the stock of R&D is approximated using a steady

[18] Adding changes in sales to the investment specification is considered by many as an adequate way to deal with investment opportunities, and then a significant estimate of cash flow can be considered to capture a liquidity effect, see e.g. Chirinko and Shaller (1995), Hall (1992), Himmelberg and Petersen (1994), and Schiantarelli (1996). For a contrasting view on a possible liquidity effect see Gomes (2001).

state approximation suggesting that $G_{i,t}$ grows at the constant rate υ_i, like $G_{i,t} = (1+\upsilon_i)G_{i,t-1}$. This yield:

$$R_{i,t} = \left(\delta_i^{R\&D} + \upsilon_i\right)G_{i,t-1} = \left(\frac{\delta_i^{R\&D}+\upsilon_i}{1+\upsilon_i}\right)G_{i,t}, \text{ and}$$

$$r_{i,t} = ln\left(\frac{\delta_i^{R\&D}+\upsilon_i}{1+\upsilon_i}\right) + g_{i,t}, \text{ where } r_{i,t} \text{ is R\&D spending}$$

Based on this steady state approximation $g_{i,t}$ can be replaced with $r_{i,t}$ and the error correction accelerator-profit specification for capital investment (3.4) can be rewritten for R&D investment:

$$\Delta r_{i,t} = \alpha_i + \alpha_t + \psi_1 \Delta r_{i,t-1} + \theta_0 \Delta y_{i,t} + \theta_1 \Delta y_{i,t-1} + \tau\left(r_{i,t-2} - y_{i,t-2}\right) + \varsigma y_{i,t-2} + \rho_0 \pi_{i,t} + \rho_1 \pi_{i,t-1} + \rho_2 \pi_{i,t-2} + \varepsilon_{i,t} \qquad (3.5)$$

In estimation, $\Delta r_{i,t}$ (first difference of the (natural logarithm) R&D variable) is used as dependent variable following the discussion of Bond et al. (2003b, pp. 18-19) since there is no actual data on a firm's knowledge stock as in the capital investment case.[19] Mulkaly et al (2001) construct a knowledge stock based on pre-sample data. In my case the lack of pre-sample data restricts me to approximate as displayed above. Bond et al. (2003b) construct a knowledge stock using perpetual inventory procedures, but "*it did not yield sensible results*" (Bond et al. (2003b, p. 19)).

3 Including debt in the specification

Following the purpose of this paper the impact of debt needs to be included into (3.5). Based on the discussion in section II long-term debt is considered. I take first difference of long-term debt (to reflect the flow of new debt) and normalize by the beginning of the period capital stock in order to be consistent with the other short-term effect variable, cash flow. The debt variable has the following appearance:

$$D_{i,t} = \frac{(Long\ Debt_{i,t} - Long\ Debt_{i,t-1})}{k_{i,t-1}}$$

The impact of debt is tested in three ways, first simply as a homogenous variable and a quadratic term to test for nonlinearity. I also test the impact of how indebted the firm is by exploring the interaction of the debt variable and previous period leverage. Leverage is calculated according to Rajan and Zingales (1995), total debt divided by total debt plus equity plus non tax reserves.

[19] The issue of R&D accumulation within econometrics is not straightforward; see Klette and Johansen (1998) for a discussion.

The third approach draws inspiration from Czarnitzki and Binz (2008)[20]. For each firm-year observation I calculate leverage. Then, for each year, the observations are ranked based on how levered they are, from lowest leverage to highest. Next, the observations for the particular year are divided into 4 classes, with each class comprising 25 percent of the observations of that year. Each class is represented as a dummy variable assigning 1 if the firm-year observation belongs to the class in question and 0 otherwise. The debt-variable will then be interacted with these dummy-variables which enables the specification to account for how debt interacts with the level of indebtedness of the firm. The dummy variable is tested both as contemporaneous and lagged value with a beforehand preference to the former since the lagged debt-variable accounts for the beginning of the period impact.

The technique just described is appealing from three specific aspects. First of all, since the dummy-variable is designed year by year it allows firms to switch classes, thus it is time variant (see section IV for a display of how firms switch debt-classes during the sample period). A widely criticized aspect of the financial constraints literature is the strategy to segment the sample ex ante into subgroups with different likelihoods of facing financial constraints, see for instance Fazzari et al. (1988), Hoshi et al. (1991).[21]

Secondly, the dummy-variable approach dividing each year's observations into four classes allows me to test the monotonicity of the relationship between debt and R&D investment. This is one of the main points of the Kaplan and Zingales (1997, 2000) critique.

And, finally, grouping the observations on previous indebtedness it is possible to see if there exist a "debt ceiling"-like feature alongside the debt overhang effect. The specification incorporating this division of debt-classes is displayed as equation (3.6) below with the debt variable in first lag form:

$$\Delta r_{i,t} = \alpha_i + \alpha_t + \psi_1 \Delta r_{i,t-1} + \theta_0 \Delta y_{i,t} + \theta_1 \Delta y_{i,t-1} + \tau\left(r_{i,t-2} - y_{i,t-2}\right) + \varsigma y_{i,t-2} + \rho_0 \pi_{i,t} + \rho_1 \pi_{i,t-1} + \rho_2 \pi_{i,t-2} + \eta_1 D_{i,t-1} + \eta_2 D_{i,t-1} * Class\_2_{i,t-2} + \eta_3 D_{i,-1} * Class\_3_{i,t-2} + \eta_4 D_{i,t-1} * Class\_4_{i,t-2} + \varepsilon_{i,t} \qquad (3.6)$$

With $\eta_1 D_{i,t-1}$ representing class 1 and serving as reference group. Class 1 is the observations with lowest leverage and class 4 subsequently displaying the highest leverage.

4 A few words on estimation

Estimating dynamic panels is associated with numerous econometric pit-falls. A firm-level panel is typically short, small T, with many firms, large N. And, in order to find a consistent specification to estimate a firm-level panel the specification should allow for firm-specific effects. These two features basically rule out ordinary least squares (OLS) and within estimation.[22] OLS suffers from an omitted variable bias since it does not include firm-specific effects which induce an upward bias on the estimate of the lagged dependent variable. The within estimator eliminates the firm-specific effects through the within transformation which basically transforms each

[20] They test financing constraints for firm's investing in R&D. They account for firm size by grouping each year's observations by its size and the interaction with the key explanatory variable.
[21] See Musso and Schiavo (2008) for a derivation of a time variant and multi-factored financial constraint measure.
[22] See Bond (2002) and Roodman (2006) for excellent descriptions of dynamic panel data estimation.

firm's observation into deviations from its mean. This transformation leads to the within estimator yielding downward biased estimates of the lagged dependent variable. The bias described for the within estimator is problematic for samples with short time-periods and many firms (see Nickell, 1981), longer time-periods correct the bias associated with the within estimator.

Besides the specific problems from above regarding dynamic panel estimation, the typical econometric problems such as simultaneity and endogeneity bias need to be accounted for. Simultaneity between the current explanatory variable and the current error term tends to induce upward bias in the coefficients because of the positive correlation. Endogeneity problems arise from the impact of past error terms on the current explanatory variable. Instrument-variable regression is typically applied to take care of simultaneity and endogeneity biases (see Balesta and Nerlove. 1966 and Anderson and Hsiao, 1982 for early examples). But these earlier instrument-variable approaches do not yield consistent estimates for dynamic panels.

Generalized methods of moments (GMM) in two particular shapes are designed to handle all the biases described above. By simply assuming that the idiosyncratic error term is serially uncorrelated GMM estimation is consistent (by including time-dummies in the specification the risk of serial correlation diminishes). As instruments GMM propose to use an appropriate set of lagged values of the variables. Based on the upward bias of OLS and downward bias of within estimation a proper specification for a dynamic panel should yield an estimate of the lagged dependent variable's coefficient in between the OLS and within estimates.

Arellano and Bond (1991) propose first-differenced GMM to avoid the biases associated with dynamic panel estimation and to obtain consistent estimates. However, there are problems with this approach. It suffers from weak instruments resulting in imprecise estimates, and the differencing procedure magnifies gaps in the typically unbalanced firm-level panel which leads to important data information being lost. Further, Blundell and Bond (1998) show that first-differenced GMM is severely plagued with finite sample bias which leads to downward biased estimates.

Instead of first-differenced GMM Arellano and Bover (1995) and Blundell and Bond (1998) propose the system GMM which remedies the drawbacks mentioned about first-differenced GMM. Instead of first differencing, system GMM subtracts the averages of all future observations of the variable instead of subtracting the previous observation from the contemporaneous as in first-differenced GMM. This is called forward orthogonal deviations transformation. System GMM also remedies the weak instruments problem allowing for additional instruments since it builds on the assumption that first differences of the instruments are uncorrelated with the fixed effects. Therefore, system GMM builds a system containing both the original level equation and a differenced equation. In estimation of the error correction accelerator-profit model in section V I apply system GMM (as Bond et al., 2003a and 2003b and Mulkaly et al., 2001 do), I do not even present first-differenced GMM results since the estimation with first-differenced GMM was clearly biased downward from weak instruments and a lot of observations were lost due to the first-differencing procedure.

Finally, the key to consistent GMM estimation is to have proper instruments. I present both the Sargan test of the over-identifying restrictions[23] (Sargan, 1958) and the Hansen (1982) test of over-identifying restrictions to properly evaluate instrument validity.

IV Initial results and the description of the sample

1 Descriptive statistics

The dataset for the empirical analysis is maintained by Statistics Sweden and is constructed from firm balance sheets. The sample consists of about 24,000 observations originally over the period 1992-2000. Appendix A contains a detailed description of the data. However, in order to be able to apply the estimation techniques presented in section III I need to look at firms which actually conduct R&D investment. By restricting sample participation to firms which have reported at least one year of positive R&D the sample size is reduced to 8,693. The average number of observations of a firm in the final sample comprising the R&D firms is 8.

The presentation of the sample and of the initial results uses a rather highly aggregated sector classification. It divides the manufacturing sector into five different sectors. Resource intensive (1) which comprises industries such food and wood, labor intensive (2) comprising textiles and parts of metal manufacturing, scale intensive (3) for instance paper and rubber manufacturing, differentiated products (4) for instance machinery, and high technology manufacturing (5) comprising pharmaceuticals and aircraft etc. The full list of the five OECD sectors and which sub-sectors expressed in the standard industrial classification code (SIC) they constitute is found in appendix B.

[Table 1 about here]

Scale intensive industries are the most influential segment comprising about 30 percent of the original manufacturing sample. However, only 35 percent of the firms in the scale intensive industries are R&D firms. As displayed in table 1 the three most influential segments in terms of the OECD classification (scale intensive, differentiated products, and high technology) have fewer R&D firms relative to its size than the two less influential sectors. For the resource intensive and labor intensive sectors 50 percent of its firms are R&D firms. Their combined weight in the original manufacturing sample is about 20 percent but in the sample of R&D firms their combined weight increases to almost 30 percent. This is further discussed later on this section.

Table 2 displays descriptive statistics of the key variables for the original manufacturing sample and for the R&D firm sample.

[23] The Sargan test is not consistent in the heteroskedasticity case (Baum et al., 2003), I still present the test statistic in line with the results sheet from STATA and because other researchers usually present it.

[Table 2 about here]

Average employment and sales double as the non-R&D firms are excluded from the sample. The average firm in the R&D sample has 273 employees and annual sales of $46,090,000. The sample is skewed which is evident from the median firm in terms of employment is 122 with annual sales of $16,730,000.

This paper is closely related to the error-correction specification on R&D investment in Bond et al. (2003b) and Mulkaly et al. (2001) and since I refer to the results of those papers a comparison of samples is in order.

[Table 3 about here]

The comparison is hard to motivate considering the vast difference in firm size of the other two papers' samples. The French sample has an average sized firm of 1,568 employees compared to the sample here of 273. By looking at the US sample an average size of 19,848 indicates the distinctly different sample characteristics.

The difference between the R&D firms for the five OECD sectors is further exploited graphically.

[Figure 1 about here]

Resource intensive (1) and labor intensive (2) firms have the highest average R&D expenditures of all sectors. They lie within the range of $200,000 to $300,000 annually compared to, for instance, high technology (5) hovering around the $100,000 level across the sample period.

This pattern persists when looking at R&D intensity. R&D intensity is expressed as R&D investment divided by capital investment plus R&D investment. Again resource intensive (1) and labor intensive (2) industries are at the top. Resource intensive (1) industries are consistently between 0.2 and 0.3, whereas high technology (5) industries are around 0.1 or less.

[Figure 2 about here]

This difference in terms of R&D behavior for the different sectors needs further exploration. By looking at each sector's capital investment rate for non-R&D firms (figure 3) and R&D firms (figure 4) the pattern persists.

[Figure 3 and 4 about here]

For both non-R&D and R&D firms the resource intensive (1) sector has the highest capital investment rate (I/K). In second place in terms of both types of firms are still labor intensive (2) industries, albeit by a small margin.

Turning to each sector's average capital-output ratio the pattern persists.

[Figure 5 and 6 about here]

Here, the resource intensive (1) sector displays much lower capital-output ratios closely followed by the labor intensive (2) sector. Instead, the high technology (5) sector has much higher capital-output ratios for both non-R&D and R&D firms. The capital-output ratio for high technology (5) is about 0.3 compared to the resource intensive (1) sector's ratio of 0.15. This is partly explained by the more capital intensive nature of the high technology (5) sector compared to the resource intensive (1) sector. This is displayed intuitively in table 15 in appendix B by using the external finance dependence measure proposed by Rajan and Zingales (1998).[24] All sub-sectors comprising high technology (5) are considered highly dependent on external finance compared to the resource intensive (1) sub-sectors where most of the firms are less dependent on external finance.

2 Debt structures

In table 1 the average and median leverage of both non-R&D and R&D firms is displayed at about 0.60. Again, comparing sectors based on leverage and also on long-debt leverage (implying that the numerator only comprises long-term debt) the same different behavior of sector 1 and 2 is displayed.

[Figure 7 and 8 about here]

In terms of leverage non-R&D firms have higher average leverage across all sectors. For the R&D firms in figure 8 the differentiated products (4) sector has a leverage ratio of between 0.62 and 0.64 across the sample period. Again, though, resource intensive (1) and labor intensive (2) industries display a different pattern. Besides the labor intensive sector having 0.61 leverage in 1992 sector (1) and (2) are below 0.60 the entire sample period. In the graphs it is a trend in the sample toward deleveraging.

[Figure 9 and 10 about here]

[24] A description of this measure can also be found in appendix B.

Instead, looking at each sector's leverage when the numerator only comprises long-term debt the pattern turns somewhat different. Now, resource intensive (1) and labor intensive (2) industries have the highest leverage, ranging between 0.22 and 0.26 compared to high technology (5) industries between 0.17 and 0.22.

Table 13 in appendix B displays Bráun (2002) tangibility index which ranks each sector based on how much tangible assets its firms at median possess.[25] Firms with high values of tangible assets can easier and cheaper access external finance and particularly long-term relational debt (see discussion in section II). Again, comparing the resource intensive (1) industries with high technology (5) industries a clear distinction is displayed. All sub-sectors comprising high technology (5) are below the median in terms of tangibility whereas all but one (leather, which is the least influential sub-sector) of the resource intensive (1) sub-sectors are above the median.

The time varying nature of the debt classes described in section III which assigns each firm-year observation a rank based on the level of leverage is also investigated. Firms turn out to switch debt classes rather frequently. I simply explore the firms which are present more than half of the sample period. There is a total of 997 (out of the total 1,125 firms in the sample) firms with five or more observations, just 168 of these firms stay in the same debt class during the entire sample period. Next I explore the firms with 9 observations, 682 firms. 61 of them stay in debt class 1 the whole time, 6 in class 2, also 6 in class 3, and 29 in debt class 4. A total of 102 firms, roughly fifteen percent, of the firms present during the entire sample period stayed in the same debt class.

As it turns out firms switch debt level more frequently than I expected. This piece of evidence is important for motivating the division into these debt classes ahead of the empirical analysis. This implies that the debt class procedure truly is a time variant credit constraint measure.

[Table 4 about here]

There are rather distinct differences in terms of the average leverage levels of each debt class (table 4). Debt class 1 displays a low leverage ratio which may indicate unsatisfactory credit access. Debt class 4 firms on the other hand are disturbingly in debt. The propositions ahead of the empirical analysis are that debt class 4 observations will display an inverse relationship between additional long-term debt and R&D investment based on a severe case of debt overhang. Further, debt class 1 seems to have poor access to credit which may indicate that they will not borrow externally at appealing interest rates, implying an inverse relationship for debt class 1-firms as well. Debt class 2 firms are expected to display a positive relationship between additional long-term debt and R&D investment. They are probably not as affected by a debt overhang effect and they also may not have reached their "debt ceiling". The debt class 3 firms are difficult to predict, and I leave their relationship to the results section.

[25] The index figures in table 15 are gathered from Bráun and Larrain (2005). In appendix B I give a brief description of how this tangibility measure is calculated.

The distinctly different patterns of the five manufacturing sectors are used to check how the results of section V alter based on industry specific characteristics. Resource intensive (1) and labor intensive (2) industries are more R&D intensive and have higher capital investment rates, they have lower capital-output ratios, and they have better access to long-term relational debt compared to the other three sectors. The reasons for these differences are many and will not be discussed in detail, but they motivate the sample split of section V.3.

V Estimation results

The vast nature of the paper's topic requires an overview and a course of action before I start discussing the empirical results.

In order to include the debt variable properly into the error correction framework section 1 presents the application of the error correction specification as in Bond et al. (2003b) with one lag of cash flow and as in Mulkay et al. (2001) with 2 lags of cash flow. After the specification is properly applied I test the impact of debt as a transitory impact factor on R&D investment in section 2.[26] I start out by including debt in a more straightforward manor in order to compare the particular debt class division which I presented in section III. In both section 1 and 2 I compare the error correction results of R&D investment with capital investment in order to evaluate the specification fit. In section 3 I split the sample based on industry belonging partly inspired by Chiao (2002), aiming to capture firms with different types of R&D investments.

1 Application of the main error correction specification

A prerequisite to even apply the error correction model is that the main variables share a cointegrated relationship. Figure 11-14 (appendix C) display correlograms of the sales and R&D investment variables respectively. Both series are, as expected, highly persistent in levels (figure 11 and 13). However, as figure 12 and 14 indicate, after first differencing transformation they both display a random walk like behavior. This means that both the sales and R&D investment variables are integrated of order 1, thus it is possible to apply the error correction model and to exploit this relationship.

[Table 5 about here]

The results from running the application of model (3.5) is compiled in table 5.[27] A common rule of thumb in terms of the specification's goodness of fit is to evaluate the lagged dependent variable's coefficient. Applying (3.5) according to Bond et al. (2003b) using one lag of cash flow the lagged dependent variable's GMM-estimate falls in between that of the OLS and within specification implying a proper specification. However, the AR (2) test cannot rule out serial correlation. In table 7 the results from model (3.4) for capital investment are displayed.

[26] By only considering the impact of debt as a transitory enable me to stay consistent with neoclassical investment theory as discussed in section III.

[27] In table 6 I experiment with the scale parameter term. I opt to include the scale parameter in the specifications since it seems to add explanatory power and because without the scale parameter the error correction term grows in size.

Comparing the different types of investments it is clear that the R&D investment version is more plagued with serial correlation than the capital investment case based on the AR-test results. This is of course expected. The severity of serial correlation is a result of the preference of firms to smooth out its R&D investment due to the high adjustment costs.

[Table 7 about here]

The error correction term is negative as expected (implying the necessary stationarity conditions). This condition is also fundamental economically. A negative value implies that when the R&D-output relation is in disequilibrium it adjusts properly. For instance, if R&D investments are below its equilibrium level ($(r_{i,t-2} - y_{i,t-2}) < 0$) then the error correction process becomes positive, and the model captures the adjustment process back towards equilibrium. The estimated error correction term from the specification with one cash flow lag is (-0.179) implying that when the R&D-output relation falls into disequilibrium the adjustment process works at a rate of about 18 percent per year (Bond et al (2003b) report a 16 percent rate in the U.K. and a 6 percent rate in Germany).

Using one lag of cash flow there are no significant contemporaneous effects (as expected). The lagged cash flow effect is almost identical as in Mulkaly et al. (2001) for U.S. and French firms (Bond et al., 2003b report a 0.14 coefficient for the U.K. and a negative coefficient for German firms), the estimated coefficient here is 0.086. For instance an increase in profits from 7 to 10 percent a year ago yields a 0.3 percent increase in R&D investment.[28] The same effect for capital investment (lagged cash flow effect of 0.179) from a 3 percentage point profit increase thus yields a 0.6 percent increase. Lagged output growth is also strongly significant. In terms of long-term effects, the long run accelerator sales level is estimated at about 0.7, however non-significant at conventional levels. The long run profit effect is also non-significant implying only a transitory cash flow effect (in accordance with expectations).

Considering instead including 2 lags of cash flow. First of all the sample is greatly reduced implying valuable information being lost. On the positive side, the serial correlation problem disappears. But the lagged dependent variable coefficient is no longer in between the OLS and within estimate. The error correction term is reduced from about an 18 percent rate to a rate of about 10 percent (-0.097). The contemporaneous cash flow effect is still non-significant. The inclusion of two lags of cash flow leads to a positive first lag estimate and negative second lag coefficient. The first lag cash flow coefficient is inflated compared to the specification with only one lag included, now estimated at 0.136 from a previous 0.086. The first lag sales growth effect has declined from a strong effect when only one lag of cash flow is included to a non-significant estimate when I include two lags of cash flow. By including two lags of cash flow there is a positive 0.4 percent impact on R&D investment from a three percentage point profit increase a year ago and a negative impact of 0.3 percent from a profit increase of the same size two years ago.

The long run sales accelerator is identical whether one or two lags of cash flow are included. The long run profit impact is severely inflated by the inclusion of a second lag, but still non-significant at conventional levels.

[28] A three percentage point increase multiplied by the coefficient estimate at 0.086: 0.03*0.086=0.00258, roughly a 0.3 percent increase.

For both specifications reported in table 5 the Hansen test of overidentifying restrictions indicates that the instruments are uncorrelated with the error term.

This section provides the foundation for the inclusion of the debt variable. The results are in line with my two benchmark specifications (Bond et al., 2003b and Mulkaly et al., 2001), which is satisfactory. The presentation of a specification with one and two lags of cash flow is not meant to serve as a way of selecting one or the other specification; this is discussed in section 4 though. In section 2 I continue to present both specifications and evaluate the advantages and disadvantages.

2 Testing the impact of debt-financing

The initial debt specification includes additional variables comprising debt lagged one period[29] and also in its quadratic form. Next I condition these two variables by firm debt level through interacting it with previous period leverage. The results are compiled in table 8.[30]

[Table 8 about here]

Including debt and its quadratic term, the error correction term grows in size as compared of table 5. Now the adjustment process is estimated at about 26 percent, which is high. The lagged cash flow effect is also inflated, from 0.086 to 0.111. The debt variables are as expected non-significant statistically, and also economically. The lagged debt coefficient is slightly negative whereas the quadratic term is zero utilizing three decimals.

The results from conditioning the debt variables, which I just estimated, by interacting them with the (two period) lagged leverage ratio, leads to practically unchanged results.

[Table 9 about here]

In table 9 the results from assigning firms to debt classes are reported. In terms of the qualitative implication of the debt-R&D investment relationship the results are the same with one and two lags of cash flow. But there are some important differences in terms of goodness of fit. The coefficient of the lagged dependent variable falls in between in the one lag specification whereas it is close to the OLS coefficient in the two lag specification. The output growth and the profit estimates are identical for both specifications. However, the same pattern persists in terms of serial correlation. In the one lag specification there is still second order serial correlation, which is not the case in the two lag specification. Also the error correction term is disturbingly inflated in the one lag specification. Including debt seems to inflate the error correction process from

[29] I only present estimation results with debt lagged a year ago, which implies the change of debt which may have had time to influence the firm's R&D investments. The results with contemporaneous changes of debt turned out non-significant both statistically and economically as expected.

[30] The results from these specifications with debt are only reported for the case with one lag of cash flow. I excluded the results with two lags since they are almost identical.

adjusting at an annual rate of 18 percent as reported in table 5 to a rate of about 26 percent in the one lag specification. In the two lag specification the error correction process is also inflated, but with a more reasonable outcome (at an annual rate of 18 percent).

The results of the debt class division yield interesting results fairly in line with the theoretical predictions of a debt overhang effect present for firm R&D investment. For both specifications the first and fourth debt class displays an inverse relationship between long-term debt and R&D investment (in the two lag specification, however, non-significant at conventional levels). Debt class 2 reports a statistically and economically significant relationship. The two lag specification reports a coefficient of 0.08 from its lagged year to year difference of long-term debt. Economically, this implies that a five percentage point increase in long-term debt a year ago yields a 0.3 percent increase in R&D investment. But, this positive relationship is only valid up to a point. During the sample period the median observation in the second debt class reports a 0.57 leverage ratio (table 4). The median leverage of the third debt class, which does not display a positive relationship between long-term debt and R&D investment, is 0.71. These results imply that there are both debt overhang effects and a form of debt-ceiling present in terms of maximizing its R&D investments in respect to debt-financing. The one lag specification reports a stronger effect corresponding to firms in the second debt class, and the inverse relationships of debt classes one and four are more pronounced. For both the one and two lag specifications there is a non-significant relationship, or a close to zero relationship, for firms in the third debt class.

Considering the two lag specification (which actually seems to be the best fit), the one year lagged cash flow effect is estimated at 0.136 and the debt coefficient is 0.08 (for debt class 2 firms). So, for firms which finance itself with about 60 percent debt, debt is almost as important as a source of finance as internal cash flow. However, even for relational long-term debt, if the firm is highly indebted more debt does not benefit R&D investments. The case of firms in the first debt class is perhaps contradictive. Firms in the first debt class display a median leverage ratio of 0.34 (table 4), which is very low. This may very well be a sign of poor credit access, which give rise to the inverse relationship of table 9.

[Table 10 about here]

In table 10 the same specifications as in table 9 are estimated but with capital investment as dependent variable. The same pattern is present also for capital investment. Firms in the second debt class report a coefficient of 0.123 in the one lag specification. This fact is reassuring and serves as a strong verification of the main results of table 9.

[Table 11 about here]

In Table 11 I have compiled the error correction specification results from Mairesse et al. (1999) on U.S. and French samples and Bond et al. (2003a) with results from the U.K., Germany, France and Belgium. The different samples include firms with distinctly different characteristics compared to the sample of this paper. Average firm size range from almost 20,000 employees (U.S. sample) to 777 (Belgium), but Bond et al. (2003a) present results also for smaller firms in their appendix (Bond et al., 2003a, p. 164, table A3). The French sample of smaller firms (average firm size 214, compared to the average size of this sample of 273) is valid as a benchmark of evaluation. The error correction process is of almost identical size for this sample as the French small sample (about 19 percent annually) and also the persistence of the investment rate is similar.

The specification of this paper displays satisfactory goodness of fit. This in turn makes the results of a rather substantial debt overhang effect on R&D investment even more appealing. The error correction specification and the reported debt overhang is put through additional trials in section 3 when the sample is split based on OECD sector belonging.

3 The impact of industry belonging

In section IV there is evidence of rather distinct differences in terms of R&D intensity, capital-output ratios and leverage between firms belonging to resource intensive (1) industries and labor intensive (2) industries and for firms belonging to scale intensive (3), differentiated products (4), and high technology (5) industries. Also, from the original sample about 50 percent of the firms in sectors (1) and (2) are R&D firms whereas the same for sectors (3)-(5) ranges from 28-35 percent of all firms. Thus, dividing the sample into one sub-sample (sub-sample 1 from here on) of firms belonging to sectors (1) and (2) and another sub-sample (subsequently sub-sample 2) comprising sectors (3)-(5) is a useful exercise. The first sub-sample (compared to the second sub-sample) comprises firms with lower capital intensities, presumably less advanced R&D projects (at least compared to high technology firms), better access to long-term relational debt (presented in figure 10), and also less transactional debt (reflected in the lower leverage ratios presented in figure 8). The results from estimating model (3.6) on sub-sample 1 (columns 1-3) and sub-sample 2 (columns 4-6) is presented with one lag of cash flow in table 12 and with two lags of cash flow in table 13.

[Table 12 and 13 about here]

3.1 Sub-sample 1: Resource and labor intensive industries

The initial reflections of the estimation results are the unusually low standard errors of the firms in sub-sample 1 compared to the estimates run on the whole sample. This of course reflects a high degree of homogeneity among firms within resource and labor intensive industries.

The one lag cash flow specification displays signs of being well specified. No serial correlation, the Hansen test implying proper instruments, and the long-run coefficients are as expected permanent for output (estimated at 0.35) and transitory for profits. The error correction process is inflated compared to the initial results of table 4, now at an annual rate of 29 percent (in the two lag cash flow specification estimated at 28 percent). Contemporaneous cash flow is significant and strongly negative whereas cash flow a year ago is strongly positive.

The relationship of debt and R&D investment for resource and labor intensive firms is inverse for firms with little debt (debt class 1) and economically insignificant for firms belonging to debt class 2-4. Resource and labor intensive firms seem to be firms with high sales and in little need of external finance (based on the lower leverage ratios and their low scores of Rajan and Zingales, 1998 external finance dependence measure (table 15)). Thus, they are able to finance its

R&D investments internally. It is interesting that debt class 1 firms even in this sector division still display an inverse relationship between debt and R&D investment.

The specification with two lags of cash flow displays a qualitatively similar relationship of debt class belonging as in the one lag specification. But, due to the similar results from including either one or two lags of cash flow I prefer the one lag specification since it allows me to utilize more information (1,055 observations compared to 850). Another worrisome feature of the two lags specification's goodness of fit is the long run cash flow effect which is permanent and negative which is un-matched in previous literature.

3.2 Sub-sample 2: Scale intensive, differentiated products and high technology industries

This is clearly a less homogenous sample than sub-sample 1. But the results bear with it some additional information. The specification for either one or two lags of cash flow displays second order serial correlation and a highly estimated error correction process around a 35 percent annual rate. Especially, the one lag specification (table 12) displays poor fit. The lagged dependent variable is unrealistically small (1-0.73=0.27), implying little persistence in its R&D investment contradicting the notion of firms smoothing its R&D spending. The error correction process is estimated at -0.38, which is high by any standard, though consistent with little persistence in its R&D spending. However, the impact of debt is particularly of interest. The one lag specification suggests that firms in debt class 1 and 2 have a strong debt impact (0.134). This implies that a 5 percentage point increase in debt a year ago responds in a 0.7 percent increase in R&D investment. The cash flow effect is also smaller in magnitude compared to sub-sample 1. Cash flow is estimated at 0.102, implying a smaller impact. The long-term debt impact on R&D investment for highly indebted firms (debt class 3 and 4) is virtually zero. The results of higher estimates of debt as compared to sub-sample 1 are not surprising if I account for the higher external finance dependence in terms of the Rajan and Zingales (1998) index (see table 15). Firms operating in industries (3)-(5) are more capital intensive and therefore require external finance, which results in them displaying higher leverage ratios than firms of sub-sample 1 and also higher debt estimates. Bear in mind that the higher debt correlations of sub-sample 2 do not necessarily having to reflect that they actually finance R&D investments with borrowed funds.

The specification with two lags of cash flow (table 13) displays more signs of being well specified than its one lag counterpart. The long run effects are as expected permanent in output and with transitory profit effects. The error correction process is not as fast as reported in table 12 and subsequently is the lagged dependent variable reflecting more persistence. There is still serial correlation of the second order which devalue the results of the second sub-sample substantially.[31] But, the debt variables are similar as in the one lag specification. The debt class 1 firms display a strong positive relationship which turns smaller for debt class 2 firms before turning negative for firms with higher leverage.

4 Summary and discussion

Overall the error correction accelerator-profit specification fit the data well. Before including long-term relational debt the estimation results corroborate with the benchmark results of Bond

[31] It is of course possible to utilize deeper lags of the explanatory variables as instruments. My intention is to follow the estimation routine of Bond et al. (2003b) and Mulkaly et al. (2001) and they instrument 1 and 2 periods back in time.

et al. (2003b) and Mulkaly et al. (2001). By also estimating the error correction model for the capital investment case the specification's goodness of fit is further verified.

The results of the inclusion of long-term debt fall in line with the theoretical predictions of section II. The empirical results provide evidence of a debt overhang effect since firms with high prior debt levels experience an inverse relationship between long-term debt growth and R&D investment. This reflects the increasing costs of being too levered including having to post excessive collateral, higher bankruptcy costs, increased monitoring costs from too high debt levels supposedly encouraging risky behavior etc. Firms with very low previous debt levels also experience an inverse relationship. This as mentioned may seem contradictive. But this feature may very well reflect these firms' poor external credit access which makes external debt too expensive in the first place. The empirical results suggest that firms with leverage ratios in the neighborhood of 0.60 are less affected by the debt overhang effect, which enables their positive relationship between additional long-term debt and R&D investment.

From decomposing the sample based on industry belonging further evidence evolves. Firms operating in less capital intensive industries are in less need of external finance thus reflecting their overall indifferent result to the impact of additional long-term debt on its R&D expenditures.

The error correction specification with added transitory effect-variables of profits and long-term debt is better applied to firms belonging to resource and labor intensive industries. By including one lag of cash flow eliminates serial correlation and the standard errors are comparatively small. The economic interpretation of the results is also appealing with an estimated permanent output effect and transitory cash flow effects (corroborating with neoclassical theory and previous empirical results).

The reflection of a strong and positive relationship between additional long-term debt and R&D investment for less levered firms in sub-sample 2 are appealing, yet unreliable results. Economically it makes sense since their capital intensive nature requires these types of firms to utilize large quantities of external finance. The fact of the positive relationship turning negative for firms with higher prior debt levels is additional evidence of a debt overhang effect on R&D investment.

The last part of this discussion comprises methodological concerns (mainly to satisfy the critical applied econometrician). In table 14 the system GMM results of table 9 with two lags of cash flow (i.e. the specification which displayed best fit) are utilized and scrutinized.

[Table 14 about here]

Instrument validity is checked by the Hansen test of overidentifying restrictions and also the AR-tests of serial correlation. Roodman (2006) proposes that a reasonable limit for number of instruments is not exceeding the number of research units (in this case number of firms), based on that criterion my results are within safe limits (about 200 instruments and 600-700 firms). The Hansen test (the null hypothesis implying exogenous instruments) never rejects the null hypothesis using conventional levels, but when the number of instruments is increased with the inclusion of the long-term debt variables (table 5 compared to table 9) the Hansen statistic approaches zero, even though the Hansen statistic of table 9 is reported at 0.107. Due to

Roodman (2008)'s warning of the Hansen test's weakness due to instrument proliferation I collapse the GMM matrix which reduces the number of instruments substantially.[32] I then compare the Hansen test statistic, which now is estimated at 0.456, implying that there are potential problems of too many instruments. In table 14 I also include the difference-in-Hansen test. This test is a generalized difference-in-Sargan test and tests the validity of a subset of instruments (Roodman, 2008, p.11).[33] The difference-in-Hansen test is also weakened by many instruments but still accepts the null hypothesis of exogenous instruments.

Table 14 also emphasizes the problem of the otherwise efficient system GMM two-step estimator in the presence of finite samples. Windmeijer (2005) discusses and proposes a remedy of a finite sample bias which biases the standard errors downward. Column 3 of table 14 comprises the results with Windmeijer (2005)-corrected standard errors. The coefficients are identical as in column 1 but the standard errors have vastly increased (on average by 276 percent!). I also present the collapsed version of the Windmeijer (2005) corrected two-step results which are identical to the collapsed counterpart of column 1.

This last piece of discussion sheds light on the many difficulties surrounding the efficient and popular GMM-estimator.

VI Conclusions

This paper starts out with a thorough investigation of the role of debt as a financing source of firm R&D investment. Based on earlier work, which incorporates internal cash flow as a potential determinant of R&D investment within an error correction accelerator-profit framework, long-term relational debt is included and tested as an alternative financing source. The hypothesis of the paper was that also R&D investment is affected by the so called debt overhang effect proposed in Myers (1977). The empirical results display results in accordance with a proposed debt overhang effect also for R&D investment. Firms which have debt levels of about 0.60 in relation to total assets display a positive relationship between additional long-term debt and R&D investment. Firms with lower debt and higher debt levels display the more familiar inverse relationship between debt and R&D investment.

[32] Collapsing the GMM-matrix implies converting the GMM-matrix into a single column, thus eliminating the zeros (Roodman, 2006, p. 23). This is of interest since each instrumenting variable generates one column for each time period.

[33] The Sargan test as mentioned before is not consistent in the presence of heteroskedasticity.

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Table 1 - Sector Statistics divided by R&D and non-R&D firms

	OECD Classification	All Firms(A)	R&D Firms(B)	Non R&D Firms(B)
1	Resource Intensive	1403 (5.8)	740 (52.7)	663 (47.3)
2	Labor Intensive	3772 (15.7)	1845 (49.9)	1927 (50.1)
3	Scale Intensive	7032 (29.3)	2466 (35.1)	4566 (64.9)
4	Differentiated prod.	6201 (25.8)	1737 (28.1)	4464 (71.9)
5	High Technology	5589 (23.3)	1905 (33.1)	3684 (65.9)
	Total	**23997**	**8693 (36.3)**	**15304 (63.7)**

Note: (A) Within parenthesis, percentage of the total number of firms. (B), percentage of firms in the considered sector.

Table 2 - Descriptive statistics on key variables and ratios

Variables	All: (A) Mean	S.D.	Median	R&D: (B) Mean	S.D.	Median
Employment	135	303	48	273	438	122
Sales (C)	21578	56855	5922	46090	85328	16730
I/K (D)	0.28	0.24	0.21	0.25	0.20	0.20
R/S (E)	-	-	-	0.01	0.02	0.00
K/S (F)	0.21	0.17	0.17	0.22	0.17	0.18
Leverage (G)	0.62	0.21	0.64	0.60	0.20	0.61
Π/K (F)	0.35	0.77	0.10	0.20	0.48	0.05

Note: (A), the first three columns correspond to all firms and (B) correspond to the R&D firms. (C) is annual sales expressed in thousands 2000 US Dollars, (D) is capital investment divided by the capital stock, (E) is R&D expenditure divided by annual sales, (F) is the capital-output ratio, (G) is firm leverage expressed as (short debt + long debt) / (total debt + equity + non-taxed reserves), (F) is after cash flow divided by the capital stock.

Table 3 – Comparison of sample characteristics with the two main studies

Variable	US	France	UK	Germany	Sweden
Employment	19848	1568	16134	16538	273
I/K (A)	0.14	0.12	0.14	0.12	0.25
R/S (B)	0.02	0.02	0.06	0.01	0.01
Π/K (C)	0.27	0.16	0.22	0.17	0.20
Firms	482	486	175	201	1125

Note: (A) is fixed investment divided by the capital stock, (B) is R&D expenditure divided by annual sales, (C) is after tax cash flow divided by the capital stock. Column 2 and 3 are compiled from Mulkaly et al (2001) and column 4 and 5 are compiled from Bond et al (2003a). The Mulkaly et al (2001) statistics are based on a sample ranging from 1982 to 1993, the Bond et al (2003a) statistics from 1985.

Figure 1 - Average R&D expenditure annually across sectors (Average by year across OECD sector classifications, in thousand US dollars)

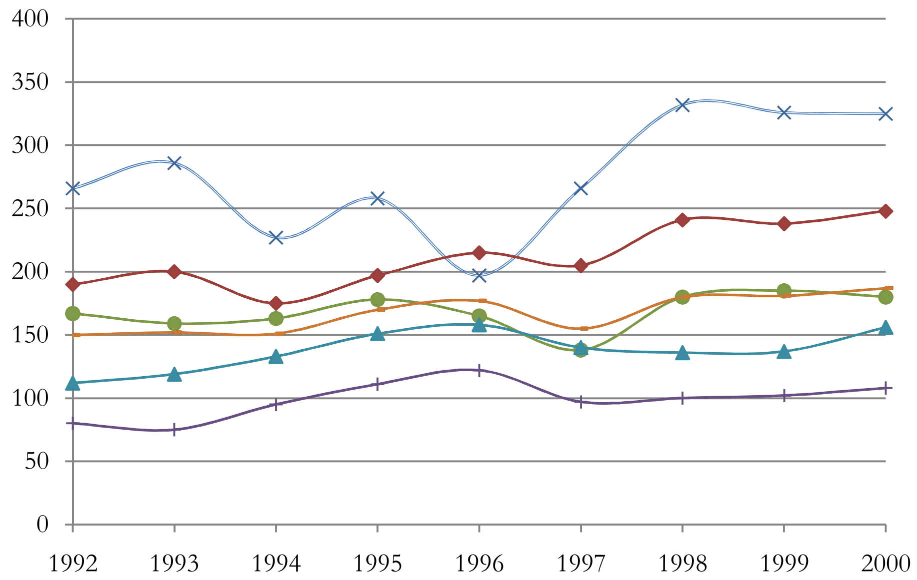

Figure 2 - Average R&D intensity defined as the share of R&D investment out of total investment expenditure, annually and across sectors (Average by year across OECD sector classifications)

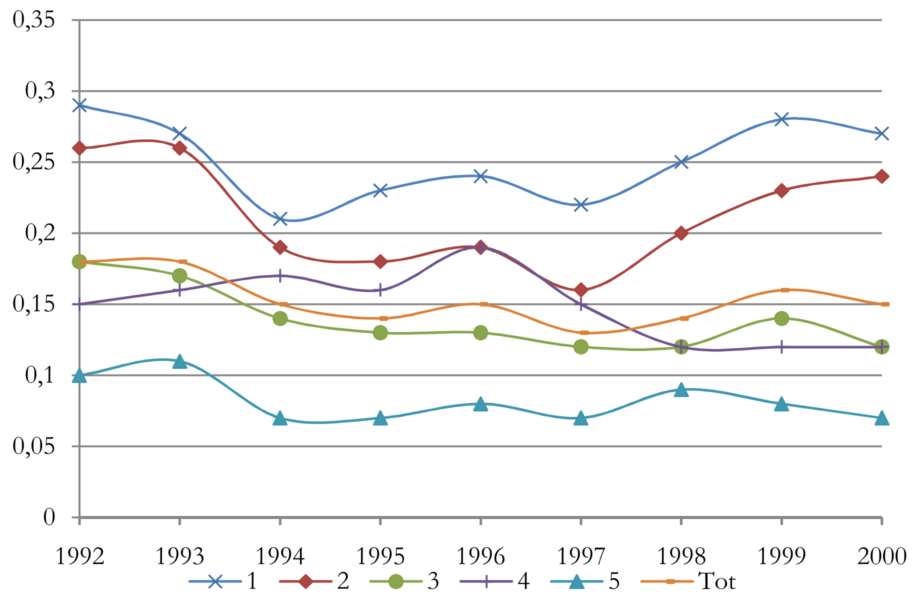

Figure 3 - Investment rate (I/K) Non-R&D firms (Average by year across OECD sector classifications)

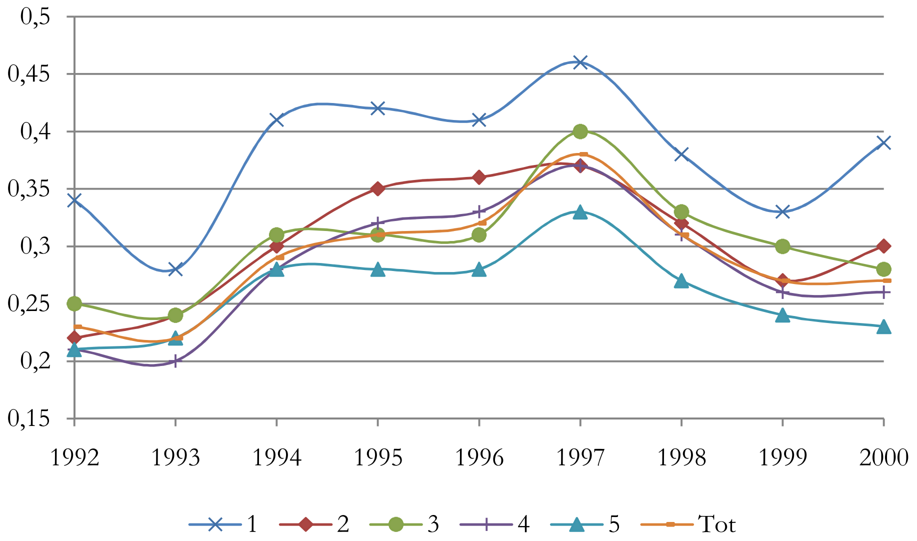

Figure 4 - Investment rate (I/K) R&D firms (Average by year across OECD sector classifications)

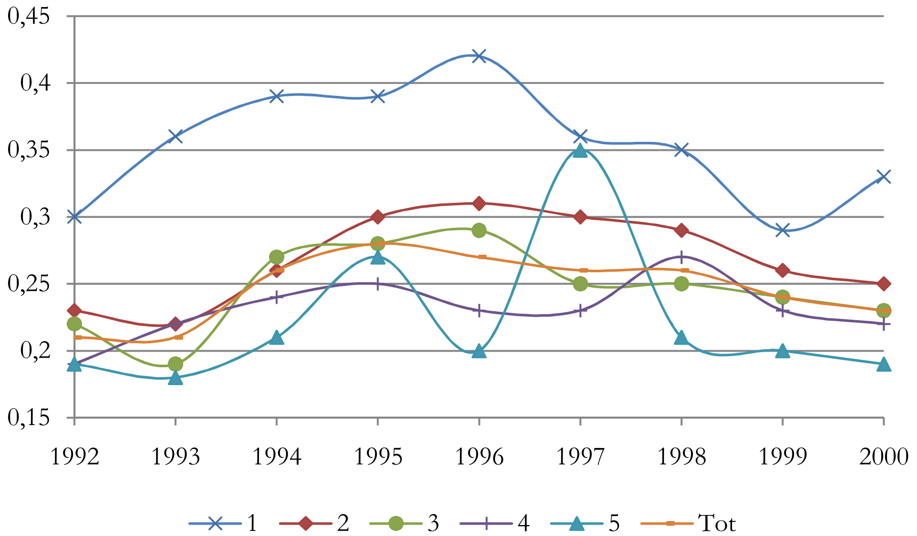

Figure 5 - Capital - Output ratio (K/S) Non-R&D firms (Average by year across OECD sector classifications)

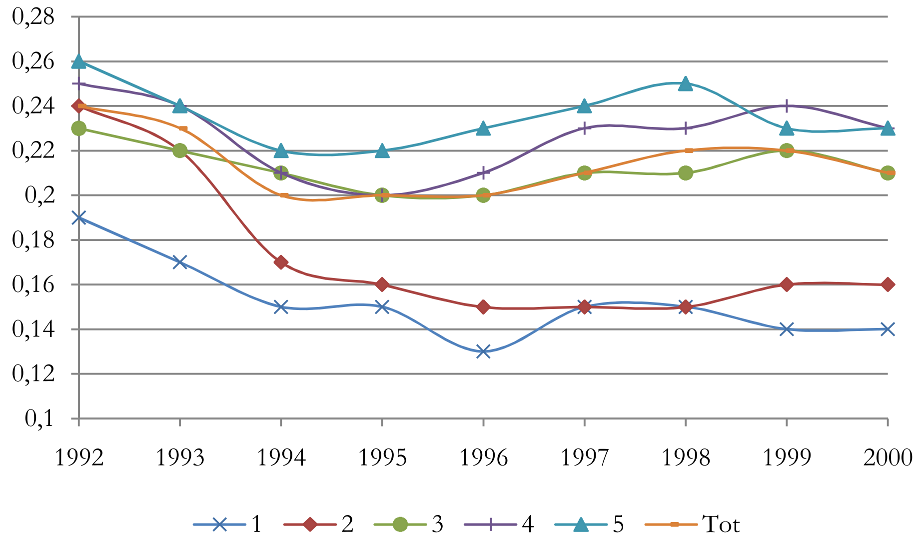

Figure 6 - Capital - Output ratio (K/S) R&D firms (Average by year across OECD sector classifications)

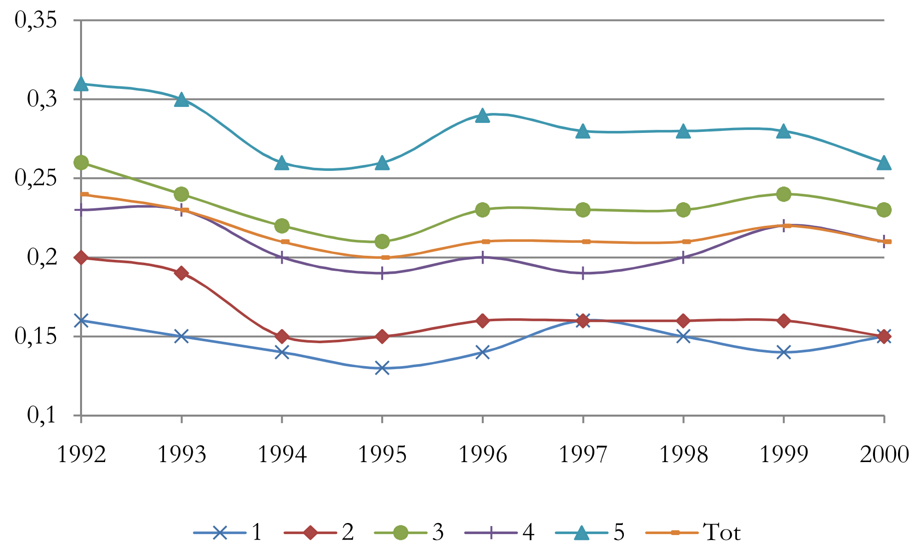

Figure 7 - Leverage Non-R&D firms (Average by year across OECD sector classifications)

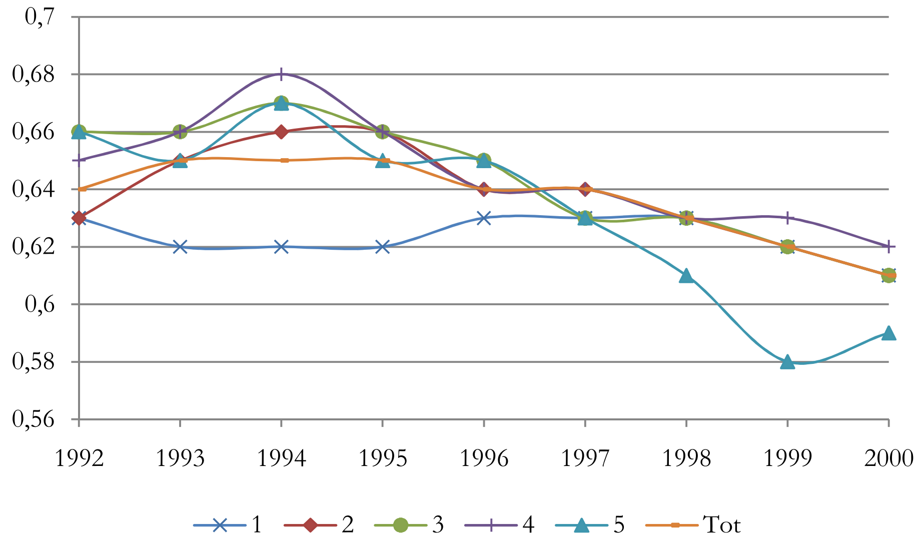

Figure 8 - Leverage R&D firms (Average by year across OECD sector classifications)

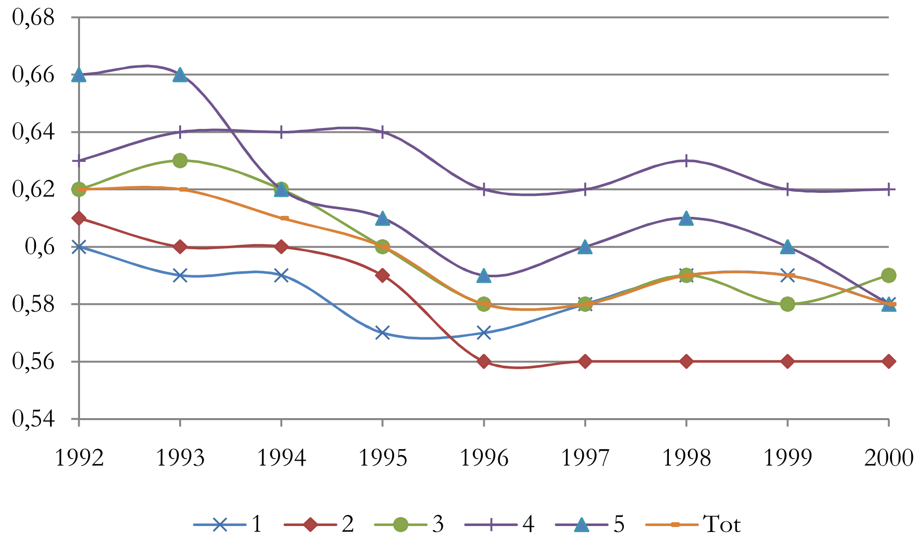

Figure 9 – Long debt leverage Non-R&D firms (Average by year across OECD sector classifications)

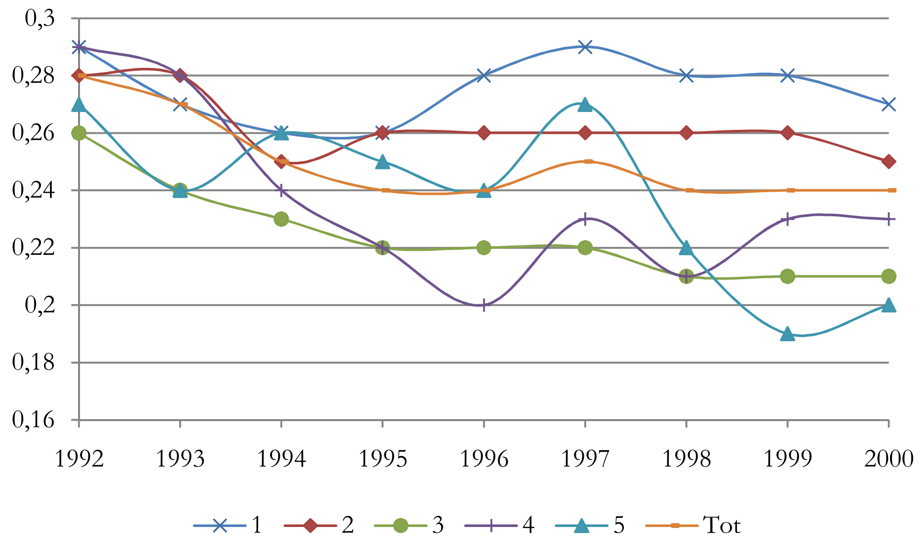

Figure 10 – Long debt leverage R&D firms (Average by year across OECD sector classifications)

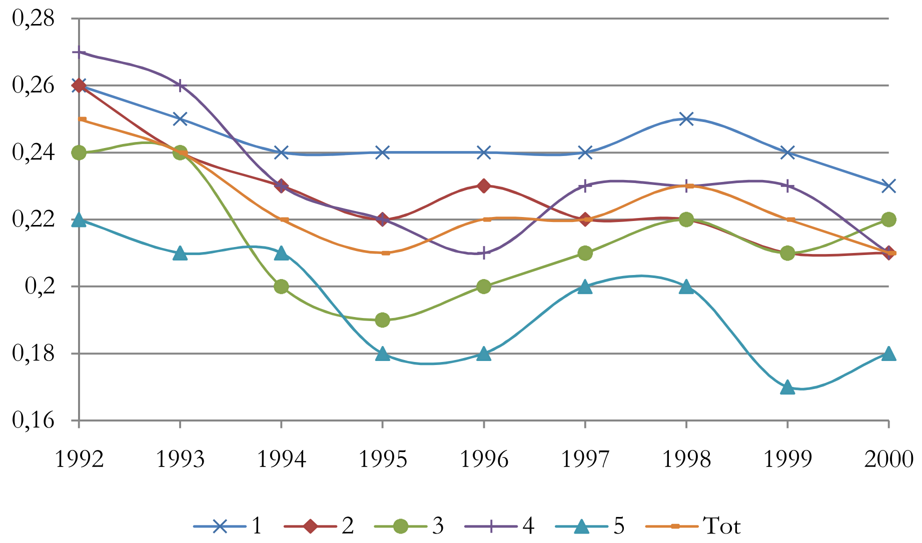

Table 4 – Descriptive statistics of debt classes and its leverage ratios

Debt Class	Average	Median	Min	Max
1	0.33	0.34	0.05	0.49
2	0.57	0.57	0.46	0.67
3	0.71	0.71	0.62	0.80
4	0.86	0.85	0.77	1.00

Note: Leverage is calculated as in Rajan & Zingales (1995): (short + long-term debt)/ (total debt + equity + non-tax reserves)

Table 5 - Estimation results without debt variable

Dep. variable: $\Delta r_{i,t}$	OLS	Within	GMM	OLS	Within	GMM
$\Delta r_{i,t-1}$	-0.422***	-0.850***	-0.636***	-0.430***	-0.870***	-0.340***
	(0.017)	(0.021)	(0.041)	(0.019)	(0.024)	(0.054)
$\Delta y_{i,t}$	0.293***	0.215**	-0.041	0.234***	0.085	0.061
	(0.081)	(0.095)	(0.165)	(0.081)	(0.107)	(0.229)
$\Delta y_{i,t-1}$	0.273***	0.343***	0.235***	0.253***	0.338***	0.086
	(0.080)	(0.110)	(0.076)	(0.094)	(0.126)	(0.081)
$\Pi_{i,t}/k_{i,t-1}$	-0.013	0.053	-0.038	0.055	0.087	0.047
	(0.054)	(0.066)	(0.072)	(0.064)	(0.089)	(0.097)
$\Pi_{i,t-1}/k_{i,t-2}$	0.077**	0.050	0.086**	0.106***	0.102	0.136***
	(0.047)	(0.056)	(0.040)	(0.065)	(0.071)	(0.052)
$\Pi_{i,t-2}/k_{i,t-3}$				-0.104***	-0.087	-0.109***
				(0.047)	(0.059)	(0.019)
$(r_{i,t-2} - y_{i,t-2})$	-0.185***	-0.850***	-0.179***	-0.179***	-0.891***	-0.097***
	(0.013)	(0.027)	(0.046)	(0.014)	(0.032)	(0.042)
$y_{i,t-2}$	-0.104***	-0.530***	-0.071	-0.109***	-0.524***	-0.029
	(0.014)	(0.108)	(0.046)	(0.016)	(0.136)	(0.039)
Observations	3003	3003	3003	2455	2455	2455
Firms	743	743	743	679	679	679
Instruments			126			117
AR(1)			0.000			0.000
AR(2)			0.000			0.423
Sargan(p)			0.000			0.000
Hansen(p)			0.116			0.164
Long run Sales	0.438***	0.376***	0.603	0.391***	0.412**	0.701
Long run Π	0.348	0.194	0.676	0.523	0.195	2.552

Note: All specification are performed including time dummies.
Robust standard errors in parenthesis. ***, **, * indicate significance at 1, 5, and 10 percent respectively.
GMM two-step estimates
Instruments for GMM: They range from t-2 to t-4, i.e. all variables are instrumented at one and two lags back in time. For differenced equations instruments used are t-1 for level equations.
The AR-tests are asymptotically normally distributed under the null hypothesis of no serial correlation.
Both Sargan and Hansen are chi-square distributed under the null of exogenous instruments. (A) is the long run elasticity of sales calculated by using the estimated coefficients: $1 - (y_{i,t-2}/(r_{i,t-2} - y_{i,t-2})$. (B) is the long run elasticity of cash flow or profits calculated by using the estimated coefficients: $-(\sum_{j=0}^{2} \Pi_{i,t-j} \div k_{i,t-j-1})/(r_{i,t-2} - y_{i,t-2})$, see Mulkaly et al (2001, p. 8) for presentation of these elasticities. In both (A) and (B) a Wald (F-distribution) test is conducted under the null hypothesis that in (A) the sum of sales coefficients sum to zero and in (B) that the cash flow coefficients sum to zero. Significant results indicate joint significance.

Table 6 - Estimation results with R&D as dependent variable experimenting with the lagged output variable, i.e. the assumption of constant returns to scale

Dep. variable: $\Delta r_{i,t}$	OLS	Within	GMM	OLS	Within	GMM
$\Delta r_{i,t-1}$	-0.422***	-0.850***	-0.636***	-0.398***	-0.839***	-0.679***
	(0.017)	(0.021)	(0.041)	(0.018)	(0.021)	(0.050)
$\Delta y_{i,t}$	0.293***	0.215**	-0.041	0.282***	0.418***	-0.104
	(0.081)	(0.095)	(0.165)	(0.081)	(0.085)	(0.203)
$\Delta y_{i,t-1}$	0.273***	0.343***	0.235***	0.271***	0.677***	0.397***
	(0.080)	(0.110)	(0.076)	(0.081)	(0.086)	(0.093)
$\Pi_{i,t}/k_{i,t-1}$	-0.013	0.053	-0.038	0.049	0.052	0.034
	(0.054)	(0.066)	(0.072)	(0.053)	(0.066)	(0.077)
$\Pi_{i,t-1}/k_{i,t-2}$	0.077**	0.050	0.086**	0.108**	0.049	0.077*
	(0.047)	(0.056)	(0.040)	(0.047)	(0.056)	(0.040)
$(r_{i,t-2} - y_{i,t-2})$	-0.185***	-0.850***	-0.179***	-0.142***	-0.826***	-0.214***
	(0.013)	(0.027)	(0.046)	(0.011)	(0.027)	(0.046)
$y_{i,t-2}$	-0.104***	-0.530***	-0.071			
	(0.014)	(0.108)	(0.046)			
Observations	3003	3003	3003	3003	3003	3003
Firms	743	743	743	743	743	743
R-Square	0.17	0.12		0.16	0.09	
Instruments			126			102
AR(1)			0.000			0.000
AR(2)			0.000			0.000
Sargan(p)			0.000			0.000
Hansen(p)			0.116			0.206
Long run Sales (A)	0.438***	0.376***	0.603			
Long run Π (B)	0.348	0.194	0.676	1.106	0.122	0.519

Note: All specification are performed including time dummies.
Robust standard errors in parenthesis. ***, **, * indicate significance at 1, 5, and 10 percent respectively.
GMM two-step estimates
Instruments for GMM: They range from t-2 to t-4, i.e. all variables are instrumented at one and two lags back in time. For differenced equations instruments used are t-1 for level equations.
The AR-tests are asymptotically normally distributed under the null hypothesis of no serial correlation.
Both Sargan and Hansen are chi-square distributed under the null of exogenous instruments. (A) is the long run elasticity of sales calculated by using the estimated coefficients: $1 - (y_{i,t-2}/(r_{i,t-2} - y_{i,t-2})$. (B) is the long run elasticity of cash flow or profits calculated by using the estimated coefficients: $-(\sum_{j=0}^{2} \Pi_{i,t-j} \div k_{i,t-j-1})/(r_{i,t-2} - y_{i,t-2})$, see Mulkaly et al (2001, p. 8) for presentation of these elasticities. In both (A) and (B) a Wald (F-distribution) test is conducted under the null hypothesis that in (A) the sum of sales coefficients sum to zero and in (B) that the cash flow coefficients sum to zero. Significant results indicate joint significance.

Table 7 - Estimation results with capital investment as dependent variable experimenting with the lagged output variable, i.e. the assumption of constant returns to scale

Dep. variable: $I_{i,t}/k_{i,t-1}$	OLS	Within	GMM	OLS	Within	GMM
$I_{i,t-1}/k_{i,t-2}$	-0.026**	-0.299***	-0.046***	-0.027**	-0.287***	-0.029***
	(0.012)	(0.013)	(0.008)	(0.012)	(0.013)	(0.008)
$\Delta y_{i,t}$	0.294***	0.207***	0.262***	0.289***	0.331***	0.286***
	(0.037)	(0.042)	(0.076)	(0.037)	(0.039)	(0.100)
$\Delta y_{i,t-1}$	0.239***	0.225***	0.285***	0.229***	0.443***	0.215***
	(0.040)	(0.052)	(0.029)	(0.040)	(0.045)	(0.031)
$\Pi_{i,t}/k_{i,t-1}$	0.200***	0.159***	0.051	0.187***	0.179***	0.015
	(0.021)	(0.024)	(0.042)	(0.021)	(0.024)	(0.051)
$\Pi_{i,t-1}/k_{i,t-2}$	0.130***	0.144***	0.179***	0.122***	0.162***	0.180***
	(0.019)	(0.021)	(0.021)	(0.019)	(0.021)	(0.024)
$(k_{i,t-2} - y_{i,t-2})$	-0.139***	-0.793***	-0.189***	-0.143***	-0.734***	-0.158***
	(0.011)	(0.031)	(0.023)	(0.012)	(0.030)	(0.026)
$y_{i,t-2}$	0.022***	-0.401***	0.068***			
	(0.007)	(0.049)	(0.016)			
Observations	6322	6322	6322	6322	6322	6322
Firms	1082	1082	1082	1082	1082	1082
R-Square	0.12	0.09		0.12	0.07	
Instruments			137			110
AR(1)			0.060			0.058
AR(2)			0.486			0.820
Sargan(p)			0.000			0.000
Hansen(p)			0.758			0.289
Long run Sales (A)	0.842***	0.494***	1.217***			
Long run Π (B)	2.374***	0.382***	0.970***	2.161***	0.465***	1.234***

Note: All specification are performed including time dummies.
Robust standard errors in parenthesis. ***, **, * indicate significance at 1, 5, and 10 percent respectively.
GMM two-step estimates
Instruments for GMM: They range from t-2 to t-4, i.e. all variables are instrumented at one and two lags back in time. For differenced equations instruments used are t-1 for level equations.
The AR-tests are asymptotically normally distributed under the null hypothesis of no serial correlation.
Both Sargan and Hansen are chi-square distributed under the null of exogenous instruments. (A) is the long run elasticity of sales calculated by using the estimated coefficients: $1 - (y_{i,t-2}/(r_{i,t-2} - y_{i,t-2})$. (B) is the long run elasticity of cash flow or profits calculated by using the estimated coefficients: $-(\sum_{j=0}^{2} \Pi_{i,t-j} \div k_{i,t-j-1})/(r_{i,t-2} - y_{i,t-2})$, see Mulkaly et al (2001, p. 8) for presentation of these elasticities. In both (A) and (B) a Wald (F-distribution) test is conducted under the null hypothesis that in (A) the sum of sales coefficients sum to zero and in (B) that the cash flow coefficients sum to zero. Significant results indicate joint significance.

Table 8 - Estimation results with homogeneous debt and quadratic homogeneous debt, and debt interacted with leverage and quadratic leverage

Dep. variable: $\Delta r_{i,t}$	OLS	Within	GMM	OLS	Within	GMM
$\Delta r_{i,t-1}$	-0.422***	-0.849***	-0.734***	-0.422***	-0.849***	-0.725***
	(0.018)	(0.021)	(0.024)	(0.018)	(0.021)	(0.024)
$\Delta y_{i,t}$	0.296***	0.218**	0.093	0.296***	0.218***	0.129**
	(0.081)	(0.095)	(0.071)	(0.082)	(0.095)	(0.064)
$\Delta y_{i,t-1}$	0.275***	0.346**	0.224***	0.275***	0.345**	0.221***
	(0.081)	(0.110)	(0.060)	(0.081)	(0.110)	(0.058)
$\Pi_{i,t}/k_{i,t-1}$	-0.013	0.051	0.015	-0.013	0.052	0.040
	(0.054)	(0.066)	(0.039)	(0.054)	(0.066)	(0.042)
$\Pi_{i,t-1}/k_{i,t-2}$	0.077	0.051	0.111***	0.077	0.050	0.095***
	(0.047)	(0.056)	(0.031)	(0.047)	(0.056)	(0.030)
$(r_{i,t-2} - y_{i,t-2})$	-0.185***	-0.850***	-0.256***	-0.185***	-0.850***	-0.260***
	(0.013)	(0.027)	(0.031)	(0.013)	(0.027)	(0.029)
$y_{i,t-2}$	-0.105***	-0.530***	-0.135***	-0.105***	-0.529***	-0.125***
	(0.014)	(0.108)	(0.035)	(0.014)	(0.109)	(0.034)
$\Delta LD_{i,t-1}/k_{i,t-2}{*}Lev_{i,t-2}$				0.004	-0.002	-0.008
				(0.018)	(0.019)	(0.009)
$(\Delta LD_{i,t-1}/k_{i,t-2} * Lev_{i,t-2})^2$				-0.000	-0.000	-0.000
				(0.001)	(0.001)	(0.000)
$\Delta LD_{i,t-1}/k_{i,t-2}$	0.001	-0.004	-0.003			
	(0.012)	(0.013)	(0.006)			
$(\Delta LD_{i,t-1}/k_{i,t-2})^2$	-0.000	-0.000	0.000			
	(0.000)	(0.001)	(0.000)			
Observations	3003	3003	3003	3003	3003	3003
Firms	743	743	743	743	743	743
Instruments			176			174
AR(1)			0.000			0.000
AR(2)			0.000			0.000
Sargan(p)			0.000			0.000
Hansen(p)			0.191			0.173
Long run Sales (A)	0.432***	0.376***	0.473***	0.432***	0.376***	0.519***
Long run Π (B)	0.346	0.120	0.492***	0.346	0.120	0.279***

Note: All specification are performed including time dummies.
Robust standard errors in parenthesis. ***, **, * indicate significance at 1, 5, and 10 percent respectively.
GMM two-step estimates
Instruments for GMM: They range from t-2 to t-4, i.e. all variables are instrumented at one and two lags back in time. For differenced equations instruments used are t-1 for level equations.
The AR-tests are asymptotically normally distributed under the null hypothesis of no serial correlation.
Both Sargan and Hansen are chi-square distributed under the null of exogenous instruments. (A) is the long run elasticity of sales calculated by using the estimated coefficients: $1-(y_{i,t-2}/(r_{i,t-2}-y_{i,t-2})$. (B) is the long run elasticity of cash flow or profits calculated by using the estimated coefficients: $-(\sum_{j=0}^{2}\Pi_{i,t-j} \div k_{i,t-j-1})/(r_{i,t-2}-y_{i,t-2})$, see Mulkaly et al (2001, p. 8) for presentation of these elasticities. In both (A) and (B) a Wald (F-distribution) test is conducted under the null hypothesis that in (A) the sum of sales coefficients sum to zero and in (B) that the cash flow coefficients sum to zero. Significant results indicate joint significance.

Table 9 - Estimation results with debt divided into sub-classes

Dep. variable: $\Delta r_{i,t}$	OLS	Within	GMM	OLS	Within	GMM
$\Delta r_{i,t-1}$	-0.422***	-0.849***	-0.609***	-0.430***	-0.869***	-0.448***
	(0.018)	(0.021)	(0.017)	(0.018)	(0.024)	(0.027)
$\Delta y_{i,t}$	0.300***	0.220**	0.264***	0.239***	0.090	0.301***
	(0.081)	(0.095)	(0.071)	(0.093)	(0.108)	(0.085)
$\Delta y_{i,t-1}$	0.282***	0.353***	0.213***	0.260***	0.350***	0.148**
	(0.080)	(0.111)	(0.059)	(0.094)	(0.127)	(0.063)
$\Pi_{i,t}/k_{i,t-1}$	-0.014	0.051	-0.004	0.057	0.083	0.080**
	(0.054)	(0.066)	(0.032)	(0.064)	(0.090)	(0.038)
$\Pi_{i,t-1}/k_{i,t-2}$	0.080*	0.053	0.133***	0.110*	0.103	0.136***
	(0.047)	(0.056)	(0.020)	(0.065)	(0.071)	(0.021)
$\Pi_{i,t-2}/k_{i,t-3}$				-0.105**	-0.088	-0.078***
				(0.047)	(0.059)	(0.010)
$(r_{i,t-2} - y_{i,t-2})$	-0.184***	-0.849***	-0.258***	-0.179***	-0.891***	-0.182***
	(0.013)	(0.027)	(0.027)	(0.014)	(0.031)	(0.025)
$y_{i,t-2}$	-0.105***	-0.527***	-0.133***	-0.108***	-0.512***	-0.106***
	(0.014)	(0.109)	(0.034)	(0.016)	(0.137)	(0.030)
$\Delta LD_{i,t-1}/k_{i,t-2}$	-0.052	-0.035	-0.057***	-0.061	-0.041	-0.004
	(0.040)	(0.041)	(0.020)	(0.053)	(0.057)	(0.027)
$\Delta LD_{i,t-1}/k_{i,t-2}$*C2	0.053	0.039	0.173***	0.034	0.011	0.082**
	(0.052)	(0.053)	(0.034)	(0.064)	(0.067)	(0.038)
$\Delta LD_{i,t-1}/k_{i,t-2}$*C3	0.056	0.038	0.056***	0.063	0.041	0.002
	(0.041)	(0.043)	(0.021)	(0.054)	(0.059)	(0.028)
$\Delta LD_{i,t-1}/k_{i,t-2}$*C4	0.066	0.032	0.041	0.072	0.045	-0.021
	(0.046)	(0.048)	(0.027)	(0.060)	(0.065)	(0.032)
Observations	3003	3003	3003	2455	2455	2455
Firms	743	743	743	679	679	679
Instruments			224			214
AR(1)			0.000			0.000
AR(2)			0.000			0.064
Sargan(p)			0.000			0.000
Hansen(p)			0.197			0.107
Long run Sales	0.429***	0.379***	0.484***	0.397***	0.425**	0.418***
Long run Π	0.359	0.197	0.970***	0.546	0.191	1.302***

Note: All specification are performed including time dummies.
Robust standard errors in parenthesis. ***, **, * indicate significance at 1, 5, and 10 percent respectively.
GMM two-step estimates
Instruments for GMM: They range from t-2 to t-4, i.e. all variables are instrumented at one and two lags back in time. For differenced equations instruments used are t-1 for level equations.
The AR-tests are asymptotically normally distributed under the null hypothesis of no serial correlation.
Both Sargan and Hansen are chi-square distributed under the null of exogenous instruments. (A) is the long run elasticity of sales calculated by using the estimated coefficients: $1-(y_{i,t-2}/(r_{i,t-2}-y_{i,t-2})$. (B) is the long run elasticity of cash flow or profits calculated by using the estimated coefficients: $-(\sum_{j=0}^{2}\Pi_{i,t-j} \div k_{i,t-j-1})/(r_{i,t-2}-y_{i,t-2})$, see Mulkaly et al (2001, p. 8) for presentation of these elasticities. In both (A) and (B) a Wald (F-distribution) test is conducted under the null hypothesis that in (A) the sum of sales coefficients sum to zero and in (B) that the cash flow coefficients sum to zero. Significant results indicate joint significance.

Table 10 - Estimation results with capital investment as dependent variable and with debt divided into sub-classes based on the R&D firms

Dep. variable: $I_{i,t}/k_{i,t-1}$	OLS	Within	GMM	OLS	Within	GMM
$I_{i,t-1}/k_{i,t-2}$	-0.026**	-0.299***	-0.046***	-0.038***	-0.309***	-0.103***
	(0.012)	(0.013)	(0.008)	(0.013)	(0.014)	(0.006)
$\Delta y_{i,t}$	0.294***	0.207***	0.262***	0.302***	0.214***	0.414***
	(0.037)	(0.042)	(0.076)	(0.037)	(0.042)	(0.044)
$\Delta y_{i,t-1}$	0.239***	0.225***	0.285***	0.252***	0.241***	0.320***
	(0.040)	(0.052)	(0.029)	(0.040)	(0.052)	(0.023)
$\Pi_{i,t}/k_{i,t-1}$	0.200***	0.159***	0.051	0.200***	0.155***	-0.293***
	(0.021)	(0.024)	(0.042)	(0.022)	(0.024)	(0.019)
$\Pi_{i,t-1}/k_{i,t-2}$	0.130***	0.144***	0.179***	0.135***	0.146***	0.319***
	(0.019)	(0.021)	(0.021)	(0.019)	(0.021)	(0.013)
$(k_{i,t-2} - y_{i,t-2})$	-0.139***	-0.793***	-0.189***	-0.140***	-0.797***	-0.244***
	(0.011)	(0.031)	(0.023)	(0.012)	(0.031)	(0.015)
$y_{i,t-2}$	0.022***	-0.401***	0.068***	0.023***	-0.399***	0.020*
	(0.007)	(0.049)	(0.016)	(0.007)	(0.049)	(0.012)
$\Delta LD_{i,t-1}/k_{i,t-2}$				-0.014	-0.021	-0.092***
				(0.014)	(0.015)	(0.010)
$\Delta LD_{i,t-1}/k_{i,t-2}$*C2				-0.026	0.006	0.215***
				(0.024)	(0.025)	(0.013)
$\Delta LD_{i,t-1}/k_{i,t-2}$*C3				0.034**	0.042	0.009***
				(0.016)	(0.017)	(0.011)
$\Delta LD_{i,t-1}/k_{i,t-2}$*C4				-0.001	-0.009	0.026***
				(0.019)	(0.020)	(0.009)
Observations	6322	6322	6322	6322	6322	6322
Firms	1082	1082	1082	1082	1082	1082
Instruments			137			242
AR(1)			0.060			0.032
AR(2)			0.486			0.794
Sargan(p)			0.000			0.000
Hansen(p)			0.758			0.437
Long run Sales	0.842***	0.494***	1.217***	0.834***	0.499***	0.918***
Long run Π	2.374***	0.382***	0.970***	2.393***	0.378***	0.107*

Note: All specification are performed including time dummies.
Robust standard errors in parenthesis. ***, **, * indicate significance at 1, 5, and 10 percent respectively.
GMM two-step estimates
Instruments for GMM: They range from t-2 to t-4, i.e. all variables are instrumented at one and two lags back in time. For differenced equations instruments used are t-1 for level equations.
The AR-tests are asymptotically normally distributed under the null hypothesis of no serial correlation.
Both Sargan and Hansen are chi-square distributed under the null of exogenous instruments. (A) is the long run elasticity of sales calculated by using the estimated coefficients: $1 - (y_{i,t-2}/(r_{i,t-2} - y_{i,t-2})$. (B) is the long run elasticity of cash flow or profits calculated by using the estimated coefficients: $-(\sum_{j=0}^{2} \Pi_{i,t-j} \div k_{i,t-j-1})/(r_{i,t-2} - y_{i,t-2})$, see Mulkaly et al (2001, p. 8) for presentation of these elasticities. In both (A) and (B) a Wald (F-distribution) test is conducted under the null hypothesis that in (A) the sum of sales coefficients sum to zero and in (B) that the cash flow coefficients sum to zero. Significant results indicate joint significance.

Table 11 – Comparison of error correction estimation results on fixed capital investment from two sources

Dep. variable: $I_{i,t}/k_{i,t-1}$	US	France	UK	Germany	Belgium	France small	Sweden
$I_{i,t-1}/k_{i,t-2}$	-0.255	-0.205	-0.015	-0.096	0.003	-0.034	-0.046
	(0.101)	(0.106)	(0.049)	(0.075)	(0.053)	(0.067)	(0.067)
$\Delta y_{i,t}$	0.163	0.177	0.179	0.017	0.189	0.155	0.262
	(0.056)	(0.086)	(0.065)	(0.036)	(0.073)	(0.046)	(0.076)
$\Pi_{i,t}/k_{i,t-1}$	-0.114	-0.197	0.520	0.180	-0.055	-0.048	0.051
	(0.074)	(0.079)	(0.168)	(0.071)	(0.087)	(0.069)	(0.042)
$(k_{i,t-2} - y_{i,t-2})$	-0.245	-0.210	-0.071	-0.134	-0.216	-0.195	-0.189
	(0.058)	(0.058)	(0.038)	(0.039)	(0.047)	(0.049)	(0.023)
Observations	4338	4374	4036	1797	2571	2544	6322
Employment	19914	1446	6342	6944	777	214	273

Note: Column 2 and 3 are compiled from Mairesse et al (1999) and column 4 and 7 are compiled from Bond et al (2003b). Column 8 for Sweden are the results from table 9. The Mairesse et al (1999) and Bond et al (2003a) results are estimated with first difference GMM. Employment in column 2 and 3 correspond to average employment 1985-1993, column 4-7 to average employment 1985, and column 8 to average employment 1992-2000.

Table 12- Estimation results with debt divided into sub-classes based on the R&D firms, one lag of cash flow – The first three columns are estimations results for OECD sectors 1 and 2 and the last three columns are estimation results for OECD sectors 3, 4 and 5.

Dep. variable: $\Delta r_{i,t}$	OLS	Within	GMM	OLS	Within	GMM
$\Delta r_{i,t-1}$	-0.368***	-0.799***	-0.506***	-0.456***	-0.887***	-0.726***
	(0.030)	(0.038)	(0.002)	(0.023)	(0.026)	(0.017)
$\Delta y_{i,t}$	0.506***	0.249	0.415***	0.259***	0.152	0.369***
	(0.151)	(0.174)	(0.007)	(0.099)	(0.117)	(0.073)
$\Delta y_{i,t-1}$	0.290**	0.320	0.504***	0.259***	0.287**	0.223***
	(0.150)	(0.194)	(0.011)	(0.099)	(0.139)	(0.046)
$\Pi_{i,t}/k_{i,t-1}$	0.023	0.064	-0.177***	-0.026	0.042	-0.160***
	(0.089)	(0.108)	(0.003)	(0.068)	(0.087)	(0.021)
$\Pi_{i,t-1}/k_{i,t-2}$	0.045	0.049	0.179***	0.060	0.080	0.102***
	(0.084)	(0.106)	(0.004)	(0.062)	(0.076)	(0.019)
$(r_{i,t-2} - y_{i,t-2})$	-0.117***	-0.749***	-0.291***	-0.235***	-0.916***	-0.375***
	(0.019)	(0.050)	(0.003)	(0.018)	(0.034)	(0.021)
$y_{i,t-2}$	-0.056***	-0.542***	-0.189***	-0.151***	-0.623***	-0.270***
	(0.021)	(0.191)	(0.005)	(0.020)	(0.137)	(0.021)
$\Delta LD_{i,t-1}/k_{i,t-2}$	-0.018	-0.015	-0.092***	-0.123*	-0.073	0.134***
	(0.048)	(0.050)	(0.001)	(0.067)	(0.069)	(0.025)
$\Delta LD_{i,t-1}/k_{i,t-2}$*C2	0.014	0.010	0.079***	0.141	0.093	0.051
	(0.062)	(0.062)	(0.002)	(0.089)	(0.092)	(0.042)
$\Delta LD_{i,t-1}/k_{i,t-2}$*C3	0.026	0.021	0.100***	0.124	0.041	-0.147***
	(0.050)	(0.052)	(0.002)	(0.073)	(0.078)	(0.029)
$\Delta LD_{i,t-1}/k_{i,t-2}$*C4	0.058	0.015	0.074***	0.118	0.065	-0.096***
	(0.060)	(0.065)	(0.002)	(0.073)	(0.076)	(0.038)
Observations	1055	1055	1055	1891	1891	1891
Firms	285	285	285	458	458	458
Instruments			224			218
AR(1)			0.000			0.000
AR(2)			0.627			0.000
Sargan(p)			0.000			0.000
Hansen(p)			0.379			0.772
Long run Sales	0.521***	0.276*	0.351***	0.357***	0.320**	0.280***
Long run Π	0.581	0.151	0.007	0.145	0.133	-0.155**

Note: All specification are performed including time dummies.
Robust standard errors in parenthesis. ***, **, * indicate significance at 1, 5, and 10 percent respectively.
GMM two-step estimates
Instruments for GMM: They range from t-2 to t-4, i.e. all variables are instrumented at one and two lags back in time. For differenced equations instruments used are t-1 for level equations.
The AR-tests are asymptotically normally distributed under the null hypothesis of no serial correlation.
Both Sargan and Hansen are chi-square distributed under the null of exogenous instruments. (A) is the long run elasticity of sales calculated by using the estimated coefficients: $1-(y_{i,t-2}/(r_{i,t-2}-y_{i,t-2})$. (B) is the long run elasticity of cash flow or profits calculated by using the estimated coefficients: $-(\sum_{j=0}^{2}\Pi_{i,t-j} \div k_{i,t-j-1})/(r_{i,t-2}-y_{i,t-2})$, see Mulkaly et al (2001, p. 8) for presentation of these elasticities. In both (A) and (B) a Wald (F-distribution) test is conducted under the null hypothesis that in (A) the sum of sales coefficients sum to zero and in (B) that the cash flow coefficients sum to zero. Significant results indicate joint significance.

Table 13- Estimation results with debt divided into sub-classes based on the R&D firms, two lags of cash flow – The first three columns are estimations results for OECD sectors 1 and 2 and the last three columns are estimation results for OECD sectors 3, 4 and 5.

Dep. variable: $\Delta r_{i,t}$	OLS	Within	GMM	OLS	Within	GMM
$\Delta r_{i,t-1}$	-0.369***	-0.851***	-0.504***	-0.474***	-0.881***	-0.572***
	(0.035)	(0.043)	(0.002)	(0.024)	(0.029)	(0.019)
$\Delta y_{i,t}$	0.361**	0.018	0.464***	0.158	0.065	0.373***
	(0.169)	(0.202)	(0.009)	(0.115)	(0.130)	(0.080)
$\Delta y_{i,t-1}$	0.315*	0.366	0.463***	0.222*	0.279*	0.119**
	(0.173)	(0.231)	(0.006)	(0.115)	(0.157)	(0.049)
$\Pi_{i,t}/k_{i,t-1}$	0.030	0.195	-0.181***	0.065	0.041	0.029
	(0.102)	(0.207)	(0.006)	(0.084)	(0.103)	(0.019)
$\Pi_{i,t-1}/k_{i,t-2}$	0.089	0.063	0.165***	0.106	0.117	0.104***
	(0.122)	(0.130)	(0.005)	(0.080)	(0.089)	(0.015)
$\Pi_{i,t-2}/k_{i,t-3}$	-0.065	-0.001	-0.094***	-0.114*	-0.108	-0.102***
	(0.075)	(0.121)	(0.001)	(0.062)	(0.071)	(0.012)
$(r_{i,t-2} - y_{i,t-2})$	-0.121***	-0.826***	-0.275***	-0.231***	-0.922***	-0.305***
	(0.022)	(0.058)	(0.003)	(0.020)	(0.040)	(0.019)
$y_{i,t-2}$	-0.065***	-0.447*	-0.197***	-0.154***	-0.632***	-0.248***
	(0.025)	(0.252)	(0.006)	(0.022)	(0.170)	(0.021)
$\Delta LD_{i,t-1}/k_{i,t-2}$	-0.030	-0.012	-0.172***	-0.088	-0.059	0.109***
	(0.081)	(0.091)	(0.002)	(0.070)	(0.075)	(0.016)
$\Delta LD_{i,t-1}/k_{i,t-2}$*C2	0.019	-0.002	0.153***	0.034	-0.022	-0.052**
	(0.090)	(0.097)	(0.003)	(0.095)	(0.101)	(0.027)
$\Delta LD_{i,t-1}/k_{i,t-2}$*C3	0.037	0.015	0.180***	0.065	0.011	-0.133***
	(0.082)	(0.093)	(0.002)	(0.081)	(0.090)	(0.029)
$\Delta LD_{i,t-1}/k_{i,t-2}$*C4	0.030	0.020	0.163***	0.103	0.053	-0.090***
	(0.092)	(0.103)	(0.002)	(0.078)	(0.084)	(0.031)
Observations	850	850	850	1540	1540	1540
Firms	258	228	215	413	413	413
Instruments			224			212
AR(1)			0.000			0.000
AR(2)			0.889			0.001
Sargan(p)			0.000			0.000
Hansen(p)			0.418			0.497
Long run Sales (A)	0.463***	0.459	0.284***	0.333***	0.315***	0.187***
Long run Π (B)	0.446	0.257	-0.400***	0.247	0.054	0.102

Note: All specification are performed including time dummies.
Robust standard errors in parenthesis. ***, **, * indicate significance at 1, 5, and 10 percent respectively.
GMM two-step estimates
Instruments for GMM: They range from t-2 to t-4, i.e. all variables are instrumented at one and two lags back in time. For differenced equations instruments used are t-1 for level equations.
The AR-tests are asymptotically normally distributed under the null hypothesis of no serial correlation.
Both Sargan and Hansen are chi-square distributed under the null of exogenous instruments. (A) is the long run elasticity of sales calculated by using the estimated coefficients: $1-(y_{i,t-2}/(r_{i,t-2}-y_{i,t-2})$. (B) is the long run elasticity of cash flow or profits calculated by using the estimated coefficients: $-(\sum_{j=0}^{2}\Pi_{i,t-j} \div k_{i,t-j-1})/(r_{i,t-2}-y_{i,t-2})$, see Mulkaly et al (2001, p. 8) for presentation of these elasticities. In both (A) and (B) a Wald (F-distribution) test is conducted under the null hypothesis that in (A) the sum of sales coefficients sum to zero and in (B) that the cash flow coefficients sum to zero. Significant results indicate joint significance.

Table 14 – Comparison of the main results with additional system GMM-estimation varieties and with collapsed GMM matrix

Dep. variable: $\Delta r_{i,t}$	(1)	(2)	(3)	(4)	(5)	(6)
$\Delta r_{i,t-1}$	-0.448***	-0.326***	-0.448***	-0.326**	-0.492***	-0.326**
	(0.027)	(0.078)	(0.078)	(0.146)	(0.078)	(0.148)
$\Delta y_{i,t}$	0.301***	-0.073	0.301	-0.073	0.334	0.334
	(0.085)	(0.414)	(0.307)	(0.093)	(0.253)	(0.643)
$\Delta y_{i,t-1}$	0.148**	0.102	0.148	0.102	0.249**	0.115
	(0.063)	(0.126)	(0.136)	(0.155)	(0.114)	(0.152)
$\Pi_{i,t}/k_{i,t-1}$	0.080**	0.096	0.080	0.097	0.058	0.050
	(0.038)	(0.121)	(0.207)	(0.252)	(0.170)	(0.315)
$\Pi_{i,t-1}/k_{i,t-2}$	0.136***	0.32	0.136	0.032	0.111	0.062
	(0.021)	(0.058)	(0.091)	(0.142)	(0.112)	(0.168)
$\Pi_{i,t-2}/k_{i,t-3}$	-0.078***	-0.113***	-0.078	-0.113**	-0.081	-0.136**
	(0.010)	(0.036)	(0.068)	(0.059)	(0.075)	(0.0069)
$(r_{i,t-2} - y_{i,t-2})$	-0.182***	-0.042	-0.182***	-0.042	-0.249***	-0.107
	(0.025)	(0.087)	(0.063)	(0.109)	(0.057)	(0.112)
$y_{i,t-2}$	-0.106***	-0.064	-0.106*	-0.064	-0.150***	-0.169*
	(0.030)	(0.082)	(0.060)	(0.107)	(0.054)	(0.102)
$\Delta LD_{i,t-1}/k_{i,t-2}$	-0.004	-0.007	-0.004	-0.007	-0.033	-0.059
	(0.027)	(0.093)	(0.113)	(0.129)	(0.046)	(0.182)
$\Delta LD_{i,t-1}/k_{i,t-2}$*C2	0.082**	0.094	0.082	0.094	0.104	0.148
	(0.038)	(0.142)	(0.154)	(0.167)	(0.130)	(0.232)
$\Delta LD_{i,t-1}/k_{i,t-2}$*C3	0.002	0.011	0.002	0.011	0.003	0.063
	(0.028)	(0.095)	(0.114)	(0.133)	(0.098)	(0.187)
$\Delta LD_{i,t-1}/k_{i,t-2}$*C4	-0.021	0.007	-0.021	0.007	0.012	0.071
	(0.032)	(0.133)	(0.131)	(0.169)	(0.119)	(0.230)
Observations	2455	2455	2455	2455	2455	2455
Firms	679	679	679	679	679	679
Instruments	214	66	214	66	214	66
AR(1)	0.000	0.000	0.000	0.000	0.000	0.000
AR(2)	0.064	0.425	0.339	0.571	0.416	0.425
Sargan(p)	0.000	0.005	0.000	0.005	0.000	0.005
Hansen(p)	0.107	0.456	0.107	0.456	0.107	0.456
Difference-in-Hansen tests						
GMM instruments levels:						
Hansen test excl. group:	0.137	0.581	0.137	0.581	0.137	0.581
Difference (null H=exog):	0.251	0.286	0.251	0.286	0.251	0.286
iv(time-dummies, eq(level)):						
Hansen test excl. group:	0.115	0.519	0.115	0.519	0.115	0.519
Difference (null H=exog):	0.285	0.258	0.285	0.258	0.285	0.258

Note: All specification are performed including time dummies.
Robust standard errors in parenthesis. ***, **, * indicate significance at 1, 5, and 10 percent respectively.
GMM two-step estimates
Instruments for GMM: They range from t-2 to t-4, i.e. all variables are instrumented at one and two lags back in time. For differenced equations instruments used are t-1 for level equations.
The AR-tests are asymptotically normally distributed under the null hypothesis of no serial correlation.
Both Sargan and Hansen are chi-square distributed under the null of exogenous instruments.

(1) is estimated with 2-step robust standard errors, (2) the same as (1) but the GMM matrix is collapsed, (3) is the 2-step robust Windmeijer corrected standard errors, (4) is the as (3) but the GMM matrix is collapsed, (5) is estimated with 1-step robust standard errors, and (6) is the same as (5) but the GMM matrix is collapsed.

Appendix A – Description of the data

The data come from Statistics Sweden and comprise all firms with a median employment of 50 during the sample period 1992-2000. Each firm is a legal entity and is identified by a unique firm identification number. It is annual balance sheet data containing most of the firm performance measures. The original data base comprises about 40,000 observations. However, about 15,000 of the observations were non-manufacturing firms hence they were excluded. This was done mainly for two reasons. First, in order to be consistent with the studies of Bond et al (2003b) and Mulkaly et al (2001) which only study manufacturing firms. Secondly, results may be biased toward different sectors if services and finance firms were to be included due their vastly different capital structures and capital intensities. Selecting only manufacturing firms the sample was reduced to 25,038 observations over 9 years. I then trimmed the sample for outliers as in Mulkaly et al (2001) for consistency. I trim one percent of each of the key ratios (I/K, K/S, EBIT/K, EAIT/K)[34], so that 0.5 percent of each tail is removed. This procedure reduces the sample size to 23,997 observations.

As a final selection step, in order to apply ordinary econometric techniques I needed a sample of firms which actually do R&D. So, firms need to have at least one observation of positive R&D expenditure. As it turns out most firms are persistent R&D firms since most firms in the sample either do no or persistently conduct R&D investment, the fragment of firms only with few years of R&D are negligible. Also, the sample of R&D firms include firms with long sample history, the average number of observations per firm in the R&D sample is 8.The sample of firms suitable for estimation includes 8,693 observations.

Finally, in the absence of sector or variable specific deflation measures the variables were deflated using the producer price index (PPI) and converting prices into 2000 prices. The values were also converted into US dollars in order to make it easier for international readers. I downloaded all daily spot-prices of SEK/USD during 2000 from www.oanda.com and calculated the mean spot-price for 2000 of 9.1681 SEK/USD.

[34] I/K=Fixed investment divided by capital, K/S=Capital divided by sales, EBIT/K=Earnings before interest and taxes divided by capital and EAIT=Earnings after interest and taxes divided by capital. The capital stock, K, is often computed by the so called permanent or perpetual inventory method (see Mairesse et al (1999), Mulkaly et al (2001), and Bond et al (2003a)). These papers had access to pre-sample history in order to construct a capital stock that way. In this paper the capital stock is simply the gross value of tangible assets reported on the firm balance sheet. In Bond et al (2003a, p. 157) they compared the perpetual inventory computed capital stock with both gross and net value of tangible assets and concludes that *"… our results remained very similar when using these alternative measures"*.

Appendix B – Sub-sectors, the Rajan & Zingales (1998) measure of external dependence and the Bráun (2002) measure of sector tangibility

Table 15- Description of sectors with RZ and tangibility measures

(A)	Manufacturing sectors:	SNI92	RZ (B)	Braun (C)
1	Food	15111-16000	Less	Above
	Leather	19100-19200	Less	Below
	Wood	20101-20520	High	Above
	Pulp	21111-21949	Less	Above
	Petroleum Refineries	23100-23300	Less	Above
	Nonferrous metal	26201-26829	Less	Above
2	Textiles	17110-18300	High	Above
	Leather	19300	Less	Below
	Metal	28100-28759	High	Above
	Other Industries	36100-37200	High	Below
3	Paper products	21200-22330	Less	Above
	Chemicals	24110-24300, 24500, 24700	High	Below
	Rubber	25110-25240	High	Above
	Nonferrous metal	26110-26200	Less	Above
	Metal	27100-27300, 27500	High	Above
	Transportation	34100-35299, 35400-35500	High	Below
4	Machinery	29110-29720	High	Below
	Electric Machinery	31110-31600	High	Below
5	Pharmaceuticals	24440, 24600	High	Below
	Office machinery	30000	High	Below
	Electric machinery	32100-33500	High	Below
	Aircraft transportation	35300	High	Below

Description: (A): The first column indicates the OECD classification sector. (B) indicates if the sector is above (highly dependent on external finance) or below (less) the US median of external finance dependence based on Rajan & Zingales (1998). (C) indicates if the sector is above or below the US median in terms of amounts of tangibility of its assets based on Braun (2002) and Braun & Larraín (2005).

B.1 Rajan & Zingales (1998) sector external finance dependence measure

Rajan & Zingales (1998) calculate the dependence on external finance of US manufacturing industries. Each industry's dependence is calculated by taking (capital expenditures-net cash flow from operations)/capital expenditures. This is conducted for each firm and year over the period 1980-1990. Then they take the average for each firm and present the median firm average as the industry's dependence on external finance (see Rajan & Zingales (1998, pp. 563-565).

The highly and less indications corresponding to each sub-sector is based on the median firm of the U.S. in terms of external finance dependence. Sectors below the median are considered less dependent on external finance and vice versa for highly dependent firms. This is a standard use of the Rajan & Zingales (1998) external finance dependence measure in the literature, see e.g. Aghion et al (2007a), Bráun & Larrain (2005), Fisman & Love (2004), and Ciccone & Papaioannou (2005).

B.2 Bráun (2002) measure of sector tangibility

The description of the Bráun (2002) tangibility measure is gathered from Bráun & Larrain (2005). Basically, Bráun (2002) constructs a measure of each sector's assets' hardness, aggregating asset tangibility figures, which implies net property, plant, and equipment over total assets. This is conducted for publicly traded U.S. firms. The above and below indications of tangibility is based on the U.S. median as described in B.1 for external finance dependence above.

Appendix C – Correlograms

Figure 11 – Correlogram of the natural logarithm of Sales in levels

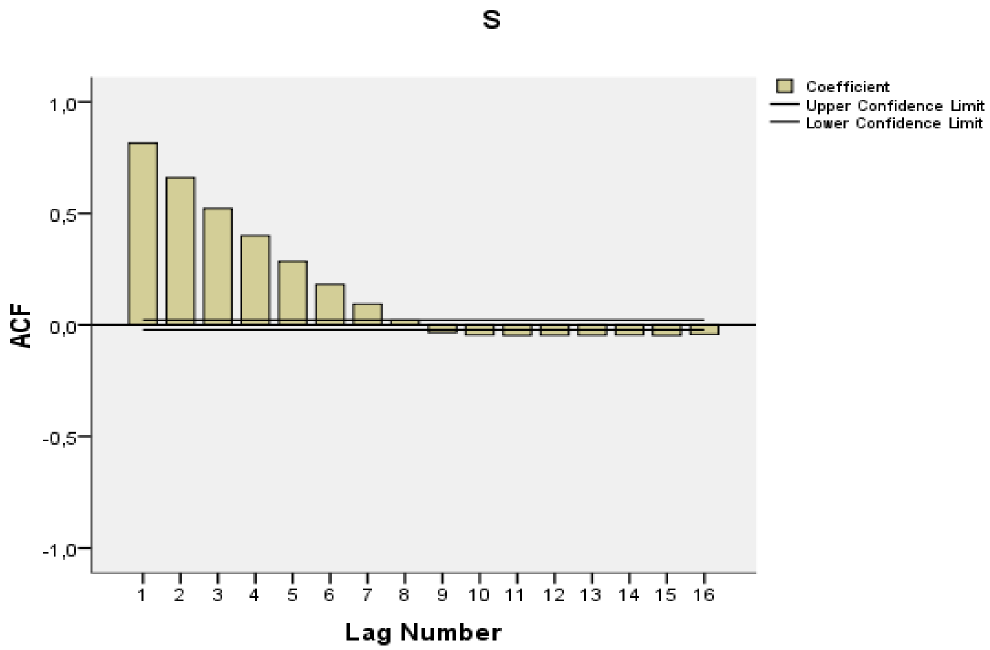

Figure 12 - Correlogram of the natural logarithm of Sales in first differences

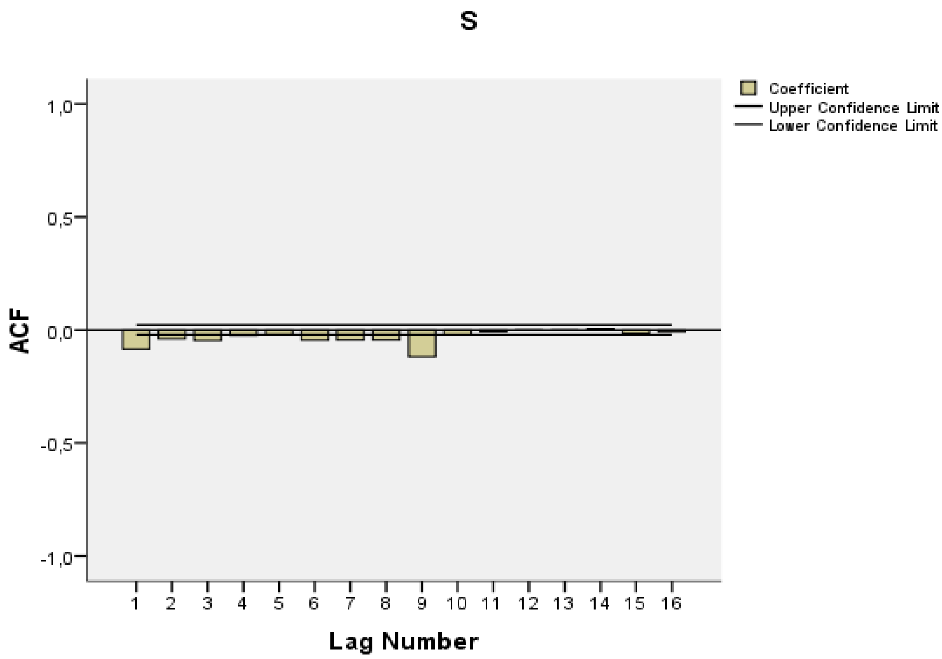

Figure 13 - Correlogram of the natural logarithm of R&D expenditure in levels

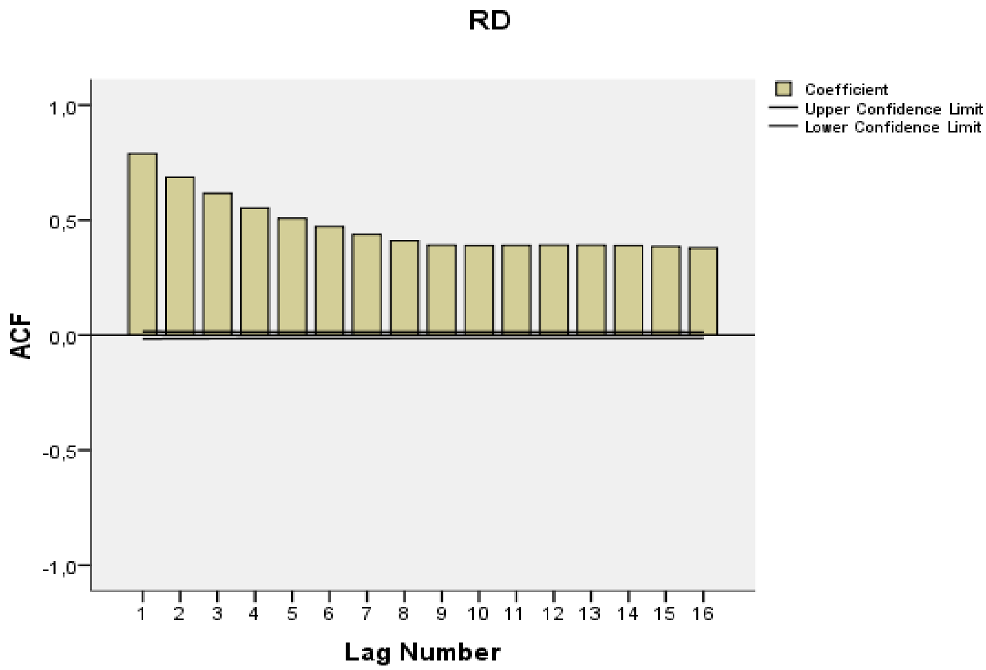

Figure 14 - Correlogram of the natural logarithm of R&D expenditure in first differences