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The Impact of Capital Market Imperfections on Capital and

R&D Investment and Financial Decisions

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Abstract

The aim of this study is to provide more insights into our understanding of several issues pertaining to the evolution of a firms' investment – cash flow sensitivity (ICFS hereafter), the evolution of a firms' research and development (R&D) ICFS and the determinants of a firms' R&D investment over total investment[1] (R&D/TINV) ratio. This thesis uses non-financial US and UK publicly listed firms. Our work consists of a number of important and original aspects that potentially contribute to the literature on capital market imperfections.

The study of the ICFS comprises one of the largest literatures in corporate finance, yet little is known about the ICFS trend over time, and the literature has largely ignored that firms invest simultaneously in two types of investment (capital and R&D) and there is some substitutability between them, thus the two decisions need to be studied together.

Initially we show that over time the ICFS: (i) declines for physical investment, (ii) is negative and increases for R&D, and (iii) is negative and fluctuates around the same level during the pre-crisis period and positive during the financial crisis period for R&D/TINV ratio. We argue that these findings can largely be explained by the changing composition of investment and the rising share of the firms with persistent negative cash flows. Secondly, substantial differences are found between the *a priori* subsamples of financially constrained and unconstrained group of firms and between US and UK firms as well as between pre-crisis and financial crisis periods.

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[1] Total investment is defined as a sum of physical investment plus R&D investment.

Chapter 1

Introduction

The aim of this study is to provide more insights into our understanding of firms' investment decisions, research and development (R&D hereafter) investment decisions and R&D investment-total investment ratio (R&D/TINV hereafter) decisions. Non -financial US and UK publicly listed firms are employed in this thesis. Specifically, 4076 US firms and 1382 UK firms are taken into account. The main firm characteristics employed in this thesis are cash flows, Tobin's Q, cash holdings, leverage, equity and debt issues, size and dividend payments.

Corporate investment is broadly accepted as a vital driver of economic growth and business cycles. Financing investment with costly external resources can have critical impacts on the economy. Financial frictions, through their influence on investment, can slow economic growth and develop business cycles (Aghion et al., 1999). For all measures, understanding the relationship between firms' investments and their financing over time is important.

Given that the irrelevance proposition of financial structure to a firm's value introduced by Modigliani and Miller (1958) holds, firms' investment decisions are independent of financial decisions. Under the assumption of perfect capital markets, there is no wedge between the cost of internal and external funds and external finances provide a perfect substitute for internal capital. The availability of internal capital does not affect investment and growth. All firms can acquire from investors the essential capital to carry out all value-increasing investment opportunities without paying an extra premium. Their responses to changes in the cost of capital or tax-based investment incentives differ only due to differences in the investment demand (Fazzari et al., 1988). Put differently, firms decide how much to invest on the basis of their growth opportunities solely, regardless of the sources of capital. Therefore, the capital expenditures of a firm are completely a function of its investment opportunities where the supply of capital is infinitely elastic. This entails an insignificant relationship between investment expenditures and internal funds.

In contrary, under the assumption of imperfect capital markets, internal and external finances are no longer perfect substitutes. Due to the imperfections of capital market the cost of external finances is relatively higher than the cost of internal finances. Firms are not necessarily able to undertake all the value-increasing investment opportunities available to them anymore. The difference between the costs of internal and external funds is usually explained

as the consequence of the premium on external finances that arise from contracting and information frictions and from agency conflicts between insiders and outside investors. Thus, the cost of external finance is argued to be a function of the extent to which firms are subject to capital market imperfections. Implicitly, firms that suffer from a shortage of internal funds and are affected by the severe informational and agency problems at the same time will be subject to limited access to external finance, this situation will force them to give up some profitable investment opportunities. Firms are not necessarily able to take all value-increasing investment opportunities anymore. These firms are recognized as financially constrained and the availability of internal funds for them becomes crucial for investment.

As shown by the models of Jaffee and Russell (1976) and Stiglitz and Weiss (1981) for the debt market and of Greenwald et al., (1984), Myers (1984) and Myers and Majluf (1984) for the equity market, outside investors do not have as much information about a company as its managers. Even if managers are considered to be acting in the interests of current shareholders, for investors it is very costly, and in some cases even impossible, to assess a firms quality for investment purposes. Thus, the cost of capital raises with agency and asymmetric information problems, and in effect, firms in need of external funds to invest will forego some positive net present value (NPV henceforth) projects (debt or equity rationing). In situations like this the firms' ability to invest is constrained since firms are forced to base their expenditures, not merely on the quality of the growth opportunities, but also on the availability of capital. Consequently this leads some firms to lower their future growth and show a decline in operating performance, this effectively reduces the firm value because even if these firms have attractive growth opportunities they do not have access to fund that allow them to make the optimal number of investments in all their growth opportunities. Consequently, the greater the capital market imperfections, the stronger the sensitivity of investment to internal resources.

However, since the seminal work by Fazzari et al., (1988), the investment research has attempted to document how investment cash flow sensitivity changes as the costs of external finance increase by focusing its attention mostly on the identification of different groups of firms that are more (or less) likely to face higher costs of capital, (see Devereux and Schiantarelli, 1990; Bond and Meghir, 1994; Hoshi et al., 1991; Chirinko and Schaller, 1995; and Elston, 1998).

Firms' cash flow has been used to proxy internal funds in an attempt to examine whether the investment sensitivity to cash flow is a useful measure of financial constraints.

All these theories lay the grounds for the research we conduct in this thesis. Specifically we study the firms' investment and financing behavior under the influence of financing frictions. This thesis is structured as three related analytical chapters that can each be treated separately but which also share some common links. Each of the three analytical chapters addresses a particular aspect of firms' investment decisions. However, the two important aspects of this study, which the analytical chapters are based on, are as follows 1) capital market imperfections make investment decisions difficult; and 2) measures of financial constraints may be wrong.

The first analytical chapter of this thesis analyses the sensitivity of corporate investment to internal cash flow for UK firms over time. This chapter also studies the lack of consensus in the literature regarding the issue of the sensitivity of investment to cash flow for firms with different levels of financial constraint.

There are two schools of thought in the literature regarding investment – cash flow sensitivity. The first one originated by Fazzari et al. (1988) considers investment to be more sensitive to cash flows for financially constrained firms. The second one initiated by Kaplan and Zingales (1997) argues the opposite that investment is more sensitive to cash flow for unconstrained firms. With both theories in mind, chapter two presents a detailed and systematic analysis of the corporate investment cash flow sensitivities (ICFS) over the period 1980 to 2009 for a large sample of non-financial UK listed firms. Then, based on the hypothesis that the sensitivity of investment expenditures of financially constrained firms to the availability of internal funds is higher than that of unconstrained firms, it puts forward several firm characteristics such as size, age to identify financially constrained firms over time.

In our first analytical chapter we attempt to shed light on two important questions. The first question relates to how ICFS changes over time whereas the second question is concerned with how this sensitivity depends on the degree of financing constraints faced by the firm over time. Although the relationship between investment and cash flow has found a prominent place in the literature on corporate finance and the importance of the link has been extensively

investigated by many studies, little is known about the stability of the ICFS over time. Exceptions are the studies carried out recently on the US listed firms samples by Allayannis and Mozumdar (2004), Agca and Mozumdar (2008), Brown and Petersen (2009), Chen and Chen (2012) and Kim (2010). Motivated by their recent research on this topic, the first analytical chapter of this thesis uses data for UK firms, divided into three subperiods: 2009-2000, 1999-1990 and 1989-1980 to investigate over time the extent to which the sensitivity of investment to cash flow differs for firms facing different degrees of different financial constraints. Our understanding of the relationship between investment and internal cash flow is improved by employing very broad panel data in terms of its time length and number of firms, especially when we examine the investment-cash flow sensitivity during the recent financial crisis.

Our second analytical chapter investigates corporate R&D investment behavior over time in the US and UK using data divided into two subperiods: 1990-1999 and 2000-2010.[2] Two strands have appeared in the literature in terms of the influence of the severity of financing constraints' on R&D investment versus physical investment. On the one hand, it has been argued by many researchers that financing constraints apply to R&D investment possibly more critically than to capital expenditures. Carreira and Silva (2010) state that the existence of financial constraints appears to be particularly severe for firms that decide to invest in R&D because of the high risks associated with the investment (typically longer term projects with uncertain outcomes). On the other hand Bond et al. (2003) amongst others, argues that innovative firms are not likely to face financial constraints as they are "deep pocket" firms, i.e. they engage in innovation activity when they have plenty of internal financial resources to do so. Therefore, the main question of this paper is whether the existence of financial constraints for firms actively investing in research and development projects is more severe than for firms intensively investing in physical capital and, if so, the implications for R&D investment. To answer this question firms are divided according to the measure of the intensity of R&D investment as well as the industry they belong to, namely high-tech versus non high-tech industries. Also the relationship between finance and R&D investment over a period of time that

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[2] We limited the sample period to only two subperiods because the data availability for UK firms over the firms subperiod was very poor.

includes a financial crisis period for panels of US and UK listed firms is examined.

The analysis of this chapter also contributes to the literature by investigating the role of cash reserves, stock and debt issues in determining the corporate R&D investment expenditures, while controlling for potential market imperfections. In addition, we conduct a comparison between the boom period and the financial crisis period to determine whether the relationship between the R&D investment and cash flows changes during these two extreme market conditions. Finally, our investigation builds on previous work by trying to distinguish different investment behavior of companies with persistently negative cash flows over time. The empirical literature has consistently documented that such firms have a negative investment to cash flow relationship. Failure to account for such investment behaviour will result in inaccurate estimates of the sensitivity of R&D investment to cash flow.

In the third analytical chapter we argue that where firms invest simultaneously in two types of investment (capital and R&D) and there is some substitutability between them, the two investment decisions need to be studied together. To support our argument we study how the R&D/TINV, where the total investment is a sum of R&D investment and capital investment, should react to variations in net worth for firms that deal with financial constraints. To the author's knowledge there is no other study investigating the impact of capital market imperfections on the R&D/TINV ratio. Our approach tests how sensitive the R&D/TINV ratio is to firm-specific characteristics, and how capital market imperfections can impact firms' decisions with respect to the R&D/TINV ratio. Therefore, the main objective of this chapter is to analyze how sensitive the R&D/TINV ratio is to firm-specific characteristics for financially constrained high-tech firms.

The third analytical chapter contributes to the literature in several key areas. First, it examines the responsiveness of the R&D/TINV ratio to variations in firm-specific characteristics, such as cash flow, cash holdings, leverage and equity issues. Second, the behavior of constrained and unconstrained firms regarding their decisions on the R&D/TINV ratio is analyzed. Finally, it uses rich financial dataset to examine the cash flow sensitivity of the R&D/TINV ratio for a sample of US and UK non-financial firms over the period 2000–2011. This data

facilitates the comparisons of the US against UK firms, the pre-crisis against crisis period as well as providing an overtime analysis.

To carry out the empirical investigation, this thesis employs cross sectional and panel data methodologies that help control for the endogeneity problem, which can appear in this context for several reasons (e.g. unobserved heterogeneity, reverse causality). Specifically, we use the average cross-sectional regression approach put forward by Rajan and Zingales (1995) and the Generalized Method of Moments (GMM) estimation procedure suggested by Arellano and Bond (1991) and Blundell and Bond (1998). We believe that with appropriate methodologies employed, our results are consistent and robust. In particular, capital investment and R&D investment analyses are based on dynamic panel data empirical models, which are estimated using the GMM methodology. Such an approach helps control for the potential endogeneity problem that is likely to arise if a) the observable and unobservable shocks affecting physical or R&D investments can also affect internal funds or growth opportunities as well as other firm characteristics used in the capital expenditures or R&D investment models, including leverage, cash holdings, debt and equity issues and b) the observed relations between capital or R&D investment and its determinants reflect the effects of capital or R&D investment on the R&D investment rather than vice versa.

This thesis employs two different data settings, namely the UK and US. Several factors make the UK and US particularly interesting environments to study. In terms of corporate ownership structure and institutional and legal framework the UK is usually described as being similar to other Anglo-Saxon countries. However, there are recognizable corporate governance characteristics in the UK, which may have important implications with regard to the ICFS of firms, especially over a long period of time. Guarglia (2009) argues that the relative lack of corporate bond and commercial paper markets, the relative thin and highly regulated banking and equity markets, and the relatively small amount of venture capital financing, seem to make the idea of financial constraints that affect firm behaviour more plausible in a European context than in the US. Hence, this work adds to the debate on the effects of financial constraints on R&D investment over time, with a focus on the UK and the US rather than just the US. This is an important issue because the controversy surrounding the interpretation of the R&D investment cash flow sensitivity is

much less developed in the UK than it is in the US. Overall, our results can shed light on the differences and similarities between the RD investment and liquidity behavior of companies operating in different market-based financial systems.

This study provides interesting results that extends our understanding of the issues investigated. The analyses in Chapter 2 find that the investment cash flow sensitivity decreases over time even after controlling for negative cash flows, and it becomes weaker over the financial crisis period. The main finding though is that the magnitude of the ICFS depends on the sample selection criteria, which in turn forms the definition of financially constrained and unconstrained firms based on the classification measure. So far, the literature seems to lack strict sample selection criteria which may lead to confounding results. Based on the assumption that high ICFS correctly reflects that firms are financially constrained and e.g., size is the right measure to classify firms into financially constrained and unconstrained categories, chapter 2 shows that ICFS does not increase monotonically with financial constraints and in fact the pick of firms who are so called financially constrained can be easily manipulated. Specifically, the distribution of the ICFS over the full sample lacks a systematic trend, thus one may pick any subsample and call it e.g., financially constrained firms. Owing to the very extensive data of the paper in the sense of time period and number of firm year observation we can summarize that the investment-cash flow sensitivity depends not only on the specific measure of financial constraints, but also on various time periods and various firms' samples. This can to some extent explain the lack of consensus in the literature regarding the investment cash flow sensitivity as a measure of financial constraints. The finding that ICFS declines over time also augments the still alive debate between Fazzari et al. (1988) and Kaplan and Zingales (1997). Measuring ICFS over time supports our understanding of corporate investment behavior. One can learn from this research that the ICFS as a measure of financing constraints is not a precise device, but it is affected itself by many other conditions, such as, for example, time period, type of considered firms, country or market conditions etc.

The main finding of chapter 3 is a persistently negative relationship between cash flow and R&D investment. This negative ICFS is almost independent from the measure of cash flow or from dropping or including the negative cash flow firm year observations or firms whose sum of cash

flow-to-assets ratio over the sample period is negative in the sample. This negative association between R&D investment and cash flow exists because the importance of cash flow as a source of financing decreases over time, while the importance of R&D investment as a form of investment increases over time. This negative association between R&D investment and cash flow is much stronger for financially constrained firms, which may indicate that these firms finance their R&D projects with other available funds. Counterparts firms also show a negative relationship between R&D investment and cash flow. However their R&D investment-cash flow sensitivity is much weaker and most of the time insignificant, suggesting that these firms are more likely to employ cash flow in the process of financing the firms' innovations, or the alternative understanding, is that they do not require as much financing for R&D because they invest relatively less in R&D projects. A similar trend is found for net stock issues coefficients, but on a smaller scale.

When the financial crisis period is considered the ICFS is even more negative and significant, whereas cash holdings coefficients are more positive and significant according to the OLS regression. In line with GMM results cash holding of the full sample of US firms' impacts R&D investment negatively during the crisis.

Chapter 3 also finds that firms of both countries experience a significant share of their financing from net equity issues, however the role of cash holdings in funding R&D investment is dominant.

In terms of comparison between the US and UK firms (e.g., economic significance) we observe that the coefficients for the UK firms are much greater than for the US firms, implying R&D investment shows a stronger dependence on financial variables in the UK than in the US market.

The findings in Chapter 3 also indicate that R&D investment is an important fraction of corporate investment spending for a significant share of publicly traded firms. According to the sample of this research the share of R&D investment in total investment, measured as the sum of physical and R&D investments, is higher than the share of capital investment for US firms since 1992 and for UK firms since 2001.

Overall, the results show that R&D investment is affected by financial constraints. Lastly this study shows a vast range of differences between R&D

firms in the US and UK. The most outstanding one is that US firms appear to be more advanced in their R&D investing process.

Although this thesis considers only three themes from a wide range of literature that discusses the impacts of market imperfections on investment decisions, the findings in this paper expand our understanding of corporate investment decisions by delivering results achieved from new perspectives on the topics. We study the physical and R&D ICFS over time and provide evidence that helps settle the debate. Studies that test the ICFS focus on an individual investment, neglecting the impact of other types of investment, which may lead to insufficient evidence about the ICFS. This study, therefore, considers the effects of financial factors on both capital and R&D investments decisions in order to examine how more and less constrained firms allocate their funds on capital and on R&D investment when decisions on both inputs have to be taken simultaneously. The findings in this thesis would be helpful to researchers, practitioners and policy makers.

Chapter 2

The Investment-Cash Flow Sensitivity over Time for UK Firms

2.1 Introduction

The investment - cash flow sensitivity (hereafter ICFS) finds a prominent place in the literature on corporate finance and the importance of the link has been extensively investigated by many studies[3]. In recent years, researchers have intensively debated the extent to which firms' investments are constrained by the availability of finance, and particularly whether a positive and statistically significant investment - cash flow sensitivity can be interpreted as an indicator of financial constraints (see Schiantarelli, 1995; Hubbard, 1998; and Bond and Van Reenen, 2005, for surveys). This debate finds its roots in Fazzari et al., (1988) (FHP hereafter) influential paper, which suggests firms with low dividend payout ratios (i.e. firms that are more likely to face financial constraints) display a high sensitivity of investment to cash flow. Subsequent extensive research confirms that a higher sensitivity of investment to cash flow is demonstrated by firms that are *a priori* more likely to face severe financing constraints. When firms encounter external financing constraints, investment spending should not solely differ with the availability of positive net present value projects, but also with the accessibility of internal funds. Accordingly, through comparing the sensitivity of investment to cash flow across firm samples sorted on the basis of ad hoc proxies for financing frictions, the influence of credit market imperfections on corporate investment should be easily measured.

FHP's (1988) finding of a positive relationship between internally generated cash flow and investment (capital expenditures) and also that this relationship is strongest for firms that are most likely to have difficulty accessing external capital markets has serious implications regarding the efficiency with which capital is allocated in the economy. Consequently the paper by FHP initiated a number of additional studies which investigated the relationship between cash flow and investment.[4] FHP (1988) argue that, *ceteris paribus,* a

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[3] See, e.g., Fazzari and Athey (1987), Fazzari, Hubbard and Petersen (1988, 2000), Devereaux and Schiantarelli (1990), Hoshi, Kashyap and Scharfstein (1991), Oliner and Rudebusch (1992), Vogt (1994), Kaplan and Zingales (1997, 2000), Hsiao and Tahmiscioglu (1997), Kadapakkam, Kumar and Riddick (1998), Hadlock (1998), Moyen (2004), Ascioglu, Hegde and McDermott (2008), Hovakimian (2009) and Bond and Söderbom (2010) among others.
[4] Followed research hasn't focused only on firms' investment behaviour, but also on firms' inventory investment (Carpenter et al., 1994, 1998; Kashyap et al., 1994; Guariglia, 1999, 2000; Benito, 2005), their R&D investment (Bond et al., 1999; Carpenter and Petersen, 2002b), their employment decisions (Nickell and Nicolitsas, 1999; Sharpe, 1994); and more in general their

sensitivity of investment levels to cash flows indicates that the cost of internal finance is lower than that of external finance. They suggest this difference might arise because external funding imposes additional costs, arising from increased agency conflicts, underinvestment incentives, or adverse selection, on firms. Moreover, findings of FHP are in line with Myers and Majluf (1984) argument that in the presence of asymmetric information firms tend to follow a hierarchy in their financing policies in the sense that they prefer internal over informationally sensitive external finance. Therefore, for financially constrained firms, the wedge between internal and external financing is high, because owing their higher level of information asymmetry, they face very costly external financing. Nevertheless, financially unconstrained firms do not have much incentive to use their internal cash flow as a source of fund, due to their relatively lower level of information asymmetry. Hence, for unconstrained firms the investment-cash flow sensitivity is not high.

However, the usefulness of the investment-cash flow sensitivity as a proxy of financial constraints has been challenged by KZ (1997) (hereafter KZ) theory, which states that "company investment decision does not suggest a monotonic association between financing constraints and the sensitivity of investment to cash flow, under profit maximizing behavior." Instead of employing the dividend payout ratio as an indicator of financial constraints like FHP did, KZ focused on other criteria. They reclassified FHP's low dividend sub-sample of firms on the basis of information contained in the firms' annual reports as well as managements' statements on liquidity. Consequently, KZ provided empirical outcomes contradictory to the results of FHP that more financially constrained firms have higher investment—cash flow sensitivities. They concluded that higher ICFS cannot be interpreted as evidence that firms are more financially constrained.

The important assumption in the theoretical models on firms' financial constraints in the existing literature (e.g., FHP (1988, 2000) and KZ (1997, 2000)) is that these constraints translate entirely into higher costs of external funds. Implicitly, both FHP and KZ assume that firms are able to acquire any amount of funds so long as they pay the required price. Therefore, a constrained firm indispensably trades off the output from greater investment and the effect of

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growth (Carpenter and Petersen, 2002a). In general, these studies maintained FHP's (1988) main conclusion.

greater investment on the deadweight costs of external finances. In consequence, their model's comparative statics depend on how financial constraints influence both the slope of the marginal (deadweight) cost of external funds and the slope of the marginal productivity of investment.

Whilst there is no theoretical consensus on the relationship between investment and cash flow sensitivities, which continues to be an important empirical question, there is ample survey evidence and recent results which support the intuition that ICFS are indeed a reflection of the extent of financing constraints (Love (2003), Beck, Demirguc-Kunt and Maksimovic (2005)). Harrison et al. (2004) explains that most papers which question this methodology relate more directly to the Q-model of investment rather than the Euler equation model (although some of the criticisms apply to both models).

Also, although there is no agreement among studies regarding the issue of how to interpret the findings in ICFS literature, ICFS regressions remain in widespread use as a tool to examine different issues in corporate finance. For instance, see Hoshi et al., (1991), the references in Hubbard (1998), Biddle and Hilary (2006), Beatty, Liao, and Weber (2007) and Almeida and Campello (2007). As Almeida and Campello (2004) point out that "a number of theories explore the interplay between financing frictions and investment to study issues ranging from firm organizational design e.g., Gertner et al. (1994) and Stein (1997) to optimal hedging and cash policies (Froot et al. (1993) and Almeida et al. (2003))."

Furthermore, in spite of the disagreements on the relative size of ICFS across sub-samples, the consensus of prior studies is that ICFS is positive in virtually all the sub-samples considered. Stein (2001) asserts that the clearest empirical evidence from research on investment is the impact of cash flow on investment, i.e. controlling for investment opportunity, and those firms with greater cash flow tend to invest more. Moreover, Stein also states that "it is much less clear what the precise mechanism is that drives this relationship". Thus this study aims to shed some light on the relationship of cash flow and investment. Following Brown and Petersen (2009), this study intends to provide further analysis of the ICFS by investigating it over time. Trend analysis allows us to plot aggregated response data over time. Also, trend analysis can be extremely valuable as an early warning indicator of potential problems and issues. "With

the past, we can see trajectories into the future - both catastrophic and creative projections." John Ralston Saul.

In spite of the prominence of ICFS literature, there is little evidence to indicate the ICFS trend over time. However, there are exceptions of studies carried out on the US listed firms samples by Allayannis and Mozumdar (2004), Agca and Mozumdar (2008), Brown and Petersen (2009), Chen and Chen (2009) and Kim (2010). Allayannis and Mozumdar (2004) report a decline in ICFS over the 1977-1996 period, particularly for the most constrained firms. The authors come up with two explanations for this, namely the improved external market efficiency or the increased supply of external funds. Agca and Mozumdar (2008) also find that the ICFS has declined over time (1970-2001). Brown and Petersen (2009) examine investment-cash flow sensitivity, when using the sum of R&D expenditure and capital expenditure of firms as the proxy for investment. They show that investment-cash flow sensitivity decline for the time period 1970–2006. Specifically, they find that the physical investment-cash flow sensitivity has declined and largely disappeared but they argue that R&D is an important form of investment. If R&D is included in the investment, then the investment-cash flow sensitivity is still strong, particularly for firms with positive cash flows. Chen and Chen (2009) documented that the investment-cash flow sensitivity declines over the 1967–2006 period and almost disappears in recent years (2007-2009). They employ the time-series variation of the investment-cash flow sensitivity as their identification strategy and they draw a different conclusion, e.g., that the sensitivity cannot be a good measure of financial constraints.

Though these papers divide the sample into sub-periods and compare investment-cash flow sensitivity of different periods, none of them compare the recession and non-recession periods apart from the study of Kim (2010). The data period Kim investigates is from 1980 to 2008. He examines whether bank-dependent firms experience significant change in investment-cash flow sensitivity during the current banking crisis, and compares them with the change in investment-cash flow sensitivity for non-bank-dependent firms. In addition, he compared the change in investment-cash flow sensitivity of bank-dependent and non-bank-dependent firms during the recession in the early 2000s. Kim (2010) finds that the bank-dependent firms experience higher increases in investment-cash flow sensitivity than non-bank-dependent firms during the IT

bubble burst period in the early 2000s and the subprime mortgage crisis in the late 2000s.

To the author's knowledge, there is no study of the ICFS over time based on the UK listed firms. Therefore, firstly, this chapter investigates how the level of ICFS for physical investment behaves over time for UK listed firms, and secondly it attempts to shed further light on the debate by employing a large panel of financial data on UK firms from 1980 till 2009. The primary objective of this document is to move the research agenda forward, delivering systematic documentation of what has happened to the ICFS over time, which opens new avenues for studying the impact of those constraints on firm investment, especially when financial crisis is considered. This chapter explores the cash flow-investment sensitivity over time during both booming and financial crisis times and tries to compare the cash flow-investment sensitivities in different periods.

This paper extends the literature in several ways. Namely, by employing the data on UK manufacturing firms with continuous coverage by Datastream for the period 1980–2009, it tests the trend of ICFS through time. Contrary to prior studies that take into account the US firms, we deliver evidence for the UK market. Despite the fact that the UK and the US are seen as functioning according to a similar "common law" regulatory system (La Porta et.al., 1998)[5], the UK market is substantially different in certain areas. In terms of firms' ownership structure and institutional and legal framework the UK is usually described as being similar to other Anglo-Saxon countries. However, there are recognizable corporate governance characteristics in the UK, which may have important implications with regard to the ICFS of firms, especially over long periods of time.

Similar to work of Chen and Chen (2012) and Kim (2010) this study period covers the financial crisis period 2007-2009. This economically significant time period provides new input to this area of research. In strong economic environments firms are likely to show a problem of free cash flow and are less likely to be financially constrained. A weak economy is expected to present the

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[5] La Porta, Lopez-de-Silanes and Shleifer (1998) describe for 49 countries the level of shareholder-rights protection. On a scale from zero (no protection) to six (high protection), UK and US firms receive a score of five. For purpose of a comparison with other continental-European countries, France, Germany or the Netherlands get low scores for shareholder protection (three, one and two, respectively).

opposite as firms are more likely to face a problem of underinvestment and they are also more likely to be financially constrained. Thus, our analysis offers a comparison of the evidence from a pre-crisis period and a crisis period which we expect to have direct implications for the ICFS trend. The crucial questions we address here are whether the ICFS shows any trend over time, up to the year of financial crisis birth in 2007 in the UK, especially at the onset of a crisis and later during the crisis, and consequently what impact, if any, had a financial crisis on the tendency of ICFS? This analysis enables us to extend the current research and investigate the influence of financial crises on investment through examining corporate investment in a period when the financial crisis became a fact in the UK. Bernanke and Gertler (1989) claim adverse macroeconomic shocks not only interfere with the central function of financial markets but also exacerbate adverse selection and moral hazard problems. As a result, during a financial crisis the hedging role of cash should be more popular because of the ability of firms to raise external finance is much smaller, due to an increasing wedge between the cost of internal and external funds. Therefore, during financial crisis periods, financially constrained firms should save a higher proportion of their cash flows, whilst unconstrained firm's cash flow policies should not show any systematic changes. The financial crisis period makes this study much more interesting and provides clear advantages for future research. A firms' viability, profitability and cash flow as well as prevalently reduced the expected return on investment opportunities are clearly affected by exogenous shocks coming from economic and financial crises. Put differently, financial crisis work as exogenous shock affecting both the size of current cash flows as well as the relative attractiveness of current investment against the future one.

Furthermore, investigating ICFS over thirty years period underlines and stamps the need to include cash holding and leverage ratio in our model, something that has not been done by previous researchers investigating ICFS over time[6]. In the spirit of BP (2009) this study argues that these variables are potentially important omitted determinants in most ICFS studies. Since firms often make very heavy use of cash holdings or debt to expand investment when cash flow is particularly low, failure to account for internal and external finance in

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[6] Only Brown and Petersen (2009) control for external finances variable impact in their model, but they do not include cash holdings. Chen and Chen (2009) includes cash holdings in one of theirs models. However, none of these studies include external finances and cash holdings at the same time.

ICFS regressions can result in a downward omitted variable bias in the estimated cash flow coefficient. On the other hand, firms experiencing positive cash flow shocks may trade off higher investment for higher cash holdings or lower debt levels. Consequently, failure to account for cash holdings and leverage may result in an upward omitted variable bias in the estimated cash flow coefficient. Hence, another contribution to the literature is that it examines the role of cash savings as well as external finance in the form of leverage ratio in the ICFS regressions by estimating dynamic investment models that include measures of cash savings and leverage. These are potentially important variables that might shed some light on the reasons of ICFS changes over time and support addressing some concerns that have been raised about interpreting ICFS. As also argued in Hubbard (1998) it is important to consider investment and financial policy jointly; firms may, for example, accumulate liquidity as a buffer against future constraints. Leverage and cash holdings are employed in the analysis because usually together with investment they account for a substantial fraction of cash flow use. Consequently they may play a substitution role for investment in firm's financial policy, meaning investment, cash and debt may compete against each other. Firms classified as financially constrained tend to hold more cash and that is consistent with the hypothesis that financially constrained firms significantly benefit from cash savings. Thus controlling for cash holdings is important in the investigation of ICFS over time.

Moreover, both free cash flow (Jensen, 1986) and asymmetric information (Myers and Majluf, 1984) problems are the types of agency conflicts within a firm that may be reduced with a help of debt servicing obligations. Corporate debt can act as a restriction of costly managerial actions and hence increases firm investment. This implies that debt servicing obligations can mitigate the costs of the manager-shareholder agency conflicts, especially when privately held debt is considered. The leverage ratio of total debt to total assets is included to approximate the lender's incentive to monitor. Basically, with the increase of leverage, the risk of default by the company grows too, thus the incentive for the lender to monitor the firm.

This paper also contributes to the literature with respect to the procedure of firms been divided into constrained and unconstrained groups. The active debate in the existing literature is whether ICFS is higher for financially constrained or unconstrained firms or alternatively, whether or not a high ICFS is

a good measure of the presence of firm's financing constraints. Thus, we are intrigued by the attempt to find consistent measures of the degree of financial constraints. Since it is necessary to define a prior proxy for financial constraint we focus on two measures which firms are usually categorized by, namely size and age. For instance, large and mature firms are described as well developed, well informed and most importantly financially unconstrained firms. However, the practice among researchers is to divide firms according to one or another measure – separately. In this paper we intend to combine these measures together in order to introduce a more intuitive approach to the firms division. However, in order to create robust financial constraints' measure we combine size, age with financial variable, namely size growth calculated by sales growth ratio.[7] [8] Many empirical papers use sales growth as a proxy for firm's investment opportunities (see e.g. D'Espallier et al., 2008). Lamont et al. (2001) points out the fact that in order to be constrained, a firm needs to have good investment opportunities. In line with this approach, we define constrained firms when their size and age are below the sample's median and sales growth is above the sample's median. Unconstrained firms though have size and age above the sample's median but sales growth below the sample's median. The sample of firms with size, age and sales growth below the sample's median should include firms most likely to be financially distressed. [9] The last sample of firms with size, age and sales growth above the sample's median should represent spurious issues. On one hand large and mature firms are classed as unconstrained firms.

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[7] KZ (1997) reclassified FHP's low dividend sub-sample of firms on the basis of information contained in the firms' annual reports as well as managements' statements on liquidity. Also, for instance KZ index is build on firm's financial data.

8 Guariglia (2008) uses firms' cash flow and coverage ratio as measures of "internal" financial constraints, and firms' size and age as proxies for "external" financial constraints to study the extent to which the sensitivity of investment to cash flow differs at firms facing different degrees of internal and external financial constraints. After combining the internal with the external financial constraints, she finds that the dependence of investment on cash flow is strongest for those externally financially constrained firms that have a relatively high level of internal funds.

[9] It is arguable whether the degree of financing constraints is properly measured by the shortfall in internal cash flow. FHP (2000) points out that a low-cash flow firm is probably in greater financial distress, but not necessarily facing tighter financing constraints. Lamont et al. (2001) also considers the distinction between financial distress and financial constraints and in effect employs negative real sales growth as a proxy for financial distress. Financing constraints refer to the difficulty of raising external financing, or the cost differential between internal and external funds. The correlation between financial distress and financial constraints is particularly problematic in empirical work. For example, Kaplan and Zingales (2000) argue that financial distress is a form of financing constraints, and Povel and Raith (2001) suggest that low cash flow is a component of financing constraints.

On the other hand, financial constraints literature dictates that firms with high growth opportunities are constrained.

However, this combined measure firms' division into constrained and unconstrained groups may follow the contrasting philosophy that firms are unconstrained if their age growth raises positively and fast enough with their size growth in relation with firms' sample, but constrained if their age growth does not reflect their size growth in relation with firms' sample. Firms might be mature according to their age classification but their size growth over the years was very slow in comparison with other firms, indicating that those firms directly or indirectly suffered from financial constraints problems, whilst firms whose size growth is aligned with age growth are classed as unconstrained firms. In agreement with the second approach firms are defined as unconstrained if they are mature, large or young, small with high speed of growth, while constrained firms are mature, large or young, small with slow speed of size growth.

The age measure is defined by our data source – Datastream as the number of years the firm is listed on the equity market rather than its actual age of existence. Firms must pass certain condition in terms of its size before they are able to be registered on the equity market therefore that is an appropriate filter for firms to be in any of the groups of our classifications. The fact that this paper use GMM technique in order to examine the model also support the firms' classification method, in the sense that for a firm to be in the sample it needs to be at least four years old, which gives basis for the judgement of firm's speed of the size growth.

The research strategy to address all these issues is as follows. We discover changes in the ICFS between 1980 and 2009 employing Datastream data for non-financial firms, broken up into three ten year subperiods: 1980-1989, 1990-1999 and 2000-2009. In order to learn about the changes of ICFS over time we divide the whole sample into smaller subperiods. These subperiods, put together, produce comparisons between decades. Testing for the full sample period only, would provide us with single set of coefficients stating the associations between variables for the chosen/setup period of time, but not over the time. In order to distinguish the financial crisis period, we also employ cross sectional analyses for the last decade. Time series analyses provide the detail picture of year by year changes as well as ten years rolling regressions.

In order to compare our results for the UK with results for the US already existing in the literature we assess the sensitivity of physical investment to cash flow with the standard pooled ordinary least squares (OLS) model. Factors affecting the firm's investment decisions change overtime. Firms with long term investment targets achieve these through an adjustment process. Moreover, it is possible that random shocks influence both dependent and explanatory variables at the same time. It is likely that the observed investment and its potential determinants indicate the effects of investment on the latter rather the other way round. To detect for investment target and control for the endogeneity issue we use the generalized method of moments (GMM) technique, which also overcomes the problems of simultaneity and measurement errors that are known to be common in firm-level data. We use panel data because the degrees of freedom are increased; there is more variability and reduction in colinearity among regressors. These advantages deliver more efficient estimations. Unobservable firm heterogeneity is controlled for by panel data. Particularly in company financial data it is also difficult to establish exogeneity between the regressors and error term. Hence, due to likelihood of endogeneity, the direction of causality between variables might be ambiguous. As a result, spurious results may come out from employing the contemporaneous observations for both dependent variable and its determinants. GMM procedure controls this problem. Additionally, it allows us to examine the dynamic nature of the investment decision of UK firms. By involving dynamic effects, owning to useful aspects of the panel data, as well as controlling for unobservable firm-specific effects and firm-invariant time-specific effects, analyses of corporate financial decisions have a more appropriate basis.

The empirical analysis of this paper provides a set of interesting results. Our major finding is that there is a substantial decline of ICFS over the thirty year period that this paper considers. This finding is confirmed by each analytical method employed in this study, namely the year by year analysis, OLS estimates, and GMM regressions. This dramatic decrease of ICFS over time appears even after controlling for negative cash flows in terms of OLS and GMM results. GMM regressions that consist of measures of cash holdings and external finances and control for negative cash flow also demonstrate strong decline of ICFS. This decline of the ICFS is consistent with previous literature on the subject. During the IT bubble burst period in the early 2000s and the credit

crunch crisis in the late 2007s firms' growth opportunities have a statistically insignificant impact on investment, while cash flow coefficients become weaker, but still statistically significant. In terms of sample division into groups of constrained and unconstrained firms, overall, constrained firms investment decisions seems to be motivated by both internal funds proxy and proxy for growth opportunities, while unconstrained firms investment decisions seems to be affected mainly by growth opportunities influence. Furthermore, our regression findings also highlight the different roles of cash holdings and leverage. Total debt coefficients are negative and rise over time for most groups of firms. While cash holding coefficients are positive and also increase over time, but most of the times they are insignificant. The economical significance of total debt coefficients indicates that the impact of total debt ratio on capital expenditures ratio has increased over time, meaning that firms have increased their ratio of leverage over time but decreased their investment ratio and in effect that suggests that firms have more and more debt dependent types of investment. The coefficients of cash holdings indicate that firm's cash holdings may participate in financing investment expenditures rather than compete against investment.

The GMM estimation also suggests that firms have target investment ratio and they adjust to the target ratio relatively fast. Therefore, it seems that for firms both the costs of being away from their target ratios and the costs of adjustment play important roles. A firms' speed of adjustment of their target investment increases with time, meaning firms fulfil their target investment more efficiently over the time period this study concerns. This implies that firms' costs of being away from their target investment or the costs of adjustment increases over time, therefore firms seem to be adjusting their investment faster in the last subperiod in comparison with the first subperiod, and that indicates that it is less and less affordable for firms to be away from their target investment.

To summarize, the ICFS for physical investment has fallen dramatically. However, we emphasize that the cash flow coefficients for capital investment, controlled for growth opportunities, should have declined a great deal because of the sharp decrease of capital expenditure ratios that occurred during the period we study. We also find that over time there is an increase in the number of firms with persistently negative cash flows, which may suggest growing number of firms financially distressed. The bottom line is that the decrease in ICFS over

time may be explained with improvements in equity markets (Brown and Petersen, 2009), but that is not a sign of lower financial constraints firms face in year 2009 in comparison with year 1980.

The rest of the paper is organized as follows: Section 2 presents literature overview. Section 3 describes methodology. Following section demonstrates data and variable selection process. Section 5 reports empirical results and section 6 concludes.

2.2 Literature review

Investment decisions are critically important because they are constantly linked with the future continuity, wealth and growth of the firm. An important factor about investment decisions faced by companies is that they are financially driven, which means that they are strongly dependent from financial decisions made by managers. Moreover, business investment is one of the most significant determinants of corporate value and is one of the major characteristics influencing an economy. Chirinko (1993) argues that the pace and pattern of business investment strongly affects economic activity, and the volatility of investment expenditure is a central contributing factor to aggregate fluctuations.

Analysis of the firms' investment decisions plays a domineering role in research programs in macroeconomics, public economics, industrial organizations, and corporate finance. These research agendas have been rising on theoretical (e.g. debates over which model explains investment behaviour the best) as well as empirical basis (e.g. recently, a growing trend to unite the investment and financial decisions by studying interactions between them, or the interdependent nature of financial variables). Thus this chapter covers some of the most active areas of corporate investment research, namely broad theoretical and empirical literature that looks at how firms make investment decisions in the face of market imperfections such as informational asymmetry problems or agency costs and tries to find an answer to one pioneer question in corporate finance, which follows: how well firms' capital is allocated to the right investment projects? This section has been structured to illustrate both a developed theoretical framework and empirical evidence challenges in both the investment decisions research and the financial characteristics research. In detail it presents models of capital-market imperfections in the investment process and demonstrates the main testable ramifications of those models. Description of problems raised by empirical studies is also incorporated in this paper.

The next section discusses the most important aspects of market imperfection that affect corporate investment. The list of market imperfections consists of asymmetric information, moral hazard and adverse selection, agency

problems, behavioral factors, diversification, industrial organizations, taxes, government regulations and subsidies. The first four of these factors are briefly discussed next.

2.2.1 Asymmetric information problems, moral hazard and adverse selection

The appearance of theoretical models of asymmetric information brought into focus again the importance of how investment is financed. Paper delivered by Akerlof (1970) demonstrated how markets function irregularly when sellers and buyers perform under various information setups, and therefore their well-known scrutiny of the role of asymmetric information in the market for "lemons" disconnected with established economic theory. Akerlof (1970) pioneered the adverse selection literature, showing the impact of informational asymmetry on quality. Literature picked up that similar argument could be referred to firms trying to acquire funds from lenders, thus applications to equity and debt markets were presented by Stiglitz and Weiss (1981) and Greenwald, Stiglitz, and Weiss (1984), who found out that asymmetric information in terms of debt financing may increase the cost of new debt or even restrict firms from borrowing because of credit rationing. The reason is that lenders do not know how the money they lend is being invested. For example, higher interest rate may result in drop out of firms with valuable projects (adverse selection). Hence, firms with prominent growth opportunities may suffer seriously from asymmetric information. Then stemming from equilibrium credit rationing by suppliers of external finances, these firms spend on investment only when their internally raised finances are available. This induces a positive association between cash-flow and investment.

Firms may choose to finance their investment from a wide array of sources of funds. In the presence of market imperfections, firms may prefer one source of funds over another. Myers and Majluf (1984) recognize this possible type of market imperfection, as the presence of information asymmetry between the firm - managers and the market - investors. They state that the information about firm's performance held by managers is superior to that known by outside

investors. Outside investors are aware of this and hence require a greater rate of return to compensate for this information asymmetry. Therefore, using internally gathered up funds is much cheaper to raising more costly external funds. When firms suffer from liquidity constraints, managers may not be willing to issue new stocks but rather forego profitable investment opportunities. This lead to the main conclusion of the approach of <u>costly equity finance</u>, which is as follows: even firms that are badly in need of new equity may be unable or unwilling to raise it.

Greenwald, Stiglitz and Weiss (1984) and Meyers and Majluf (1984) employ asymmetric information as the explanation for this financing hierarchy. Myers and Majluf (1984) introduce pecking order theory, which contend that raising equity externally will be problematic due to an adverse-selection problem. According to pecking order theory firms first use their internal funds, then the debt resources and finally will reach for equity funds to finance their investment projects. In other words, firms first employ the cheapest funds then gradually the most expensive. Fazzari et al. (1988), Bond and Meghir (1994), Gilchrist and Himmelberg (1995), and Lamont (1997), among others, deliver empirical evidence of the pecking order of financing costs and its influence on corporate investment levels. These studies find that investment levels of mostly financially constrained firms are most sensitive to the availability of internal funds.

Asymmetric information between corporate insiders and the capital market is supposed to explain the investment distortions. Asymmetric information is the reason why external financing is more costly than they would be in a world of perfect markets. This is because outsiders cannot distinguish between firms having high versus low quality projects, and so will estimate every security issue as if it finances an average quality project.

In the presence of asymmetric information, investors would estimate the value of the firm by observing signals given by managers. In situations of information asymmetry coexistence with agency problems, investors have much more difficult task to value the firm's performance. Narayanan (1988) finds that firm overinvests when it sells risky securities to finance a project with an unknown quality to investors. This is explained with the assumption that securities are valued according to the average project quality.

When the market cannot distinguish between high-quality and low-quality investment opportunities, firms with high-quality opportunities are more likely to

finance their projects internally. The resulting adverse selection raises the cost of external financing compared to internal financing, forming a clear hierarchy for firms' sources of financing. In the presence of asymmetric information, internally generated cash flow is the most likely source of funds for corporate investments.

Summarizing financing constraints caused by asymmetric-information conflicts in the issuance of equity are the reason for the cash-flow-investment dependence. Explaining it from a different point of view, one source of raising external financing in order to achieve liquidity is to generate capital by issuing new equity. According to the theory of Myers and Majluf (1984), insiders of the firm have an advantage of better information about firm value than capital markets have. The insiders, such as managers and informed current shareholders, intend to pass wealth from new suppliers of capital to the existing shareholders. Outside investors, who are not as well informed as insiders, expect insiders to raise capital when this new capital is overvalued. This adverse selection implies that managers and firms face a premium on external financing. Therefore, firms will firstly use internal sources to fund investments. But, when investment expenditures exceed the internal funds, the premium on external financing starts to be relevant. This premium induces a liquidity constraint for firms, such that a proxy for internal funds becomes an important determinant of investment expenditures. Additionally, if the internal funds are insufficient, firms may pass on some positive net present value projects (underinvest) rather than issue securities for less than they are worth. Myers and Majluf (1984) show that firms' investment spending does not only depend from investment opportunities. The availability of internal funds also affects investment decisions, as external funds are excessively costly. Put differently, because of informational asymmetries good firms are undervalued by the capital market, and managers are biased odds to debt financing and underinvestment. According to Myers and Majluf this conflict can be sorted out when the firm can finance projects out of available cash. Therefore the "lemons premium" linked with external funds may cause investment to be sensitive to the availability of internal finances for the project. Dybvig and Zender (1991) highlighted that a critical assumption for information asymmetry to produce underinvestment in the Myers and Majluf analysis is that management acts in the interests of existing shareholders.

All in all, extensive research on information asymmetry and capital market imperfections demonstrates that because of market frictions, internal financing

are less costly than external financing because the latter comprises a 'lemons' premium. The theory implies that cash flow will significantly influence investment behaviour, and managers are presumed to either overinvest or underinvest. Stulz (1990) demonstrates that managers are more likely to overinvest when cash flow is high, and underinvest when cash flow is low. Berkovitch and Kim (1990), studying investment, and Lang et al. (1991), studying merger and acquisition activity, have provided evidence which they interpret to be supportive of Stulz's hypothesis. Jensen (1986) claims that free cash flow may be employed to finance negative NPV projects. This hypothesis of overinvestment states that a firm with free cash flow problems should increase dividend, because thanks to it, the market's estimate of the amount of cash that will be wastefully invested, will decrease, hence a firm's value will increase.

The information asymmetry problem is closely linked with adverse selection and moral hazard problems. When actions of managers cannot be watched, then moral hazard arises; and "incentives have to promote the correct actions" (Holmstrom, 1977). In cases, where firm is not a solely-owned and finance its investment projects with help from external markets, the moral hazard problem seems unavoidable in terms of the relationship between managers and investors.

Outside investors are often not able to verify the manager's act of investment or how managers make the investment decision. Scarifying resources into the monitoring of actions and employment of this information in the contract would be the most natural method of solving this problem. Despite the fact that monitoring is supportive in following the action of managers, it is never perfect. Notwithstanding, when a potentially profitable investment opportunity exist in the firm, this monitoring will carry further, since investors "have to watch how cash flow is used" (Myers, 2000).

In situations when firms have to raise costly external equities, adverse selection becomes also a direct outcome of the information asymmetry problem. According to Stein (2001) managers who favour their present shareholders at the expense of potential future investors may wish to sell new shares at times when their private information implies that these new shares are most overvalued. Consequently, the market rationally interprets equity issues as bad news (Asquith and Mullins, (1986)). In effect of this, managers of good firms may be unwilling to sell equity in the first place and even firms with proven prosperous

investment potential but financially constrained will be reluctant to issue equity. Nevertheless, Myers (1984) and Myers and Majluf (1984) claim that in general the equity market is likely to be more severely affected by adverse selection problems, the debt market can be referred with the same basic adverse selection argument. Stein (2001) argues that at any given interest rate, managers will be more prone to borrow if they are aware of the fact that their firm is likely to default. Moral hazard is also recognized by Stein in the situation where managers who borrow have a greater incentive to take the kind of risks that lead to default. Jaffee and Russell (1976) and Stiglitz and Weiss (1981) present that credit rationing stems from these sorts of considerations, where firms suffer from not been able to acquire all the debt financing they would like at the generally accepted market interest rate.

Firm's investment decisions can be highly influenced by the asymmetric information problem, moral hazard and adverse selection. Hubbard (1998) states that a gap between the cost of external financing and internal financing is a result of the problem of asymmetric information between borrowers and lenders. With information lack about the riskiness or quality of the borrowers' investment projects, adverse selection leads to a gap between the costs of external financing in an uninformed capital market and internally gathered up funds. Hence, when managers make investment decisions they would depend on the availability of internally raised funds. The major conclusion is that investment is significantly correlated with proxies for changes in net worth or internal funds, ceteris paribus. According to Hubbard (1998) this correlation is most important for firms likely to face information related capital-market imperfections, that is, those companies experiencing severe financial constraints.

Investment decisions of financially constrained firms with potentially good investment opportunities will be especially affected by moral hazard and adverse selection. A model of optimal financing of investment projects where managers have to apply unobservable effort and can also switch to riskier or less profitable projects has been studied by Biais and Casamatta (1999). They find that firstly, when the risk-shifting problem is more critical, optimal financial contracts of debt and equity combination can be carried out and secondly, when the effort problem is the most severe, stock options are needed to be included in the manager's

compensation scheme. However, the overall investment level would decline, if the moral hazard problem becomes worse.

Furthermore, firm's investment behavior can be influenced by the cash flow effect linked with other aspects of a firm. Lang and Litzenberger (1989) imply that over-investing firms announcing unexpected dividend change pass on information about the firms' levels of future investment. An increase of dividend conveys to the market that firms will invest less in the future than was expected. Therefore, dividend changes carry information to the market and impact common stock prices. The signaling hypothesis contends that managers have information about the future opportunities of the firms, but this information is not available to the shareholders.

2.2.2 Agency problems

The agency problem is another major market imperfection constituent that impacts investment substantially. The influential document of Jensen and Meckling (1976) initiated the issue of the misalignment of managerial incentives and shareholder interests, which arise mainly from the separation between ownership and control. According to this view, managers' objectives differ from those of outside investors and managers act in their own best interests when opportunities arise, usually at the expense of outside investors - managers overinvest to derive private benefits such as "perks," large empires, and entrenchment. This may be done in different ways such as excessive salaries, dilution of the ownership of outsiders, and spending resources on negative NPV investment projects. In other words the idea is that managers' pursuit of their own self interest makes them to pick a level of investment lower or higher than the optimum level for a completely manager owned firm.

Managers may have an excessive taste for running large firms, as opposed to simply profitable ones. This agency problem, in which again managers' interest diverge from those of shareholders is claimed to be the cause of empire-building and overinvestment. This "empire-building" tendency is emphasized by Jensen (1986, 1993), among many others, who argue that empire-building desire will lead managers to spend essentially all available funds on investment projects. This causes the prediction that investment will be increasing in internal

resources. It also suggests that investment will decline with leverage, because high current debt payments require great amounts of cash out of the firm, therefore decreasing managers' discretionary budgets. Put another way, leverage serves as a disciplinary device in a sense that interest payments lower free cash-flow. More than this, the fixed obligations to debt holders, with underlined bankruptcy risk pressures managers to invest in valuable projects (Jensen (1986) and Zwiebel (1996)). Stulz (1990), Harris and Raviv (1990), Hart and Moore (1995), and Zwiebel (1996) further developed and refined Jensen's ideas into formal models. These models in some states of the world, such as when the level of free cash flow relative to investment opportunities is higher than expected, predict ex post overinvestment and in others ex post underinvestment.

Conflict between managers and shareholders may also appear when managers are concerned with how their actions impact their reputations – career concern, and ultimately their perceived value in the labour market. Narayanan (1985) contends that managers concerned with their labour-market reputations may have incentives to take actions that boost measures of short-term performance at the expense of long-run shareholder value. A similar approach comes from Stein (1989), who states that managers are not so concerned with their own reputations per se, but rather with their firms' stock prices over a near-term horizon. In both cases, the central point of the argument is that managers can do things that are unobservable to outside investors. As a result, underinvestment is rewarded with an increase in either manager's personal reputations or in the stock price. Specifically, overinvestment, rather than underinvestment, is more likely to happen in some circumstances as a cause of an excessive taste to impress the labour market or the stock market in the short run.

All in all, managers' utility is positively correlated with firm size since this increases their pay, status and power. The target to maximize firm size disagrees with shareholders' interests in case of firms without valuable investment opportunities. Free cash flow is defined as the cash-flow that is at the discretion of managers, after valuable investments are carried out. This free cash flow is likely to be wasted by managers, who take on projects at the expense of shareholders' welfare, resulting in overinvestment. Simply saying, the availability of free cash-flow causes overinvestment in the sense that the

available free cash flow is invested in projects increasing firm size but with negative net present value. Therefore cash-flow may be positively correlated to investment. Berle and Means (1932), Baumol (1959), and Williamson (1964) were among the earliest to investigate this interests' conflict. Jensen and Meckling (1976) also propose that the interest between these two different groups of claimholders can run in the same direction through alterations of managerial ownership and, therefore, reduce the total agency costs within the firm. They introduce the model, where the relationship between managerial ownership and agency costs is linear and the optimal point for the firm is obtained when the managers own all of the shares of the firm. Simply saying, Jensen and Meckling (1976) state that, increased equity ownership by insiders reduces agency cost. Higher equity ownership of the managers would better align the interest of managers and investors. Lambert et al. (1991) imply that the problem of managerial myopia can be solved, or at least reduced, by closely connecting the market stock price with the manager's compensation. The object should be efficient investment, that is, the investment that maximizes value regardless of the project's time perspective. However, it is not clear whether stock compensation on its own can result in efficient investment. Narayanan (1996) point out that if the manager works on the basis of a cash compensation contract solely, she underinvests in the long run. If the manager is attracted with a stock-only compensation contract with the stock being restricted (stock that cannot be traded immediately) the manager overinvests in the long term. A compensation contract combining both cash and stock might encourage the manager to make efficient investment decisions.

Two main assumptions are relevant to the managerial-discretion problem. First one is the absence of valuable investment opportunities for firms to overinvest. The second assumption states about imperfect monitoring and incentive structures. If monitoring would work ideally and managers-shareholders' interests were at the perfection level aligned then managers would not overinvest. Corporate governance therefore plays critical role in the managerial-discretion conflict. This is because equating the interests of managers and shareholders to the same level alleviates agency costs.

Literature reports that leverage, dividend and higher management ownership can act as the effective instruments in reducing the agency problems. Jensen and Meckling (1976) contend that due to the agency problem, holding constant

the manager's absolute investment in the firm and raising the stake of the firm financed with debt increases the manager's share of equity and makes the loss from the conflict between the managers and shareholders less severe. Jensen (1986) claims that increased leverage forces managers to pay out their excess cash flow instead of overinvesting. Borokhovich et al. argue that agency problems can be mitigated with dividends as they find that firms with more outside investors would experience a lower abnormal return when an increase in dividend is announced.

Jensen (1986) analyzes empire building by addressing the agency problem directly to the ability of the firm to generate free cash flow (cash flow left after funding positive NPV projects). Shleifer and Vishny (1989) studied managerial entrenchment. Hoshi, Kashyap and Scharfstein (1991) establish clearly the overinvestment problem by recognizing as different firms with low and high investment opportunities. Firms with bad prospects are supposed to suffer from the overinvestment problem. Vogt (1994) set up an empirical model that identifies when underinvestment or overinvestment is the ruling over cause of sensitivities between cash-flow and investment. Additionally, corporate governance starts to be relevant to the degree of Jensen's (1986) managerial-discretion problem and the involved as the consequence overinvestment.

All in all, in the real world a corporate investment decision is a process that is affected by various components of imperfect market. This thesis studies corporate investment behavior under the assumption of an imperfect market.

2.2.3 Theoretical model reflecting the relation between internal funds and investment

Figure 2.1 presents the demand for capital by a firm and supply of funds to the firm. The demand curve, D, implies that an increase in the cost of funds reduces the firm's desired capital stock. The supply curve, S, has two components: a horizontal segment at r, the market real rate of interest; and an upward-sloping component, reflecting the costs associated with imperfect

information. The slope of this segment is determined by the marginal information costs, i.e. the higher are the marginal information costs the steeper is that upward-sloping portion of the *S* curve.

Figure 2.1 Informational Imperfections and Underinvestment
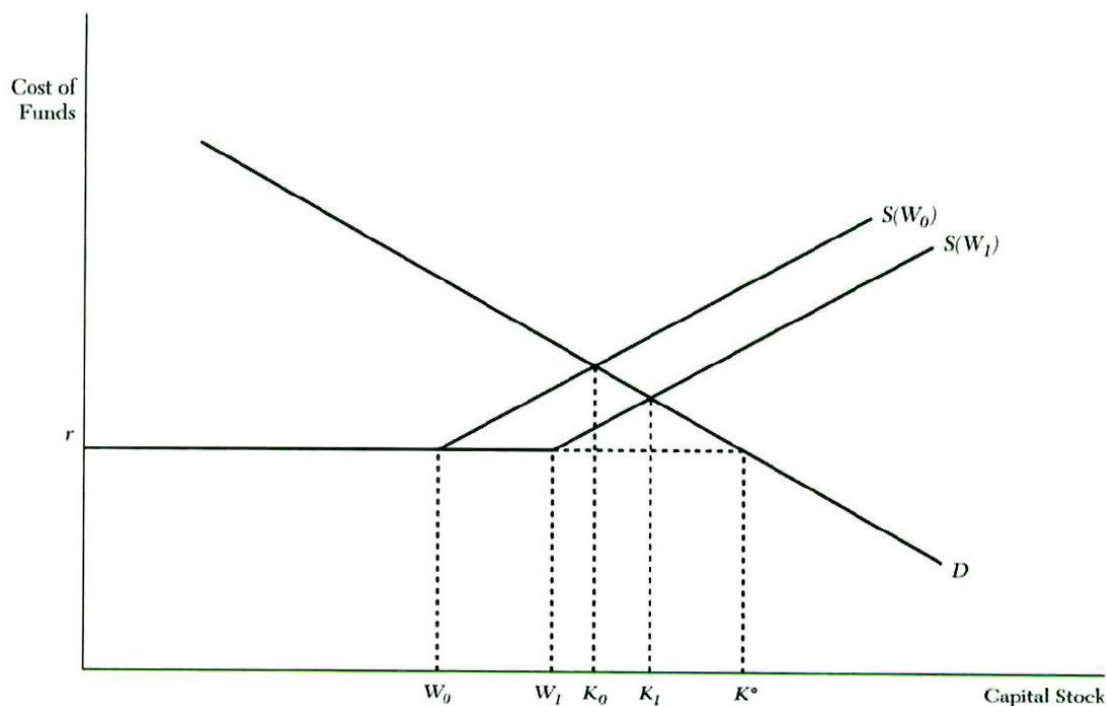
The first-best capital stock, *K**, is determined by the intersection of the *D* curve and the *S* curve at the interest rate *r*. At this level the expected marginal profitability of capital equals the interest rate. The important point is that in this set up there is no role for the firm's internal funds to play in determining investment. The opportunity cost of internal funds is the market rate of interest at which the firm can borrow and lend in the capital market. It is also assumed that the firm's insiders and outside investors are symmetrically informed about the firm's choice, investment opportunities and riskiness of projects.

In the presence of information costs, the equilibrium capital stock for the firm is given by K_o. This is less than the first-best desired capital stock in a frictionless setting, *K**. That is, there is underinvestment relative to the setting with no information costs.

A firm facing no information costs or with sufficient internal funds to finance its desired capital stock, the equilibrium capital stock remains at *K**. In other words, an increase in net worth independent of changes in investment opportunities has no effect on investment. For firms with sufficiently high

information costs, an increase in net worth leads to greater investment, all else being equal, while a decrease in internal funds lowers investment.

In macro terms, during a boom, net worth of borrowers is high, shifting the *S* curve to the right, the cost of financing is relatively low, stimulating the demand for capital by firms facing information costs. Conversely, the decline in net worth during a recession raises cost of external financing, further reducing investment.

The empirical strategy stemming from the model is to assess the impact of net worth on investment for firms with low and high informational costs. The hypothesis is that for given levels of investment opportunities, information costs, and market interest rates, firms with higher net worth should invest more.

2.2.4 The sensitivity of investment to cash flow - theoretical literature review

This section presents theoretical aspects of the sensitivity of investment to the internal cash flow. Since FHP and KZ (1997) reported contrasting outcomes for the sensitivity of investment to cash flow, the puzzle has attracted broad attention in the research world and many attempts have been undertaken to find a solution. Previous literature stresses the fact that information asymmetry is one of the most recognized market imperfections substantially affecting investment decisions of firms, i.e. while controlling for investment opportunity, firms with more cash are inclined to invest more. Hubbard (1998) argues that a gap between the cost of external financing and internal financing is an effect of the problem of asymmetric information between borrowers and lenders. This suggests that all else being equal, firms without information costs and firms with adequate net worth to finance their satisfying capital stock will not be influenced, while firms suffering from great information costs and low net worth encounter a positive association between internal funds' availability and levels of investment.

Cash flow received great attention in the investment literature in the 1980s following the emerging of asymmetric information models, and an empirical breakthrough in 1988 by FHP. They examine whether investment determinants disagree between firms for which, *a priori*, the cost of internal financing and external financing are similar and firms for which the cost of

external financing exceeds the cost of internal financing. They left behind the assumption of representative firm, and employed firm-level US sample of 422 firms over the 1970 to 1984 time period to study differences in levels of investment among firms categorized in accordance with earnings retention. Put differently, they test differences in the sensitivity of investment to cash flow across groups of firms separated on the basis of the *a priori* possibility that they face serious financial constraints. Specifically, in order to examine the forecasted association between investment and its funding as well as investigate the importance of financing constraints FHP categorize a Value Line sample of US firms into subsamples based on the dividend payout policies, Firms that have low dividend payout ratios were regarded as 'most financially constrained' and those that have high dividend payout ratios as 'least constrained' firms. They claim that investment expenditures of the 'most constrained' firms, in comparison with the 'least constrained' ones, should be more sensitive to internal cash flows and stock of liquidity. The empirical examination they provide uncovers considerably higher sensitivity of investment to cash flow and liquidity in the case of firms that keep nearly all of their income. This supports the hypothesis that cash flow affects a firms' investment because of capital market imperfections.

The main assumption in their analysis is that dividends are related to financial constraints. The hypothesis is that lower dividends indicate higher constraints. This hypothesis is confirmed through the outcomes presented that show the influence of cash-flow on investment is greater for firms with low dividends. Generally, FHP test the financing hierarchy hypothesis and find that firms' investment policies are indeed sensitive to their cash flow fluctuations and that most financially constrained firms have greater cash flow sensitivity than least constrained firms. In other words they argue that the sensitivity of investment to internal funds should increase with the wedge between the costs of internal and external funds (*monotonicity hypothesis*). According to FHP's notion, one should be able to gauge the influence of credit frictions on corporate spending by comparing the sensitivity of investment to cash flow across samples of firms sorted on proxies for financing constraints. The FHP framework can be interpreted as employing cash flow to measure net worth change. Thanks to this influential methodology they were able to classify between different possible functions of cash flow. Specifically, they estimated a fixed effect regression of physical investment on cash flow and Tobin's Q, which is a proxy for firms'

investment demand, but it might be a poor measure of them. If the latter was true, then the coefficients on cash flow could be biased because of the correlation between cash flow and investment demand, and the effects of cash flow on investment would be expected to be approximately equal for all groups of firms.

Alternatively, due to imperfect capital markets, cash flow could influence investment and internal finance is cheaper than external finance. In this situation, cash flow coefficient is expected to be higher in association with investment of firms more likely to face financial constraints. Comparing the level of the cash flow coefficients for firms more and less likely to encounter financial constraints would therefore facilitate beneficial measure stating the existence of financial constraints.

FHP (1988) assert that firms with greater retention ratios encounter greater conflicts of informational asymmetry and were more likely to be liquidity constrained. They provide evidence that the investment levels of firms that have exhausted their internal finances are much more sensitive to fluctuations in cash flow than those of mature, high dividend firms.

In the first stages of the evolution of the investment-cash flow sensitivity and firm financing constraints literature,[10] FHP (1988), by providing the empirical evidence, initiated the traditional view that firms with a high degree of financial constraints show investment more sensitive to cash flow or put differently firms that confront more binding financing constraints, i.e., a higher differential cost between internal and external finances, have no other choice, but to depend more on internal funds for fulfilling investments. In particular, they argue that the investment decisions of firms with high dividend payout ratios would be less sensitive to fluctuations in their cash flows as compared with firms who have nearly exhausted all their low cost internal finances (i.e., have low dividend payout ratios). Firms suffering from information costs would decrease capital expenditures due to reduction in internal funds, holding constant the investment opportunities of a firm. They write "If information problems in capital markets lead to financing constraints on investment, they should be most evident for the classes of firms that retain most of their income. If internal and external finance are nearly perfect substitutes, however, then retention practices should reveal

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[10] See Hubbard (1998) for a detailed review of this literature.

little about investment by the firm. Firms would simply use external finance to smooth investment when internal finance fluctuates," (p. 164).

Many firms' growth potential is constrained by limited internal capital and critically depends on bank loans, equity issues, or venture capital investment. In this practical context, a firm's investment decisions may in fact be closely related to its financial choices. In other words, in the presence of market imperfections there is no perfect substitution between internal and external funds. The cost of external finance will now be measured as a function of the extent to which firms are subject to capital market imperfections, which means that generally firms will encounter an upward-sloping supply curve of external capital where capital market imperfections will in part determine its slope. This implies that firms that deal with severe informational and agency problems face both, limited access to external finance and restricted internal funds, and thus will have to give up profitable investment opportunities in some states of the world. Such firms are considered to be financially constrained and their investment starts to rely strongly on the availability of internal funds. The hypothesis that the sensitivity of investment expenditures of financially constrained firms to the availability of internal funds is higher than that of unconstrained firms has been examined broadly. To test this hypothesis, few firm characteristics such as size (Gertler and Gilchrist (1994), Himmelberg and Petersen (1994) and Gilchrist and Himmelberg (1995)), age (Schaller (1993) and Hubbard, Kashyap and Whited (1995)), dividend (Fazzari and Petersen (1993), Bond and Meghir (1994), Gilchrist and Himmelberg (1995), Hubbard et al., (1995) and Gugler (1998)), leverage (Whited (1992)), credit rating, close relationships with industrial or financial groups (business affiliation), bank-affiliated (Hoshi et al., (1991) and Van Ees and Garretsen (1994)), science-based (Audretsch and Weigand (1999)) and R&D (Brown (1997)), type of industry (Devereux and Schiantarelli (1990)), financing scheme (Bond and Meghir (1994)), the presence of a bond rating or commercial paper program(Gilchrist and Himmelberg (1995)) and capital intensity (Hsiao and Tahmiscioglu (1997) and Kalatzis et al. (2008) and Kalatzis and Azzoni (2009)), have been employed among others to recognize financially constrained firms. Additionally, firms' cash flow has been used as a proxy of internal funds in order to investigate whether the investment sensitivity to cash flow is a useful measure of financial constraints. In other words, a measure of assessing the degree of financial constraints faced by firms, which is

the sensitivity of investments to the availability of internal finance, controlling for investment opportunities expressed by Tobin's Q, became very popular.

In accordance with both agency problems theory and asymmetric information theory, the level of investment should be sensitive to the level of cash flow in the firm. Due to information asymmetries and capital market imperfections, corporate investment expenditures are strongly influenced by a firm's ability to internally generate cash flow. Under the agency view, investment raises internal fund because the external capital market restricts the level to which managers can execute self-interested investment.

2.2.5 The sensitivity of investment to cash flow - empirical literature review

Overall, whether financing frictions affect real investment decisions is an important matter. The relationship between a firm financing constraints and investment–cash flow sensitivity has taken prominent place in the finance world in recent years. Extensive empirical literature highlights the existence and robustness of investment-cash flow sensitivity after controlling for investment opportunities. The majority of this literature links investment-cash flow sensitivity to imperfections in the capital market. The view is that firms facing tighter financing constraints, i.e., a larger cost differential between internal and external funds, have to rely more on internal cash for making investments. Amongst others, Devereux and Schiantarelli (1990) have followed and extended these notions. They examine a sample of UK firms to see whether different cash-flow-investment sensitivities exist in subsamples based on proxies for agency costs of external capital. The proxies include firm size (capital stock and employees), the number of years since initial quotation, and the industry (growing or declining). The investments of large firms, newly-listed firms and firms in growth sectors show higher cash-flow sensitivities.

Hoshi, Kashyap and Scharfstein (1991) study the cash-flow-sensitivities within a set of Japanese firms, which were categorized into groups– 121 firms (relatively strong ties with bank - members of keiretsu) and non-group – 24 firms (relatively weak ties with banks – not members of keiretsu). The latter ones had a higher cash-flow-coefficient and were presumed to be more financially constrained. The idea is that Keiretsu firms have access to external funds from

the "main bank" of the group, which monitors closely member firms and mitigates information cost in external financing. Hoshi, Kashyap and Scharfstein (1991) indicate the overinvestment importance through the various influences of cash-flow for firms with good and bad opportunities. The latter classification is carried out by considering firms with a Tobin's Q above and below median respectively. Overinvestment has no support in their analysis in terms of the evidence.

Both the analyses by Hayashi and Inoue (1991), who employ data for 687 quoted Japanese manufacturing firms during the period 1977 to 1986, and Blundell et al. (1992), who take into account data for 532 UK manufacturing firms during the period 1971 to 1986, discover that cash flows have a positive and highly significant effect on company investment, in addition to Tobin's Q.

Oliner and Rudebush (1992) studied 99 NYSE listed firms and 21 OTC firms over the 1977-1983 time period. They interact the cash-flow coefficient in an investment regression model with proxies for information asymmetry (firm age, listing at exchange, and stock trades by insiders), agency costs (insider shareholdings and ownership concentration) and transaction costs (firm size). In order to compare with FHP the authors also test for the dividend yield. Despite the fact that for the full sample of US firms the individual interaction terms are insignificant, a compound measure of information asymmetry is significant and achieves the predicted positive effect. Oliner and Rudebush (1992) find that investment is most closely related to cash flow for firms that are young, whose stocks are traded over-the-counter, and that exhibit insider trading behaviour consistent with privately held information. Their conclusion is that financial constraints were worsening due to information conflicts.

To avoid the problems related with the estimation and use of Tobin's Q, Whited (1992) and Bond and Meghir (1994) use an Euler equation approach to directly test the first-order condition of an inter-temporal maximization problem. Another advantage of this model is that it controls for the impact of expected future profitability in investment spending without the need for an explicit measure of expected demand or expected costs. FHP outcomes are supported by both studies.

For Canadian firms Schaller (1993) provide evidence that the cash flow effects are more pronounced for young firms, firms with dispersed ownership, and nongroup firms. Two years later Chirinko and Schaller (1995) for a set of

Canadian firms, divide the sample according to age (years of inclusion in a financial database), concentration of ownership, industry (manufacturing and other), and group or independent. Their studies demonstrated that the cash flow constraints were most articulated in young firms, firms with dispersed ownership, independent firms and manufacturers. Furthermore, Gilchrist and Himmelberg (1995) detect a group of US firms and discriminate subsamples on the basis of size, dividend payout ratio and the availability of rating for bonds and commercial papers.

Hubbard, Kashyap and Whited (1995) imply that identified connections between investment expenditures and internal financing may refer to the overinvestment of managers. Jensen (1986) suggests that in mature industries overinvestment is expected to be relevant. The definition of mature industries is based on profitability and 39 four-digit S.I.C. industries. In these mature US firms, agency costs do not seem to be important for business fixed investment after employing Euler equations. Vogt (1994) involve an interaction term between Tobin's Q and cash-flow in the regression equation in order to empirically distinguish between managerial discretion and asymmetric information. In the context of the US firms' sample he uses, there is strong evidence for the presence of managerial discretion as well as the influences of asymmetric information which cannot be ignored. Both problems are appearing to be reduced by dividends. Hadlock (1998) tests the effect of insider ownership on the cash-flow-sensitivity of investment based on both free-cash-flow problems and asymmetric-information problems. For insider ownership below 5%, an interaction term of cash-flow and insider ownership is found to be positive, while for insider ownership above this threshold is found to be negative. Hadlock (1998) comes to the conclusion that the findings are consistent with asymmetric-information conflicts but are inconsistent with the free-cash-flow theory. In other words, the sensitivity of investment to cash flow seems to be more highlighted when managers have a large ownership stake in the firm. This is consistent with the asymmetric information story, but not the agency story in its simplest form. The results of Morck et al., (1988) suggest that the agency explanation holds where there is low or high levels of managerial ownership, but not for an intermediate level of managerial ownership. Erickson and Whited (2000), Gomes (2001), and Alti (2003) all show that the results reported by FHP are consistent with models in which financing is frictionless. Both the studies of

Fohlin (1998) and that of Audretsch and Elston (2002) based on German firms samples find that accordingly during the 1903-1913 and 1970-1986 periods, greater cash flow-investment sensitivity is observed for liquidity constrained German firms.

Other researchers that support or use FHP methodology are Fazzari and Petersen (1993), Himmelberg and Petersen (1994), Calomiris and Hubbard (1995), Kadapakkam et al. (1998), Fazzari et al. (2000), and Allayannis and Mozumdar (2004).

A large number of empirical studies confirmed higher ICFS for firms facing tighter financing constraints by employing various proxies for financing constraints. This approach had freely functioned in the corporate finance world until Kaplan and Zingales (1997) (hereafter KZ) queried it in an influential paper which delivers utterly opposing evidence that investment is more sensitive to cash flow for unconstrained firms. They employ a mixture of qualitative and quantitative information obtained from company annual reports to rank each firm in terms of its apparent degree of financial constraint. KZ reanalyze the sample of low dividend payout firms examined by FHP. Specifically, their evidence was from the low dividend payout subgroup of the FHP 1970-1984 sample, FHP categorized 49 firms as the most constrained by putting into service information contained in the firms' annual reports and management's statements on liquidity. Whilst, based on statements contained in annual reports, KZ classify firms into groups: "not financially constrained," "possibly financially constrained," and "financially constrained". They deliver a result contradicting FHP finding, namely they discover that the group of "financially constrained" firms actually demonstrates the lowest sensitivity of investment to cash flow of the three groups. Based on their outcome, they argue that investment-cash flow sensitivities do not provide any evidence of the presence of financing constraints. Furthermore, KZ (1997) disagree with FHP (1988)'s classification scheme on the basis that a firm's dividend policy is a choice variable, thus firms are not necessarily financially constrained when they choose to pay out less even though they could pay high dividend. For instance, in reaction to a decrease in the personal dividend income tax rates firms may raise dividends. They recognize firms that have more funds than needed to fund their capital expenditures as 'never constrained' and if they have no access to more finance than needed to fund their investment as 'likely constrained' by employing

qualitative and quantitative information from financial statements and reports. Their results point out that the investments of 'never constrained' firms are more sensitive to cash flows than the investments of 'likely constrained' firms, which is a complete contrast to the findings of FHP (1988). KZ (1997) argue that the presumably financially constrained firms could have augmented their use of cash and lines of credit at a particular moment in time. They also argue that the *monotonicity hypothesis* is not a necessary property of optimal constrained investment.

The main issue with KZ's (1997) work, which is pointed out by their critiques was their small sample size and their classification criteria. FHP (1997) and Schiantarelli (1995) contend that the criteria depend on "managerial statements about liquidity that may be self-serving and problematic and somewhat subjective operational definitions of what it means for a firm to be financially constrained." FHP (1997) also highlight that categorized by KZ (1997) the firm-years observations as most financially constrained are in fact observations from years when firms are financially distressed. FHP (1997) stress that KZ (1997) designed the sample, which excludes financially distressed firms, hence very few observations belong to the category KZ (1997) label as "constrained." Consequently, the sample is homogeneous and thus lacks sufficient heterogeneity to identify meaningful differences across their sample. However, KZ empirical result is supported by other empirical papers too. For example, Kadapakkam et al., (1998) demonstrate that when financial constraints are measured by firm size, financially unconstrained firms have higher investment-cash flow sensitivities than constrained firms. Cleary (2006) after analysing the empirical results of seven different countries, provides the evidence that financially constrained firms have lower investment-cash flow sensitivity than financially unconstrained firms. Dasgupta et al. (2009) show that even when a long-time horizon is taken into account, the negative relationship between financial constraints and investment-cash flow sensitivity still holds.

The results of KZ (1997) are puzzling because they imply that firms decide to depend firstly on internal cash flow for investment, in spite of the availability of additional external funds. Cleary (1999) continues this puzzle and also supports KZ's results by employing more recent and clearly heterogeneous data (1987–1994). He tests a large cross-section (1317 US firms), and by a discriminant score estimated from several financial variables measures financing

constraints. In particular, he divides firms according to financial variables that are linked with financial constraints. Multiple discriminant analysis, similar to Altman's Z factor (Altman, 1968) for predicting bankruptcy, determines financial status of the firm. Cleary (1999) study follows KZ's (1997) approach by categorizing firms into three different groups: financially constrained (FC), partially financially constrained (PFC) and not financially constrained (NFC). Whilst opposite to previous studies, Cleary (1999) introduce reclassification of firm financial status in every period, and proposes that the groups' composition may vary over time to reflect changing levels of financial constraints at the firm level. Cleary surely improved on KZ (1997)'s methodology. His results indicate that whilst all firms are very sensitive to firm liquidity, in line with KZ (1997) outcomes, firms that are more creditworthy show higher investment-liquidity sensitivity than those categorized as less creditworthy. Simply saying, Cleary finds that the cash flow coefficients are largest for the NFC firms, supporting the findings in KZ.

KZ and Cleary find that the relation between sensitivities and liquidity measures is non-monotonic. They state that financially constrained firms in fact show up a lower sensitivity of investment to cash flow than unconstrained firms. Similarly, asymmetric information does not appear to be a plausible explanation for the "socialistic" allocation of internal funds from a cash windfall within firms or the poor quality of projects financed with those funds (Lamont (1997) and Blanchard et al., (1994)).

The continuation of the discussion on the usefulness of cash-flow-investment sensitivities appears again in FHP (2000) and KZ (2000). Even though the result of the discussion is indecisive, KZ demonstrate that the outcomes of analyses in which the approach of FHP is employed, should be interpreted with caution.

In the response to KZ, FHP (2000) underestimate KZ inferences by pointing out that gross investment cannot be below zero even when firm cash flows are extremely low or negative. Moreover, by definition, the more restricted access to external financing encounters the more constrained firm, thus they face this minimal investment level much quicker. Therefore, when internal cash flows reach a particularly low stage, the less constrained firm is likely to show higher investment–cash flow sensitivity than the more constrained firm. FHP (2000) claims that KZ (1997) and Cleary (1999) used methodology which tends

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to categorize financially distressed firms as being financially constrained. KZ (2000) claimed in their response that the distinction between financing constraints and financial distress is not important. Another important indication by KZ (2000) is that investment cash-flow sensitivities should not be expected as a good measure of financing constraints.

This above short discussion emphasises the controversy that has been generated here. Opposing views of the impact of financial constraints on the cash flow-investment relationship have been supported with empirical literature. A stronger relationship for the most financially constrained firms is supported by one subgroup of finance literature while another counterpart subgroup supports a stronger relationship for the least constrained firms. Another subgroup of research in this area has concentrated on reconciling the two sides of the debate.

As the previous literature indicates, moral hazard together with adverse selection will evolve credit rationing, where external markets might be totally inaccessible by firms. In terms of the debate on cash flow-investment sensitivity referred to the level of financial constraint, the general assumption is that firms which are financially constrained are those which face greatly expensive external capital costs to finance a project, while the unconstrained firms can access external markets with no/little problems. Constrained firms may find that the main source of financing is internally generated cash flow and its availability may affect the firm's ability to invest. However, access to the external market may be totally unavailable for some of the most constrained firms because off the moral hazard problem. Equally, partially constrained and non-constrained firms whose investment relies on external financing and which confront costly external costs of funds will regard increases in internal cash flow as beneficial since more low-cost funds become available for investment. This field of research considers different predictions of cash flow-investment sensitivity than those of FHP and KZ (1997), and implies a U-shaped association.

Povel and Raith (2001) offer a theoretical model predicting a U-shape relation between investment and cash flow, which is supposed to explain the findings of KZ. They analyze the optimal investment under financial constraints. Firstly, they define the financially constrained firms as firms suffering from imperfections in the capital markets when searching for outside capital. Next, the study defines "more financially constrained" firm as a firm, which either need

more external capital, or it faces a higher cost of raising any given amount in the capital market. Effectively, the authors argue that a firm's financial constraints depend on both the imperfection of the external market and the level of its internal funds.

Theoretical papers of Almeida and Campello (2001), and Povel and Raith (2001) argue that the relationship between cash flow and investment may not be monotonically increasing across firms with different liquidity constraint levels, but may be U-shaped. According to Povel and Raith (2001) large negative cash flows lead to the complex influences of asymmetric information and the financial distress, to which firms response in the U-shape. Povel and Raith (2001) find that more information asymmetry generally increases the investment-cash flow sensitivity. Their solution for accurate assessment of the effect of asymmetric information on investment – cash flow sensitivities is a sensible choice of sample splitting criteria, or getting rid of firms that have large negative cash flows from the sample, or both. We include their recommendations in our empirical analysis.

The theoretical approach to examine the puzzle is demonstrated by Almeida and Campello (2002). They claim that the existing interpretation of the relationship between investment and cash flow assumes that financial constraints translate entirely into higher costs of funds. Nevertheless, they stress that firms often have to deal with quantitative limits such as credit rationing, and the firms' investment and the use of external finance are endogenously related. These researchers contend that the direct effect of a cash flow shock on investment would be similar for all firms (one for one), since constrained firms invest all of their internal funds, while the indirect effect would be different because of the endogenous change in borrowing capacity, and given the change in investment, it will be greater for firms that can borrow against a higher proportion of the value of their investment. A theoretical model was developed by Almeida and Campello (2002) predicting that the investment-cash flow sensitivity increases as the credit constraints are relaxed.

Lhabitant and Tinguely (2002) examines Swiss firms during both boom and recession periods. The researchers discover that when boom time is regarded, investment-cash flow sensitivities are homogeneous as in KZ (1997), while when the recession time is a focus, this relationship is heterogeneous with the sensitivity increasing monotonically, and with financing constraints, as in FHP (1988).

The disagreement on the cash flow-investment sensitivity of firms with different levels of financial constraint evolved various attempts to resolve the contradicting results of FHP (1988) and KZ (1997). Particularly, the focus on how to define a firm as financially constrained versus not financially constrained engaged a major portion of the theoretical papers. Maestro et al. (2000) and Moyen (2004) concentrate on finding a better way to distinguish less financially constrained firms from more financially constrained ones. To identify financially constrained firms from unconstrained firms Maestro et al. (2000) develope a dichotomous separation model. They conduct their study by using international data and argue that their method better categorizes firms as financially constrained and not financially constrained.

Alti (2003) and Moyen (2004) estimate firms' models that substitute internal finance with debt and run OLS regressions on simulated data from the models to show that ICFS can be generated even if firms do not face financing frictions and that it is difficult to unveil firms with financing constraints, and the investment-cash flow sensitivity crucially depends on the classification procedure employed. Certain methods of financial constraint classification present high sensitivity between investments and cash flows, while others, demonstrate just the opposite. For example, Moyen (2004) proposes that different standards by which firms are classified into constrained and unconstrained groups can be made and this may lead to outcomes compatible either with FHP (1988) or with KZ (1997). Simply saying, Moyen (2004) asserts that the opposing outcomes of FHP (1988) and KZ (1997) originate mainly from their different criteria for financial constraints. Specifically, the models developed in Moyen (2004) suggests that the relationship between investment and cash flow for firms that pay low dividends and do not have access to external capital markets should be consistent with FHP (1988), while the relationship for firms that pay high dividends and which have access to external markets should support KZ (1997) and Cleary (1999).

Also Cleary et al. (2007) point out that one strand of the literature have used variables that proxy asymmetric information as the criteria to distinguish between financially constrained and unconstrained firms. Some examples of this strand may have included: firms belonging to Keiretsu or not (Hoshi et al., 1991), NYSE firms vs. OTC firms (Oliner and Rudebush, 1992), bond rating (Huang, 2001), firms followed by financial analysts (Liu and Qi, 2001),

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commercial paper and bond market access (Gilchrist and Himmelberg, 1995). Another strand of the literature employs variables (indexes mentioned below) that asses the firm's liquidity or its financial strength. Cleary et al. (2007) argue that if the data set consists mainly of positive cash flow large firms and the measure to differentiate financially constrained firms from unconstrained ones proxies for asymmetric information (i.e. market imperfection), then test outcomes will be in agreement with that of FHP (1988). Further, Cleary et al. (2007) claim that if the firm's financial strength measures are employed, results are likely to be aligned with those of KZ (1997) and Cleary (1999). The work of FHP (1988) and Cleary (1999) have been replicated by Cleary et al. (2007) who used the same data but with different methodologies and received the predicted results.

Guariglia (2008) studies the extent to which the sensitivity of investment to cash flow differs as firms facing different degrees of internal and external financial constraints. They find that when the sample of UK firms is split on the basis of the level of internal funds available to the firms, the relationship between investment and cash flow is U-shaped. However, the sensitivity of investment to cash flow tends to increase monotonically with the degree of external financial constraints faced by firms. After combining the internal with the external financial constraints, Guariglia (2008) discovers that the dependence of investment on cash flow is strongest for those externally financially constrained firms that have a relatively high level of internal funds.

Carreira and Silva (2010) in their review of recent empirical work on financial constraints faced by firms, recommend "the best that one can do is either to use *a priori* firm classification and/or to construct indexes that allow one to measure the degree of constraints that, in their turn, use proxies such as (a) dividend payout ratio; (b) firm self-evaluation; (c) cash stocks; (d) degree of leverage; (e) age, size; (f) institutional affiliation; (g) credit ratings." The current literature provides a few examples of indexes, such as: (a) a discriminant score estimated from several financial variables by Cleary (1999), (b) the KZ index developed by Lamont *et al.* (2001) and based on the argument of KZ (1997), (c) the WW index suggested by Whited and Wu (2006), (d) the index created by Musso and Schiavo (2008), (e) the size–age or SA index proposed by Hadlock and Pierce (2010).

Additional papers in this area have concerned themselves with data and methodology issues. Allayannis and Mozumdar (2001) argue that the

anomalous results reported by KZ (1997) and Cleary (1999) are due to the negative cash flow observations. Accordingly, the KZ results are driven by the outliers in their small sample and Cleary's results are driven by negative cash flow observations. For example, Allayannis and Mozumdar (2004) employ a similar sample and the same discriminate analysis as Cleary (1999) in order to reinvestigate Cleary's results. They obtain the same major findings, such as financially constrained (hereafter FC) firms have the lowest sensitivity of cash flow. However, they recognize that FC firms contain more negative cash flow observations than the less constrained firms' category. Once they dropped these observations, they receive a strong increase in the coefficient of cash flow for the FC class, but still the same coefficients for cash flow across the remaining groups. Consequently they conclude that the firms with negative cash flows included in the sample may be the reason for KZ and Cleary findings, because these firms are distressed financially and hence their investments are not sensitive to cash flow. Specifically they write in the following way about low ICFS amongst firms with negative cash flows: "when the cash shortfall is severe, the firm is pushed into financial distress and is able to make only the absolute essential investment," and thus "any further cutback in investment in response to further declines in cash flow is impossible" Allayannis and Mozumdar (2004, p. 902). Furthermore, their study proposes that investment-cash flow sensitivities have been declining in recent years and the authors come up with two explanations for this, namely the improved external market efficiency or the increased supply of external funds. Huang (2001) also states that sample selection problems could explain the different results in the previous literature. He takes into account the data employed in several papers that generate different results and summarizes them, then he claims that most of the data used in the previous papers may not be representative because it is biased towards large firms. This data selection bias, according to the author, is the reason for differences in prior results and the monotonic relationship between cash flow and investment collapse when pooling the financially constrained and unconstrained firms in the tests.

Hovakimian and Titman (2003) took a different route and detected the importance of financial constraints for a firm's investment expenditure by studying the relationship between investment and proceeds from voluntary asset sales in financially healthy US manufacturing firms. They claim that because the

proceeds of asset sales are not positively correlated with a firm's investment opportunities, they appear to be a cleaner indicator of liquidity than cash flow. They also apply the model of an endogenous switching regression with unknown sample separation, which does not require an *a priori* classification of firms. They find that cash raised from asset sales is a significant determinant of corporate investment, and the sensitivity of investment to proceeds from asset sales is significantly stronger for firms that are relatively financially constrained.

A firm's dynamic investment decision, subject to an endogenous financing constraint, has been investigated by Boyle and Guthrie (2003). They argue that firm's investment behaviour can be distorted by capital market frictions. They find that the threat of future funding decreases the value of the firm's timing options of investment, suggesting that the cash flow - investment sensitivity can be highest for high-liquidity firms and greater uncertainty has an ambiguous effect on investment.

Gilchrist and Himmelberg (1995), Erickson and Whited (2000) and Alti (2003) state that the assessed sensitivity of investment to the availability of internal finance is influenced by the measurement problems linked with Tobin's Q. Therefore, they made an effort to recognize the impact of capital market imperfections on investment by using alternative measures of investment fundamentals, rather than employing Q as a measure of investment opportunities. Such as Gilchrist and Himmelberg (1995) assessed a group of VAR forecasting equations for a subgroup of information available to the firm, and subsequently on behalf of a measure of firms' investment opportunities they evaluated a linear expectation of the present discounted value of marginal profits. They then appraised regressions of investment on the latter variable and cash flow followed. Once the new variable is built in the investment regression, imperfections of the capital markets exist if the coefficient on cash flow as forecasting variable included in this new measure of investment demand stays significant. Their outcomes obtained after examining US data demonstrate that the neoclassical model (without cash flow) is only valid for firms less likely to face financial constraints, while cash flow is significantly built in the regressions of constrained firms. These results are in agreement with those in FHP (1988).

To certain extent this misunderstanding of FHP versus KZ comes from difficulties in measuring investment opportunities. If investment opportunities are measured wrongly, then cash flows, in addition to conveying information about

internal liquidity, can also cover information about future investment opportunities that are not picked out by proxies for q. Since the measurement of q include firm market value, this effect is likely to be more serious for firms suffering from information asymmetry problems, which are also the firms that are most likely to be financially constrained. In consequence, higher estimated coefficients of cash flow in investment regressions for firms *a priori* grouped as financially constrained can be expected.

To solve this problem many different notions have been applied. One of them is to find shifts in a firms' internal funds that are uncorrelated with shifts in investment opportunities (e.g. Lamont (1997), Hubbard, Kashyap, and Whited (1995), and Fazzari and Petersen (1993)). Generally the results for these imply that investment is positively related to the firms' internal capital that is not correlated with their future profitability.

GMM estimators that make the best use of the information in the higher order moments of the regression variables is offered by Erickson and Whited (2000, 2002) as a solution for the problem of the measurement error emphasised in their critical commentary. They introduce these estimators in the examination of a sample of US manufacturing firms from 1992-1995 period of time, they recognize that in comparison with conventional OLS estimates, Q explanatory power improves substantially, while cash flow as a determinant of investment loses significance.

Gomes (2001) and Alti (2003) claim that sensitivity of investment-cash flow canld be positive even with no financial frictions. Gomes (2001), and Cooper and Ejarque (2001) also challenge the theoretically hypothesis that financial constraints existence can be stated by a significant coefficient on cash flow in an investment reduced-form regression.

Charlton et al. (2002) find that the relationship between financial constraints of a firm and its investment-cash flow sensitivity depends on the industry of the firm.

Financially distressed firms show a negative ICFS in the study of Bhagat et al. (2005), where after splitting the sample of distressed firms according to the sign of operating incomes: positive and negative, firms with negative operating incomes are the reason for the overall negative ICFS.

Rauh (2006) however, brings new evidence that as internal finance decrease because off mandatory pension contributions, capital expenditures drop down as well.

Carpenter and Guariglia (2008) show that when the insiders' evaluations of investment opportunities are considered in the model, then financially constrained firms have higher investment-cash flow sensitivity.

Another alternative understanding of the contradictory relationship between financial constraints and investment-cash flow sensitivity comes from the study of Almeida and Campello (2010). The authors imply that high-costs external financing plays a differential role between financially constrained and unconstrained firms. Consistent with the assumption of previous literature, the internal cash flow and outside financing are substitutes for unconstrained firms. Hence, when reducing costly outside financing, investment-cash flow sensitivity increase in terms of the unconstrained firms. Nevertheless, when reducing costly outside financing, the constrained firms decrease the amount of internal funds as their source of investments. Therefore, usually constrained firms have a low level of cash flow. Only when they have enough cash flow and outside financing at the same time can they make investments. Thus, for these financially constrained firms, internal cash flow and outside financing complement one another. This explanation leads to a conclusion that the constrained firms have lower investment-cash flow sensitivity than unconstrained firms.

Another avenue of research in this area is represented by papers conducting tests on the interaction between cash flow and other factors, which can be related to the firm's investment decision. The impact of various factors on the investment-cash flow sensitivity is explained by the cash flow augmented investment equation. Almeida and Campello (2007) analyse the interaction term between cash flow and asset tangibility of a firm. They show that for financially constrained firms, asset tangibility increases investment-cash flow sensitivity, while for financially unconstrained firms, asset tangibility does not have a significant effect on the investment-cash flow sensitivity. Agca and Mozumdar (2008) study the interaction between cash flow and the determinants that mitigate capital market imperfections. They discover that investment-cash flow sensitivity declines with increasing fund flows, institutional ownership, analyst following, antitakeover amendments and the existence of a bond rating. A negative association on the coefficient of the interaction term between cash flow

and the probability of information-based trading (PIN, developed by Easley et al., (1996) using a sequential trade microstructure model) was found by Ascioglu et al., (2008). This confirms FHP because it suggests a negative relationship between a firm's information asymmetry and their investment-cash flow sensitivity.

To sum up, because the degree of financial constraint is not observable, different papers use different proxies for financial constraints and obtain different cash flow sensitivity results. A number of empirical studies, after employing various proxies for financing constraints, demonstrate that the estimated investment–cash flow sensitivity is indeed higher for more constrained firms. Examples of some of the proxies for no or only minor financing constraints are: high dividend payments (FHP; Hubbard, Kashyap, and Whited, 1995), bond ratings and access to debt markets (Calomiris et al., 1995; Gilchrist and Himmelberg, 1995), business group affiliation (Hoshi et al., 1991; Calem and Rizzo, 1995; Shin and Park, 1999), banking relationships (Houston and James, 2001), and age and dispersion of ownership (Schaller, 1993), or low surtax margins (Calomiris and Hubbard, 1995), bond ratings and access to debt markets (Calomiris et al., 1995; Gilchrist and Himmelberg, 1995), membership in corporate groups (Hoshi et al., 1991; Calem and Rizzo, 1995; Shin and Park, 1999), banking relationships (Houston and James, 2001), and age and dispersion of ownership (Schaller, 1993). In line with the notion that the correlation between investment expenditures and cash flow is because of financing constraints, researchers have identified that the sensitivity of investment expenditures to cash flow are much stronger for firms that are likely to be financially constrained (FHP; Hoshi et al., (1991); Whited (1992); Gilchrist and Himmelberg (1995); Hubbard (1998); and others). Additionally, the previously contradictive results in empirical research seem to be driven by choice of the measure to categorize firms into financially constrained and unconstrained firms' groups as well as whether the data samples exclude observations with negative cash flow.

2.3 Methodology

In this chapter we present hypotheses and the methodology utilized in this study. Then we explain the approach used in characterizing constrained and unconstrained companies.

Firstly, this study employs year by year OLS analysis in order to examine if there is a decline of ICFS by year. Then cross sectional analysis are used to better understand what happened before and during the financial crisis period. OLS analysis of the three subperiods is included too. Lastly, the focus lays down on the analysis of GMM technique.

2.3.1 Hypotheses

We propose four main hypotheses for this chapter.

The development of capital market should reduce the marginal cost of external finance, leading to a reduction in the ICFS (Brown and Petersen, 2009). This leads to the following hypothesis:

H1: Given the development of equity market over the last thirty years, the ICFS is expected to decrease over the last thirty years, *ceteris paribus*.

Hall and Lerner (2010) and Islam and Mozumdar (2007) argue that in the presence of market imperfections, external funds may not provide a perfect substitute for internal funds, given that the premium for external financing will be higher. Financial crisis should increase the marginal cost of external finance, leading to a rise in the ICFS. This leads to the following hypothesis:

H2: Other things equal, financial crisis should lead to an increase in the ICFS.

H3: Other things equal, cash holdings are positively related with capital investment given that cash is an effective hedging device.

H4: Given the development of equity market over the last thirty years, leverage has a negative impact on investment, *ceteris paribus*.

2.3.2 Financial constraints criteria

FHP claim that ICFS would identify the financial status of a firm. Since FHP (1988) and KZ (1997), the debate on the consistency of ICFS as a measure of the degree of financial constraints has been intensive in the literature and is still open for discussion. The definition and the measurement is the starting point when examining financial constraints. If one considers a 'classical', more straight forward, but broader definition that a firm is financially constrained if there exists a wedge between the costs of using external and internal funds (see, for example, KZ, 1997), and then strictly speaking all firms can be labeled like this. Notwithstanding, the concept of financial constraints extends into the inability of a firm or a group of firms to raise the necessary amounts (usually due to external finance shortage) to finance their optimal line of growth. Put differently, financing constraints refer to the difficulty of raising external financing, or the cost differential between internal and external funds. [11] Consistent financial constraints categorization is a central issue of ICFS analyses. "Financial constraints are an abstraction, so researchers use proxies and indexes that allow them to identify and measure the degree of constraints." (Carreira and Silva, 2010).

This study is interested in the relationship of investment and cash flow itself over time as well as in examining this relationship after firms' division into financially constrained and unconstrained groups in order to test the empirical implications of the model. Similarly to the work of FHP (1988), the standard approach in the literature is to use exogenous sorting conditions that are hypothesized to be associated with the extent of financing frictions that firms face (e.g. Whited and Wu (2006), Campello et al. (2009), Fee et al., (2009) and Almeida and Campello (2010), for recent examples of this strategy). Brown and Petersen (2009) split firms based on the number of years since their first stock price appears in Compustat, typically the year of their IPO - age. They also report

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[11] For instance, Lamont et al. (2001) employ negative real sales growth as a proxy for financial distress.

separate results for positive and negative cash flow firms. In terms of robustness checks they sort firms based on whether they have a positive net payout during the sample period and also according to firms' size.

To aid in the comparability of our results with those of BP (2009), we also use the more traditional *a priori* firm classification approach to test our theory.

The set of variables we consider borrows directly from Hovakimian and Titman (2006) and is also extended to other variables. The proxies included seem to naturally capture different ways in which financing frictions may be manifested. For example, this set of variables includes a firm's size (proxied by the natural logarithm of total assets), a firm's age based on the number of years since their first stock price appears in Datastream, in other words the year of their IPO, a firm's sales growth and a firm's dividend payment (proxied by dividend ratio). Furthermore, we also control for firm's negative and positive cash flows.

In the traditional literature, these variables are used individually as *a priori* measures of firm constraint category assignment. The next subsection explains that approach in more detail.

However, we also attempt to combine three specific variables together in order to explore better measure of financing constraints. Specifically, we develop simple measure of firms' growth by referring to firms' size and age. Firstly we find the rate of growth of firms' size - measured this time by net sales, from one year to the subsequent year. Then we calculate the average of those firms' size changes from one year to another. On the basis of the median of this average of firms' size increments over time we classify firms as financial constrained and unconstrained. Lastly we compare firms above and below the median of this size growth measure with the firms' age and size (measured by natural logarithm of total assets).

In line with Lamont et al.'s (2001) approach stating that in order to be constrained, a firm needs to have good investment opportunities, we define constrained firms when their size and age are below the sample's median and sales growth is above the sample's median. Unconstrained firms though have size and age above the sample's median but sales growth below the sample's median. The sample of firms with size, age and sales growth below the sample's median should include firms most likely to be financially distressed. The last sample of firms with size, age and sales growth above the sample's median should represent spurious issues. On one hand large and mature firms are

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classed as unconstrained firms. On the other hand, financial constraints literature dictates that firms with high growth opportunities are constrained.

However, this combined measure firms' division into constrained and unconstrained groups may follow the contrasting philosophy that firms are unconstrained if their age growth raises positively and fast enough with their size growth in relation with firms' sample, but constrained if their age growth does not reflect their size growth in relation with firms' sample. In line with this approach we classify firms as financially constrained if they are young, small and below the median of the size growth measure, less constrained if they are young, small and above the size growth median as well as mature and large firms with the speed of the size growth below the sample median and finally unconstrained firms when they are mature with size growth above the sample median. Although there are two groups of firms in this classification named as less constrained, we hypothesize that group of large, mature but slowly growing firms is more constrained than group of small, young and quickly growing firms.

Several studies consider the evolution of firm size distribution and come up with the idea that growth rates and growth volatility are negatively related with firm size (and age). The financial constraints argument is one of the explanations for it e.g., the presence of financing constraints leads to a skewed distribution of firm size. Consistent with the optimal lending contracts models (Albuquerque and Hopenhayn, 2000), and Cooley and Quadrini (2001) built a model of financial market frictions and propose that smaller firms face higher probability of default, issue more debt and more shares and pay less dividends, and have higher growth rates and volatility. Hence, they assert that imperfect markets will lead to a skewed size distribution of firms.[12]

The contradictive results from FHP (1988) and KZ (1997) have been explained by some later studies on the basis of the disagreement among researcher in identifying appropriate factors to separate less financially constrained firms from more constrained ones (Moyen, 2004; Cleary et al.,

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[12] At the entrepreneur level Cabral and Mata (2003) create a model of heterogeneous constraints and investigate the evolution of the firm's size distribution. They consider only two periods and employ entrepreneur's age as proxy for financial capacity. They claim that a higher probability of being financially constrained applies to younger firms/entrepreneurs. Their findings based on a sample of Portuguese manufacturing firms from 1984 to 1991, imply that age has a significant impact upon the size distribution and, in detail, the younger firms/entrepreneurs are, the greater is the skewness of the distribution explained by the financial constraints. This argument found support in papers of Desai et al. (2003) and Faggiolo and Luzzi (2006).

2007). There are clear drawbacks of the criteria employed to divide firms into less and more constrained classes, e.g. dividend payout ratio, debt financing, financial distress, debt rating, firm size and firm age. The financial constraint feature itself may already influence these firm-specific variables. Furthermore, these classifying factors are time variant in the sense that a company categorized as financially constrained now may not remain constrained in the future.

This speed of firms' size growth does not state what is the average size of a firm over the years, as the 'classical' size classification, common in empirical literature on ICFS does, but in contrast, it shows how fast a firm was growing over time, which gives a clue on how constrained firm was up till now. Therefore, it looks at firms past and assesses how a firm has grown over time despite the possible financial obstacles. When a firm is mature and has high speed of size growth then that should indicate that this particular firm dealt well with financial constraints over time or that their policies and financial and investment decisions were successful. This measure differs from the absolute value of size measure in the sense that the latter one does not control for the fact that firms start from different size levels, hence the small one might be making appropriate policy decisions and "slowly but surely" developing its size (and that might help them in accessing the external funds in the sense that their credit rate estimated by a bank might be higher because of lower risk, hence banks might favour those firms in financing their investment projects against, e.g. mature but hardly growing firms). While a firm with large amount of assets at the start of its listing might be reversing its size slowly, because of undertaking the wrong investment projects or making incorrect decisions about funding them e.g., leading to higher agency costs. For German firms for the period 1970 - 1986 Audretsch and Elston (2002), demonstrate that after the division of their sample into four groups of firms according to their size, they find that the medium size firms show a higher and most significant ICFS. They argue that SMEs in Germany are prevented from facing higher liquidity constraints thanks to a bank-oriented financial system and an institutional set. Very large firms in this analysis do not appear to be liquidity constrained.

Small and young firms suffer more severely from the asymmetric information problems in comparison with their counterparts firms. This occurs because lenders struggle to get necessary information about these firms, such

as the 'quality' of the risk, or they are unable to control over the firm's investment, or because of 'weight' and visibility of such firms. For instance, Jaffee and Russell (1976) and Petersen and Rajan (1995), develop models where under these circumstances, smaller and younger firms are expected to be more credit rationed.

However, for developed countries, Kadapakkam *et al.* (1998), and Cleary (1999) show that ICFS is greatest in the large firm size category and smallest in the small firm size group. These outcomes have been explained by Kadapakkam et al. (1998) as "larger firms have greater flexibility in timing their investments and have more managerial agency problems". Pratap (2003) after taking into account dividend payout ratio proposes that "adjustment costs explain the possible insensitivity of small firms' investment cash flow, as firms do not take major investments before they attain a threshold level of liquidity."

For the period 1980–1992, Carpenter and Petersen (2002) employing a panel of US small firms demonstrate that the typical firm uses relatively little external funds and holds on to all of its income and that for the 90% of firms in their sample, which depend mainly on internal funds, the influence of cash flow on growth is above the unity, indicating that the growth of most small firms is constrained by internal finance. Carreira and Silva (2010) summarize that "even if for constrained firms cash flow is independent of size, then growth will be independent of size, but the variance of growth rates will decline with size as larger firms appear to be less constrained to internal finance." The supporting evidence for this notion can be found in Oliveira and Fortunato (2006) who after examining a panel of Portuguese manufacturing firms (1990–2001) demonstrate that smaller firms' growth are more sensitive to cash flow suggesting that such firms suffer from financing constraints.

Overall, firms do not face costly external funds or its shortage only because of market they deal in. Intuitively one can state that firms' acting, such as internal or external funds management, also contributes into the constraint or unconstraint firm's position. Therefore, observing firms' speed of size growth according to their age indicates whether a firms' management has well assessed and predicted the market moves and trends as a background of their firms' development and maximization of firms' shareholders interest.

All firms in the sample of this study employ debt finances, so the division cannot be criticized on the basis that some firms might have been only growing

due to successful management of internal funds. A firms' age could be considered as a bias of the combined measure, but in fact the firms in the sample are at the minimum four years old, which gives the market the basis for stating if the firm is doing well or not. Moreover these firms are UK listed firms, which means that those firms have already achieved a certain level of performance.

2.3.3 The standard regression model (ex-ante constraint selection)

The standard empirical approach uses ex-ante firm sorting into constraint categories and least square estimations of investment equations, separately for each constraint regime. We also use this approach in our tests on investment, implementing the ex-ante separation schemes discussed in Almeida et al. 2004):

Scheme 1: We rank firms based on their age and assign to the financially constrained (unconstrained) group those firms in the bottom-50th percentile (top-50th percentile) of the age distribution. Firms are not able to switch between young and mature groups within a given subperiod.

ICFS literature employs firms' age which is an important determinant of its performance variability.[13] On average, small firms are younger than large firms, and hence their lack of experience, e.g. industry experience, in comparison with their large counterparts, this explains their financially constrained growth and the increased odds of failure of small firms in the industry. Young firms without established reputations may have a harder time raising external finance (Diamond (1991); Baker et al. (2003)).

The age of the firm is potentially strongly correlated with asymmetric information problems and it is usually employed by the researchers as a proxy for the existence of financing frictions (e.g., Rauh, 2006; Hadlock and Pierce (2010); Brown et al., 2009; Fee et al., (2009)). Additionally, the effect of developments in capital markets should be most important for firms in the starting time of their life-cycle. Mature/older firms have a well set up opinion in the market, which allows them more beneficial access to external finance, due to

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[13] Sakai et al. (2010) study how firms' borrowing costs evolve as they age. They discover that as firms age their borrowing costs decline and that "the evolution of borrowing costs is partially due to selection (i.e., total borrowing costs decline as defaulting firms exit) but is mainly attributable to adaptation (i.e., surviving firms' borrowing costs decline as they age)".

their established contacts with creditors within a longer time period (Berger and Udell, 1995).

Scheme 2: We rank firms based on their size (proxied by the logarithm of total assets) and assign to the financially constrained (unconstrained) group those firms whose samples' years' average size lies below 50th percentile (above 50th percentile) in the sample. Firms are not able to switch between small and large groups within a given subperiod.

"Firm size is predominantly identified by the extant industrial economics literature as one of the sources of heterogeneity in firm growth." (Rahaman (2011))

The most important issue here is that smaller companies are more likely to be financially constrained as they are subject to higher asymmetric information and agency problems, and hence, have difficulties in obtaining external finance. One of the characteristic and cause identified for the smaller companies is that their struggle to raise outside finance and are enforced to depend only on internal finance therefore their growth is constrained. If financial systems are not working correctly then this matter would be further sharpened.

Scheme 3: We rank firms based on their dividend payout ratio and assign to the financially constrained (unconstrained) group those firms with zero (positive) dividend payout ratio over firm year observations for the whole sample. Firms are not able to switch between paying and not paying dividend groups within a given subperiod.

Following FHP (1988) we stick to the theory that dividend paying, as against to non-dividend paying companies, are less likely to be financially constrained since they are able to shorten or stop dividends whenever their ability to access external financing becomes conflicting or impossible. Yet, this variable should be considered with caution due to the fact that cutting dividends for the sake of liquidity can also have opposite signalling impacts for the firm's stock in the market (e.g. Healy and Palepu, 1988).

Scheme 4: We rank firms based on their sales growth from one year to another and assign to the financially constrained (unconstrained) class those firms in the bottom 50th percentile (top-50th percentile) of the sales growth distribution for the whole sample.

High sales growth firms are likely to have valuable investment opportunities stemming directly from their beneficial acting in past, so

underinvestment problems should appear in high sales growth firms. Low sales growth firms are less likely to have valuable investment opportunities, so they should suffer from overinvestment problems.

Scheme 5: Finally we also divide firms into two groups according to cash flow sign: firms with negative (positive) cash flows.

We also estimate separate regressions that capture only positive cash flow firms on the average over ten years period and regressions that covers only firm observations with negative cash flow on average over ten years period. Put differently, for each firm we calculate the sum of the cash flow ratio during the subperiod and if the sum of the firm's cash flow ratio during the period is less than or equal to zero the firm is classed as a negative cash flow firm.[14] Firms are not able to switch between negative and positive cash flow groups within a given subperiod. This split relates to Povel and Raith (2001), who argue that the association between investment and cash flow is in U-shape and only expected to be positive when firms have positive cash flows. Further, Allayannis and Mozumdar (2004) and Bhagat et al., (2005) indicate that negative cash flow observations can bias the results because the investment expenditures of firms are unlikely to respond to cash flow changes when they are in sufficiently bad shape. The implication of this possibility for our results may prove to be significant if, for example, there are firms among the so called flexible firms with negative cash flow observations.

2.3.4 Four way split

Taking into account the size of the sample we have also decided to split firms into four categories of the same size according to the same measures mentioned above, namely 1st quarter: up to 25th percentile, 2nd quarter: 25th – 50th percentile, 3rd quarter: 50th – 75th percentile and 4th quarter: above 75th percentile. This has been introduced in order to specify or define constrained and unconstrained firms in more detailed way, which is to better observe more particular changes and better control for such a big sample. The advantage of four-way sample split is that it controls better for firms which are on the edge of

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[14] Brown et al. (2009) and BP (2009) apply similar method of differentiating between negative and positive cash flow firms.

being financially constrained or financially unconstrained. The first 25 percent of the sample should clearly represent the constrained firms, the last 25 percent of the sample should clearly include the unconstrained firms, while the 50 percent of the sample in the middle could be constrained or unconstrained. Very often researchers in the process of splitting the sample into constrained vs. unconstrained categories introduce various ideas to get a better clear cut between constrained and unconstrained firms, e.g. they neglect the 10 percent of the sample from the very middle (see Florackis and Ozkan, 2004) or divide firms into three classes (see FHP, 1988). Furthermore, due to various changes in the capital market observable in recent years, a greater share of firms shows negative cash flows, which may confound the results. Hence, the division of the firms into four quartiles may be able to control for these firms better. Also, as mentioned above, the four-way split is introduced because of very extensive data in terms of the number of firm year observations and time period data is collected for. Usually, researchers work with smaller samples in effect of very robust cleaning procedures, such as e.g. removing 5 percent of data from the bottom and top of data distribution for each variable in the model, eliminating firms with total assets or sales below 1 or 10 mln units, getting rid of firms with negative sum of cash flows over years or dropping firms with less than 6 consecutive years observations etc. Very modest cleaning procedures have been applied to the sample for this study, therefore, it is left with very robust data. Owing to this, the sample requires some extra divisions in order to control sufficiently for various aspects. Hence, the detailed sample split is carried out.

Furthermore, we also estimate results for a four-way division based on size, age and sales growth. Large, mature firms with high sales growth are less likely to have problems of asymetric information. Underinvestment by such firms is most likely due to agency conflicts. In contrary, small, young firms with high sales growth are more likely to underinvest due to financial constraints linked with asymmetric information. Another advantage of four way split is that it helps to find firms which are very constrained and firms truly unconstrained. This combined measures related with both proxy for asymmetric informations as well as proxy for firm's financial strength shed more light on the ICFS as a measure of financial constraints.

2.3.5 Base model

Next after FHP (1988), we study the relationship between fixed-investment expenditures and cash-flow. We also include Tobin's Q to capture investment opportunities and industry dummies to control for industry – specific effects as well as time dummies to control for time – specific effects. All in all, we test firstly the following model:

$$INV_{i,t} = \beta_0 + \beta_1\, CF_{i,t} + \beta_2\, Q_{i,t} + \varepsilon_{i,t} \tag{1}$$

where INV is the ratio of capital expenditures to total assets for firm i in period t, CF is the after-tax income before extraordinary items plus depreciation and amortization over total assets and Q represents growth opportunities, expressed by the ratio of book value of total assets minus the book value of equity plus the market value of equity to book value of assets. We want to maintain a common scale factor for all regressions therefore we divide by total assets the same as Baker et al. (2003). We also control for industry dummies and time dummies in all regressions, $\varepsilon_{i,t}$ stands for measurement error. The primary variable of interest in this model is investment. A significant and positive coefficient of CF suggests that companies firstly rely on internal rather than external funds for financing investment, which is considered as a signal of financial constraint. On the other hand, an insignificant estimated coefficient of CF is taken as evidence that firms are financially unconstrained.

2.3.6 Augmented model

The impact of cash holdings on investment decisions

In corporate finance cash stands as an effective hedging device for firms that are expected to be exposed to substantial capital market imperfections. In perfect capital market, investment expenditures are independent of companies' financial policies, including cash policies, due to unlimited access to external capital available to all firms. In the real world capital markets suffer from several significant imperfections containing information asymmetry and agency costs, which lead to a wedge between the cost of internal and external funds. As an

outcome, firms are expected to hold higher cash reserves, because thanks to them they are more able to avoid the necessity of resorting to costly external financing in order to fund valuable investment opportunities.

In general, there are three views in the literature related with cash holdings. The first one states that higher cash holdings of financially constrained firms are a value-increasing response to costly external financing. Higher cash holdings allow the firm to undertake positive net present value projects that would otherwise have been bypassed. For the financially constrained firms greater cash holdings might be more valuable owing to the fact that they allow the firm to invest when other funds sources are too expensive, limited or unavailable. The firm that faces external financial constraints with greater level of cash holdings is able to avoid underinvestment and reduced growth. The second view claims that constrained firms maintain higher cash balances to facilitate empire-building overinvestment. The third one asserts that the greater value of cash for constrained firms is a reflection of the market rewarding the firm for holding cash rather than overinvesting that cash in unprofitable projects. To distinguish between these alternative interpretations, we test whether higher cash holdings are associated with greater investment and whether this association is stronger for constrained than for unconstrained firms over time. In our model cash holdings are used as a measure of internal liquidity, which, similar to cash flow, may directly affect firms' investment.

As emphasized in the literature, cash holdings may permit constrained firms to undertake valuable future investments that they would otherwise have to forego. Denis and Sibilkov (2010) find that for constrained firms cash holdings are more valuable and they present evidence that more cash permits constrained firms to increase investment and that the marginal value of added investment is greater for constrained firms than for unconstrained firms. Brown and Petersen (2009) also provide direct evidence that cash holdings positively influence the real investment spending of constrained firms (but for R&D rather than physical investment).

Overall, a number of researchers have pointed out that internal liquidity apart from its direct impact on firm investment is an important dimension of ICFS capital markets. There is an ambiguous connection between the stock measures of internal liquidity and cash flow sensitivity. One strand of literature argues that firms rich in cash savings are not really liquidity constrained because they can

employ it in order to undertake desired projects (KZ, 1997). Another strand states that firms are not forced to hold high levels of cash reserves unless they encounter difficult access to external capital and predict an internal liquidity shortage. [15] Hence, greater levels of cash holdings may indicate potential liquidity constraints.

Nevertheless, the majority of ICFS studies fail to incorporate the role of cash holdings. According to Luo et al. (2007), Campbell et al. (2008), Lins et al. (2008) and Gamba and Triantis (2008) the cash-holding can be the liquidity reserve for future capital investment. Several papers stress the importance of cash holdings in achieving financial flexibility and decreasing problems of underinvestment. Faulkender and Wang (2006) show that the marginal value of cash is substantially higher for constrained than for unconstrained firms, especially in terms of high growth options firms. Recently Denis and Sibilkov (2010) found that constrained firms are able to undertake value-increasing projects owing to higher levels of financial slack. Their results are consistent with Faulkender and Wang (2006) in the sense that cash holdings are more valuable for constrained than for unconstrained firms. Gamba and Triantis (2008) develop a theoretical model where firms can mitigate the negative influence of financial constraints thanks to an appropriate liquidity policy, although their model ignores agency costs. Nevertheless, Harford (1999) present evidence that the overinvestment problem is more likely to affect the cash rich companies and that these companies tend to make value-decreasing acquisitions. Furthermore, due to the fact that cash-holding is a component of operating capitals which compete with capital investment for funds (Fazzari and Peterson, 1993), the cash holdings can significantly impact the behaviour of the capital investment. We try to tackle all these issues by including cash holding into our augmented investment regressions to control for the potential impact of financial slack. There are several papers which include cash holdings in the investment equation, such as

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[15] Consistent with this argument, Kim, Mauer, and Sherman (1998) show positive correlation between investment in liquid assets and the costs of external financing. Almeida, Campello, and Weisbach (2004) present that financially constrained firms seem to enlarge their cash balances with increases in their cash flows, and that constrained firms' cash flow sensitivity of cash increases during recessions. They argue that "a firm's cash balances and incremental savings out of new cash flows should be a function of the firm's position in the financial market." Subsequently Acharya et al. (2005) come up with similar result through demonstrating that financially constrained companies have a great inclination to save cash out of cash flow. Two latter researches take into account approach that cash reserves increase the capacity and ability of firms to invest.

work of Kadapakkam et al., (1998), Charlton et al. (2002), Dasgupta et al. (2009), Kim (2010) and Marchica and Mura (2010).

<u>The impact of leverage on investment decisions</u>

We also take into account leverage, which has an ambiguous expected effect on investment-cash flow sensitivity and may also more directly influence a firm's capital expenditures. Lang et al., (1996) assert that leverage may impact investment in a number of ways. The amount of cash that can be employed for investment may be reduced thanks to leverage. Excess leverage may also impair a firm's ability to raise additional capital. Myers (1977) claims that the managers of firms with great leverage level may forgo positive NPV projects because some or all of the benefits from the investment may be transferred to debt-holders, i.e. the underinvestment effect. According to Jensen (1986) and Stulz (1990) high leverage in low-growth firms discourages management from undertaking unprofitable investments. A negative relationship between leverage and investment is predicted by these theories. Lang et al. (1996), state that managers may sell assets, in order to provide finances in cases when other finances are either too costly or unavailable. Capital markets as a source of financing might be far too expensive for greatly leveraged or poorly performing firms due to adverse selection costs (Myers and Majluf, 1984) or agency costs of managerial discretion (Jensen, 1986; Stulz, 1990). Lang et al., (1996) study a numerous samples of US assets sales industrial companies within the time 1970 – 1989 and explore the scenario where firms selling assets are characterized by high leverage or poor performance. In other words, they report a strong negative association between leverage and later investment only for corporations with low growth potentials (with Tobin's Q less than one). Their outcomes again agree with the hypothesis that leverage provides a weaker motive to invest in projects with poor prospects. Overall, the typical selling assets firm is motivated by its financial situation rather than by its comparative advantage.

Hovakimian et al., (2001) find that firms with relatively high leverage ratios are reluctant to issue debt since excessive leverage increases the probability of financial distress. Nevertheless, for a certain category of firms, high leverage may also be understood as high capacity of debt and lower financial constraints Hovakimian (2009). This may induce a positive relationship between leverage and investment. Leverage may also decrease the amount of free cash flow,

which may reduce managers' likeliness to overinvest. The former view is supported by the majority of empirical literature. For example, Lang et al., (1996), Aivazian et al., (2005) and Ahn et al., (2006) employing US or Canadian data, all show a negative association between investment and leverage and that the correlation is much stronger for firms with low growth. Aivazian et al. (2005) study overinvestment evolved by a manager–stockholder agency conflict identified by Jensen (1986), where a firm with weak growth opportunities should use debt as a tool to discipline managers, so the overinvestment is reduced in leverage. For a sample of Chinese listed firms, Firth et al. (2008) also find a negative relationship between leverage and investment, but indicate a weaker link among firms with low growth opportunities, poor operating performance, and high level of state shareholding. They assert that this is in line with the hypothesis that the state-owned banks in China impose fewer restrictions on the capital expenditures of low growth and poorly performing firms, as well as firms with greater state ownership.

In this paper we investigate the role of external finance in ICFS regressions by including measures of leverage in our augmented dynamic investment models. We argue that this variable together with internal finances are potentially important omitted variables in most ICFS paper, and their inclusion helps address some concerns related with ICFS interpretation and understanding. Potentially all these variables matter a great deal for investment but are rarely included in ICFS analysis.

We base our empirical analysis on an augmented version of the standard model of capital investment, which is as follows:

$$INV_{i,t} = \beta_1 INV_{i,(t-1)} + \beta_2 CF_{i,t} + \beta_3 Q_{i,t} + \beta_4 Cash_{i,t-1} + \beta_5 LEV_{i,t-1} + \alpha_i + d_t + u_{i,t}$$

$$(2)$$

where INV is the ratio of capital expenditures to total assets for firm i in period t, CF is the after-tax income before extraordinary items plus depreciation and amortization over total assets and Q represents growth opportunities, expressed by the ratio of book value of total assets minus the book value of equity plus the market value of equity to book value of assets. We want to maintain a common scale factor for all regressions therefore we divide by total

assets the same as Baker et al. (2003). We also control for industry and time dummies in this regression, d_t controls for year fixed effects, α_i is a firm specific effect that controls for all time-invariant determinates of INV at the firm level, and $u_{i,t}$ stands for random error term.

Our model takes from Bond and Meghir (1994), who include debt terms, instrumented with lagged values, in a dynamic model of physical investment. We consider cash and debt issues to control for potential omitted variable biases and to estimate the changing role of cash and debt finance for investment.

We also use panel data to examine our predictions. According to Hsiao (1986) a large number of data points and combining features of both cross-sectional and time series data provided by panel data, improves the efficiency of econometric estimates. Thanks to panel data the degrees of freedom are increased, hence there is more variability and reduction in colinearity among regressors and all that lead again to more efficient estimations. Another of the motivations for employing panel data is to control for unobservable firm heterogeneity. Furthermore, panel data in comparison with cross-sectional data, is more flexible in the choice of variables used as instruments to control for endogeneity. The endogeneity problem appears because observable as well as unobservable shocks influencing corporate investment decisions are also likely to impact some of other firm-specific characteristics. The exogeneity between the regressors and error term, particularly in the financial data of the company is difficult to establish. Hence, the direction of causality between variables might be ambiguous because off potential endogeneity. It can be the case that observed relations between investment and firm-specific characteristics reflects the influences of investment on the latter instead of the other way round. The Generalised Method of Moments (GMM hereafter) technique used on panel data reduces this problem by incorporating firm-specific effects (which reflects the cross sectional components of these unobservable shocks) and time dummies (which account for the common to all firms macroeconomic shocks). As a result, this allows us to pick up more efficient instruments to control for endogeneity. In other words, firm-specific effects are controlled for by estimating the dynamic investment model in first differences, instead of in levels. Specifically, in first difference GMM technique the model is estimated in first differences employing level regressors as instruments to control for unobservable firm heterogeneity. In the estimated

model also year dummies are included in order to control for time-specific effects. Methods, such as OLS and the fixed-effects estimator ignore the endogeneity problem, hence they provide inconsistent estimates of the parameters of the investment function. To control for potential endogeneity among regressors and alleviate the simultaneity bias cash holding and leverage measures are introduces to the model as lagged once variables.

Overall, GMM estimation procedure structured by Arellano and Bond (1991) is employed to estimate this dynamic model covered by equation 2, which is our preferred model. Papers of Beck et al. (2000), Bond et al. (2003A), Beck and Levine (2004), and Brown et al. (2009) demonstrate similar approaches. Thanks to this method of analyzing this model we can cope with following problems. At the start, equation 2 is treated as dynamic models with firm fixed effects, however, in panels with proportionally few time periods, both OLS levels and within-firm group estimates will be biased (Nickell, 1981). Next, potentially every financial variable in equations 2 are endogenous, especially cash savings and total debt issues, therefore there is a need to use instrumental variables. At last, as Himmelberg and Petersen (1994) highlights, in case of high adjustment costs, firms reacting to transitory shocks may smooth investment to cash flow, which may, in effect deprive the long-run association between investment and cash flow. In detail, in a regression including fixed effects the estimated coefficient of cash flow will be biased downward if investment rather than respond to the transitory component, it responds to the permanent component due to adjustment costs. Among others solutions to this problem Himmelberg and Petersen (1994) proposed instrument lagged values of cash flow.

Following Arellano and Bond (1991) who claim that if the error term in the undifferenced model is identically and independently distributed, then lagged levels dated as t-2 are potentially valid instruments and Sargan test of instruments validity do not reject the validity of the t-2 instruments. Thus we use instruments dated t-1 and t-2 for the following GMM regressions. The literature (e.g. Martonsson, 2009) shows that any earlier instruments do not yield consistent estimates for dynamic panels, thus we don't include them.

2.3.7 Optimal investment ratio and the speed of adjustment

The central objective of Equation 2 is to shed more light onto the empirical determinants of a firms' target investment and the adjustment process towards this target. This empirical model by concentrating on the dynamics of investment decisions and the nature of the adjustment process captures two important characteristics of a firms' investment behaviour stemming from relaxing assumptions of a perfect market by Modigliani and Miller (1958). In the first place, firms have to pursue to their long-term optimal target investment ratio. This target investment is assumed to be a function of numerous firm-specific characteristics, however, unstable over time, different for each firm or various over both time and firms (see e.g. Dasgupta et al., (2008) or Gatchev et al., (2010)). In the second place, adjustment costs of investment are present, which cover a lag in adjusting to changes in the optimal target investment level. Various market imperfections are likely to disturb a firms' adjustment process to their target investment, especially complete adjustment to their target investment and immediate offsetting the results of events which take them away from their target ratios. Due to adjustment costs firms may not be able to adjust their investing ratio promptly and a delay is highly likely. Therefore, equation 2 is a partial adjustment model where the firm's financial behavior is described as a partial adjustment to a long-run target investment. This setup makes it possible to study both the potential determinants of target investment ratios and the character of the adjustment to these targets. The need for accounting adjustment costs of investment led to the input of the lagged investment term to the formal models of investment behavior.

The following procedure is applied in order to find the existence of a target investment ratio. This equation assumes that the target / desired long run investment ratio of firms is determined by a number of variables,

$$I^*_{it} = \Sigma_k \beta_k x_{kit} + \varepsilon_{it} \qquad\qquad (3)$$

Where ε_{it} is the disturbance term, which is assumed to be serially uncorrelated with mean zero and possibly heteroscedastic, and β_k's represent common to all firms the unknown parameters that need to be estimated. A firm's current investment ratio is assumed in the model to adjust to firm's target investment ratio with the degree of adjustment coefficient θ.

$$I_{it} - I_{it-1} = \theta \, (I^*_{it} - I_{it-1}) \tag{4}$$

where $0 < \theta < 1$, I_{it} and I^*_{it} are respectively the actual and target investment ratio of firm i at time t. When $\theta = 1$, then actual $I_{it} - I_{it-1}$ changes in investment level is equal the target one without any delay ($I^*_{it} - I_{it-1}$) and the model is considered as functioning in perfect capital market. However, when the assumptions of the perfect capital market are distorted firms are only able to change partially. When $\theta = 0$, then there is no adjustment and firms set their current investment ratio to its past value. Substituting equation (3) into equation (4) yields:

$I_{it} = (1 - \theta) \, I_{it-1} + \Sigma_k \theta \beta_k x_{kit} + \theta \varepsilon_{it}$

And rewritten as

$I_{it} = \gamma_0 I_{it-1} + \Sigma_{k=1} \gamma_k x_{kit} + \mu_{it}$

where $\gamma_0 = (1 - \theta)$, $\gamma_k = \beta_k$, and $\theta \varepsilon_{it} = \mu_{it}$ (where μ_{it} has the same properties as ε_{it}).

2.4 Data and sample description

This section demonstrates the data sources and descriptive statistics for variables employed in the sample.

The data used in this study is collected from Datastream database, which is the most comprehensive source of data on investment and other explanatory variables currently available to me. This dataset is based on the sample of UK listed non-financial firms, over the time period of thirty years: 1980-2009. These companies are classified according to the sector of their main activity, e.g. mining, retailers, technology or chemicals. Because the characteristics of the banking and insurance sectors companies are different from the companies of the other industrial departments in terms of financial statement, profitability measures and liquidity assessment, these companies are eliminated from this study. Also utilities sectors are not considered in this study. The detailed information about each enterprise is included in data set. Balance sheets and income statements are the key items of interest, as the law requires disclosure, the entire balance sheets and income statements are available from companies. Definitions for all variables employed in this analysis are provided in Table 2.1. Detailed summary statistics for the variables employed in the econometric analysis for entire sample are represented in Table 2.2.

2.4.1 Variables selection

Several cleaning procedures have been applied to the data, for the purpose of this paper. Firstly, financial and utility companies have been removed from the sample because of certain factors of their financial ratios and the peculiarity in their regulatory conditions. Next, observations with missing values are excluded. In terms of OLS regressions the dataset is much bigger firstly and it shrinks for the requirements of GMM analyses solely, companies with at least four successive years observations during the sample period has been selected. Then we drop outliers at the 1% level from the top and bottom cut-offs for the following variables: total assets, sales investment, cash flow and Tobin's Q. We then eliminated all firms whose growth of total assets from one year to another was more than 100%. This cleaning restriction has been applied in order to avoid

any firm year observations representing mergers or acquisitions of firms, which could influence the results. Finally we also get rid of firms whose sum of sales over the years equals to 0 or only the last observation for the firm is above 0 and the previous ones are 0. This last limitation has been included because of the need of calculating sales growth and its mean for each firm, though, this has not reduced the sample substantially. Huang (2001) asserts that a dataset that covers more companies and various sorts of companies will provide more reasonable outcomes, therefore negative cash flow and small firms are included in the sample along with positive cash flow and large firms. The intention of this paper is to cover a long time period to study the time-varying features of the ICFS relationship as in, e.g. Allayannis and Mozumdar (2001).

In order to observe the changes of ICFS over time we present separate regression outcomes for three different subperiods: 1980-1989, 1990-1999 and 2000-2009. The starting and finishing years of the full sample has been decided by data availability, Datastream at our research place does not provide data before 1980 and the years after 2009 are very incomplete, at least at the time of our data collection. The overall sample is divided between these time periods of exactly equal length of time to keep the consistency of the analysis. This division into three subsample stems from the intuition that without it one can only deliver single coefficients for each variable from the model, which do not include any information about the changes over time. The full sample has not been divided into any smaller subsamples because of the GMM analysis which requires a minimum of four years observation per firm. In view of this last condition the sample size drops substantially. As described before we also categorize the firms according to their age, size, dividend payout ratio, sales growth and cash flow sign.

Before we begin the empirical investigation in the following section, we provide descriptive statistics, namely mean and median, and discuss preliminary characteristics of the sample.

The sample summary statistics are carried out according to the annual firm observations. As previously mentioned all variables are scaled by total assets.

We concentrate our analysis on changes over time by investigating both three subperiods as well as year by year summary statistics. Descriptive statistics of differences between small and large, not paying dividend and paying

dividend as well as negative and positive cash flow ratios firms are also demonstrated over the five years of the sample in order to get a clear cut of the booming and financial crisis years.

According to Cleary et al. (2007) one critical factor of the opposing results reported by the previous literature is whether to include the observations with negative cash flow or not. Because this study detects the changes of ICFS over time, it would have been biased to neglect those firms with negative cash flow on average over years, since in last subperiod these firms account for 30% of the sample. Furthermore, avoiding these firms would bias the years of booming and financial crisis even more, meaning the full picture of how firms acted during the economic growth and then during the economic downturn would be deprived.

When a firms' size proxied by the natural logarithm of a firms' total assets is differentiated by either positive or negative cash flow, it demonstrates that on average, firms with positive cash flow are usually larger and firms with negative cash flows are usually smaller. The same discovery was produced by Cleary et al. (2007) who argue that the monotonic increasing relationship between cash flow and investment found by FHP (1988) is driven by data selection bias in selecting only large companies and ignoring one third of the total sample that has a negative relationship between cash flow and investment.

Table 2.1 Variables Definitions

Variable	Definition
TA	Total Assets
INV	The ratio of capital expenditures to total assets
CF	The ratio of net income before extraordinary items plus depreciation and amortization to total assets
Q	The ratio of book value of total assets minus the book value of equity plus the market value of equity to book value of total asset
CASH	The ratio of total cash and short term investment to total assets
LEV	The ratio of total debt to total assets
SIZE	The logarithm of total assets
AGE	End date-Base date according to Datastream
DIV	The ratio of total cash dividend to total assets
SG (%)	The ratio of sales growth equal to Δsales over 1-period lagged sales

Notes: This table provides the definitions of the main variables used in our analysis.

Table 2.2 Descriptive Statistics

Full Sample	2000-2009	2000-2009	1990-1999	1990-1999	1980-1989	1980-1989
	Mean	Median	Mean	Median	Mean	Median
INV	0.045	0.030	0.064	0.052	0.080	0.066
CF	-0.005	0.069	0.084	0.095	0.103	0.101
Q	1.864	1.380	1.610	1.364	1.349	1.213
CASH	0.165	0.091	0.104	0.064	0.085	0.059
LEV	0.189	0.150	0.191	0.176	0.124	0.112
SIZE	11.241	11.044	11.345	11.018	12.362	12.150
AGE	20.040	15	25.999	25	32.33	34
DIV	0.021	0.012	0.027	0.025	0.022	0.021
Obs.	9563		9361		2863	
Obs. with CF<0	2556		951		52	
Obs. with CFSUM<1	2897		928		17	
Firms	1382		1234		385	

Notes: This table shows UK firms' sample characteristics over the period 1980-2009. Analytical definitions for all the variables are provided in table 2.1.

Table 2.1 demonstrates that the investment expenditures halved in size between third: 2000-2009 (mean and median: 0.045 and 0.03) and first subsample: 1980-1989 (mean and median: 0.08 and 0.066). On average the cash flow measure dropped dramatically from 10% in the first subperiod, 8% in the second subperiod and down to a negative value of -0.5% in the last

subperiod. In contrast the proxy for growth opportunities has increased over time (1.3 to 1.6 to 1.8), as has the firms' cash savings (0.8 to 0.1 to 0.16). Leverage level, in terms of its mean measure, seems to increase from 12 % in the first subperiod to 19% in the second subperiod and stays around this level in the third subperiod. Importantly on average, the firms' size and age have declined, and the size median for the last and second last decade are much smaller than the size mean, and the age median in the last decade is much smaller than the age mean. This indicates that over the last three decades the number of small and young firms has increased its share in the full sample, which is in line with two major events related with listed firms in the UK, namely establishment of both the Alternative Investment Market in 1995 and an international equity derivatives business EDX London in year 2003.

Table 2.3 shows that interestingly, the capital expenditures ratio decreased prominently over time for all the firms group, in particular full sample ratio were 0.08 in 1980 year but only 0.035 in the last period. From the view of the finance sources, for all the firms in the sample, on average the cash flow variable slowly fluctuates over short periods of times ,but overall it decreases critically from 9% in 1980 to -1% in 2009 year. The fall into negative values appears first time in year 2001, after the IT bubble burst and the subprime mortgage crisis events occurred in year 2000. In contrast, the cash holding ratio grows almost systematically from 5% in 1980 to 16 % thirty years later, and total debt ratio grows from 10 % in the first year to 18 % in the last year of the sample period. The total debt ratio grows slowly over the first subperiod and jumps to 18 % in year 1989 and stays around this level for the rest of the sample period. As in table 2.2 the firms' size and age have plummeted over time. Dividend payout ratio fluctuates over time but on a very small scale and overall it moves around 2% levels.

Table 2.03 Descriptive Statistics by Year

		INV	CF	Q	CASH	LEV	DIV	SIZE	AGE	Obs.
1980	Mean	0.080	0.093	0.995	0.055	0.107	0.020	12.276	33.187	203
	Median	0.068	0.091	0.886	0.035	0.096	0.019	12.205	35	
1981	Mean	0.073	0.091	1.022	0.068	0.103	0.019	12.371	33.038	211
	Median	0.060	0.091	0.901	0.044	0.099	0.018	12.278	35	
1982	Mean	0.072	0.081	1.054	0.075	0.109	0.018	12.452	32.635	222
	Median	0.059	0.080	0.942	0.052	0.106	0.017	12.375	34	
1983	Mean	0.071	0.089	1.168	0.084	0.111	0.019	12.468	32.261	238
	Median	0.058	0.086	1.006	0.058	0.104	0.018	12.421	34	
1984	Mean	0.078	0.100	1.277	0.083	0.103	0.020	12.312	31.850	299
	Median	0.065	0.096	1.064	0.054	0.089	0.019	12.043	33	
1985	Mean	0.081	0.098	1.360	0.083	0.105	0.022	12.213	31.778	342
	Median	0.068	0.096	1.165	0.059	0.092	0.021	11.937	33	
1986	Mean	0.083	0.104	1.515	0.094	0.116	0.023	12.146	31.408	365
	Median	0.070	0.105	1.364	0.071	0.095	0.022	11.815	32	
1987	Mean	0.084	0.118	1.648	0.101	0.136	0.025	12.308	31.971	347
	Median	0.067	0.119	1.488	0.074	0.126	0.024	12.006	33	
1988	Mean	0.086	0.120	1.509	0.096	0.153	0.026	12.483	32.706	327
	Median	0.073	0.118	1.406	0.075	0.146	0.025	12.239	34	
1989	Mean	0.085	0.115	1.512	0.092	0.181	0.027	12.671	33.317	309
	Median	0.074	0.113	1.409	0.062	0.176	0.026	12.381	35	
1990	Mean	0.085	0.104	1.367	0.095	0.193	0.028	11.113	27.312	866
	Median	0.069	0.106	1.229	0.050	0.181	0.026	10.813	27	
1991	Mean	0.069	0.084	1.388	0.095	0.201	0.028	11.098	27.043	905
	Median	0.055	0.093	1.253	0.051	0.188	0.027	10.760	27	
1992	Mean	0.057	0.073	1.415	0.101	0.205	0.027	11.101	26.859	932
	Median	0.044	0.086	1.247	0.057	0.191	0.025	10.766	27	
1993	Mean	0.055	0.066	1.597	0.108	0.193	0.024	11.086	26.336	997
	Median	0.043	0.086	1.421	0.064	0.172	0.022	10.743	26	
1994	Mean	0.060	0.081	1.678	0.109	0.180	0.024	11.317	25.654	1046
	Median	0.048	0.093	1.494	0.077	0.161	0.022	10.922	25	
1995	Mean	0.064	0.086	1.654	0.106	0.184	0.026	11.460	25.516	1040
	Median	0.053	0.097	1.421	0.068	0.168	0.024	11.073	25	
1996	Mean	0.064	0.087	1.802	0.108	0.184	0.028	11.452	24.646	1051
	Median	0.053	0.097	1.514	0.071	0.166	0.026	11.083	23	
1997	Mean	0.065	0.096	1.779	0.110	0.182	0.031	11.543	24.905	979
	Median	0.053	0.103	1.444	0.075	0.170	0.027	11.167	23	
1998	Mean	0.065	0.085	1.722	0.106	0.192	0.030	11.651	25.562	847
	Median	0.054	0.098	1.344	0.066	0.177	0.026	11.322	24	
1999	Mean	0.061	0.077	1.653	0.097	0.204	0.029	11.711	26.719	698
	Median	0.049	0.094	1.277	0.061	0.188	0.024	11.427	25	
2000	Mean	0.056	0.044	2.176	0.152	0.188	0.026	11.550	22.952	855
	Median	0.041	0.079	1.414	0.080	0.166	0.017	11.214	19	
2001	Mean	0.055	-0.014	1.755	0.159	0.190	0.021	11.387	21.977	936
	Median	0.040	0.066	1.264	0.069	0.158	0.016	11.146	17	
2002	Mean	0.046	-0.042	1.547	0.162	0.202	0.019	11.282	21.255	1026

Year										
	Median	0.034	0.058	1.196	0.080	0.160	0.013	11.085	16	
2003	Mean	0.042	-0.018	1.750	0.158	0.204	0.019	11.214	20.768	1085
	Median	0.030	0.066	1.265	0.084	0.161	0.012	10.973	16	
2004	Mean	0.042	0.008	2.013	0.171	0.193	0.020	11.109	20.094	1084
	Median	0.028	0.069	1.494	0.096	0.155	0.010	10.925	15	
2005	Mean	0.045	0.006	2.091	0.175	0.182	0.018	11.114	19.081	1074
	Median	0.028	0.071	1.561	0.103	0.135	0.009	10.938	14	
2006	Mean	0.044	0.004	2.127	0.179	0.176	0.024	11.119	18.221	1045
	Median	0.029	0.073	1.621	0.109	0.132	0.007	10.928	13	
2007	Mean	0.042	-0.007	2.023	0.172	0.178	0.020	11.139	18.047	929
	Median	0.026	0.077	1.609	0.104	0.138	0.010	11.009	13	
2008	Mean	0.041	-0.020	1.496	0.160	0.188	0.022	11.257	18.690	809
	Median	0.025	0.069	1.146	0.095	0.145	0.012	11.118	14	
2009	Mean	0.035	-0.011	1.529	0.160	0.185	0.020	11.349	19.315	720
	Median	0.020	0.061	1.204	0.102	0.143	0.009	11.173	14	

Notes: This table shows the averages and medians for the variables in each year of the period 1980-2009. Analytical definitions for all the variables are provided in table 2.1.

To show the trends over time of investment, cash flow and Tobin's Q the graphical representation is provided next.

Figure 2.2 Plots of the Yearly Averages of INV, CF and Q
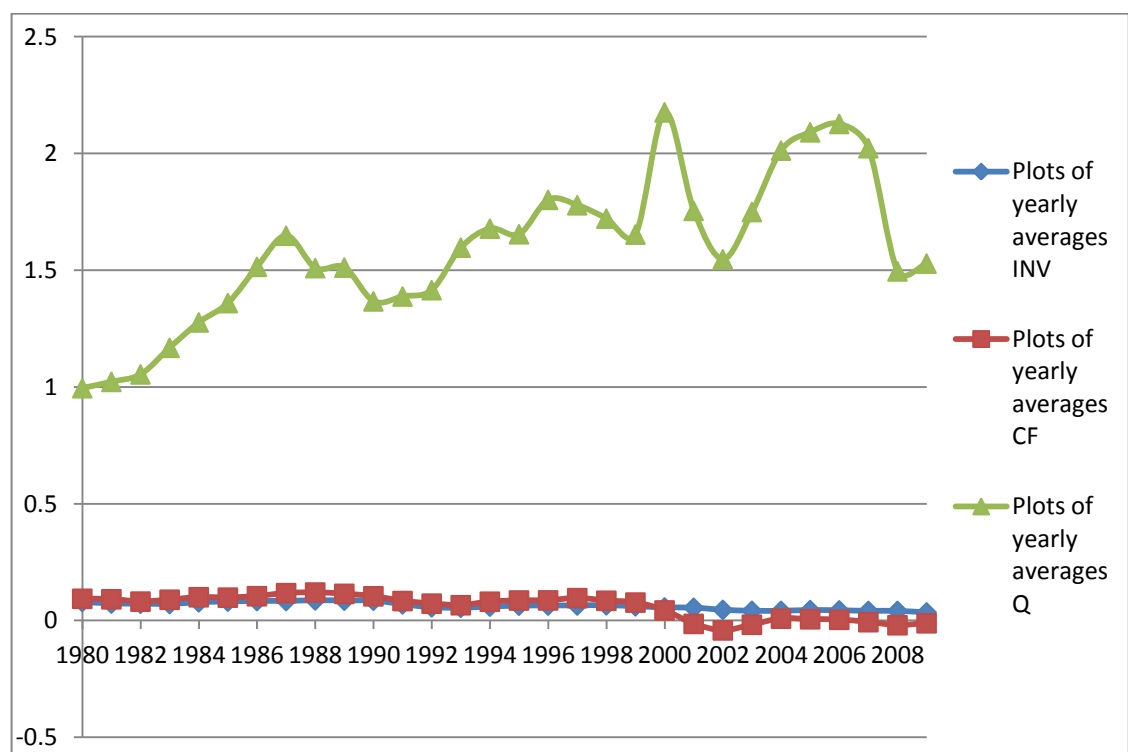
Overall, the descriptive statistics suggest that the first subsample is rather different from the last two ones, and that does not only apply to the sample size

but also to variables characteristics, in the sense that it covers mainly large and mature firms with high positive cash flow and high capital expenditures ratios, which are leveraged at low levels and save cash rather modestly with small investment opportunities proxies. It is almost as if the first subsample covers only unconstrained firms when in fact, this subperiod contains only three firms with a negative cash flow sum over the firm's year observations. Therefore, one needs to be careful in analyzing all three subperiods. All this is not supposed to imply that the first subsample could have any biased features, this is impossible because the criteria for all subsamples in terms of the data collection were the same, but it rather suggest the changes of the market conditions, and thus changes of a firms characteristics and also changes in firms investment decisions and financial decisions.

In order to highlight the financial crisis and the booming time beforehand this paper covers detailed descriptive statistics over the last five years of the total sample period. The sample has been split according to the sign of firms' cash flows-table 2.4 Panel A, dividend payout ratio – whether firms' pay or not pay dividend-table 2.4 Panel B and size median-table 2.4 Panel C per each individual year. The firms were also divided according to age and sales growth, the results are very similar.

Table 2.4 Descriptive Statistics by Year across CF, DIV and SIZE

	INV	CF	Q	CASH	LEV	DIV	SIZE	AGE	Obs.
Panel A									
				CF<0					
2005									277
Mean	0.035	-0.275	2.881	0.277	0.202	0.003	9.499	14.628	
Median	0.015	-0.144	1.757	0.169	0.080	0	9.141	10	
2006									281
Mean	0.033	-0.283	2.614	0.284	0.157	0.003	9.528	12.605	
Median	0.018	-0.154	1.683	0.181	0.052	0	9.266	9	
2007									236
Mean	0.033	-0.347	2.490	0.279	0.177	0.003	9.453	11.890	
Median	0.017	-0.184	1.781	0.216	0.069	0.000	9.192	9	
2008									223
Mean	0.036	-0.345	1.807	0.223	0.202	0.014	9.791	13.336	
Median	0.018	-0.196	1.068	0.131	0.126	0	9.462	9	
2009									218
Mean	0.024	-0.269	1.888	0.201	0.205	0.006	9.961	15.092	
Median	0.010	-0.146	1.206	0.119	0.125	0.000	9.726	10	
				CF>0					
2005									797
Mean	0.049	0.103	1.817	0.139	0.176	0.023	11.675	20.629	
Median	0.032	0.095	1.529	0.092	0.149	0.017	11.376	16	
2006									764
Mean	0.048	0.109	1.948	0.140	0.182	0.032	11.704	20.287	
Median	0.032	0.098	1.613	0.098	0.154	0.016	11.445	15	
2007									691
Mean	0.045	0.109	1.860	0.135	0.179	0.026	11.727	20.184	
Median	0.030	0.100	1.583	0.089	0.158	0.016	11.549	15	
2008									585
Mean	0.044	0.104	1.377	0.136	0.182	0.025	11.823	20.737	
Median	0.028	0.094	1.167	0.088	0.149	0.017	11.647	15	
2009									501
Mean	0.040	0.101	1.374	0.143	0.176	0.026	11.956	21.110	
Median	0.024	0.089	1.203	0.097	0.147	0.016	11.776	16	
Panel B									
				DIV=0					
2005									468
Mean	0.041	-0.111	2.512	0.248	0.178	0.000	9.739	13.474	
Median	0.020	-0.006	1.709	0.158	0.079	0.000	9.505	10	
2006									475
Mean	0.039	-0.115	2.405	0.237	0.164	0.000	9.823	12.608	
Median	0.021	-0.007	1.633	0.154	0.091	0.000	9.578	10	
2007									393
Mean	0.034	-0.152	2.260	0.237	0.167	0.000	9.721	12.580	
Median	0.018	-0.013	1.627	0.158	0.082	0.000	9.484	10	

2008									323
Mean	0.038	-0.174	1.731	0.219	0.186	0.000	9.713	12.591	
Median	0.018	-0.022	1.165	0.139	0.100	0.000	9.509	9	
2009									305
Mean	0.030	-0.127	1.771	0.204	0.199	0.000	10.120	14.669	
Median	0.014	-0.015	1.283	0.132	0.139	0.000	9.811	10	

<div align="center">DIV>0</div>

2005									606
Mean	0.049	0.096	1.766	0.118	0.186	0.031	12.175	23.411	
Median	0.035	0.098	1.506	0.077	0.166	0.024	11.915	21	
2006	DIV>0								570
Mean	0.048	0.103	1.895	0.130	0.185	0.045	12.198	22.898	
Median	0.036	0.102	1.611	0.091	0.166	0.024	11.977	20	
2007	DIV>0								536
Mean	0.047	0.100	1.849	0.125	0.187	0.035	12.179	22.056	
Median	0.033	0.101	1.596	0.083	0.166	0.023	11.968	17	
2008	DIV>0								486
Mean	0.044	0.083	1.339	0.121	0.189	0.036	12.284	22.743	
Median	0.030	0.087	1.105	0.078	0.167	0.023	12.106	21	
2009	DIV>0								415
Mean	0.039	0.074	1.351	0.129	0.175	0.034	12.252	22.730	
Median	0.026	0.085	1.172	0.085	0.144	0.023	12.155	21	

Panel C

<div align="center">SIZE<Median</div>

2005									537
mean	0.040	-0.070	2.405	0.224	0.150	0.010	9.266	14.030	
p50	0.019	0.031	1.615	0.138	0.063	0.000	9.441	10	
2006									523
mean	0.037	-0.072	2.354	0.229	0.135	0.012	9.283	13.015	
p50	0.021	0.041	1.572	0.146	0.052	0.000	9.433	10	
2007									464
mean	0.034	-0.091	2.212	0.217	0.137	0.012	9.285	12.961	
p50	0.019	0.044	1.612	0.141	0.063	0.000	9.420	10	
2008									404
mean	0.034	-0.108	1.675	0.204	0.147	0.018	9.380	13.611	
p50	0.018	0.040	1.151	0.123	0.060	0.000	9.554	10	
2009									360
mean	0.028	-0.088	1.653	0.203	0.147	0.015	9.472	14.819	
p50	0.015	0.026	1.157	0.140	0.068	0.000	9.672	10	

<div align="center">SIZE>Median</div>

2005									537
Mean	0.050	0.082	1.777	0.125	0.215	0.025	12.962	24.132	
Median	0.037	0.091	1.548	0.085	0.192	0.019	12.590	21	
2006									522
Mean	0.051	0.080	1.899	0.128	0.216	0.037	12.958	23.437	
Median	0.037	0.089	1.652	0.088	0.192	0.019	12.556	21	

2007								465
Mean	0.049	0.078	1.835	0.127	0.220	0.029	12.990	23.123
Median	0.034	0.093	1.608	0.084	0.198	0.020	12.675	20
2008								405
Mean	0.048	0.068	1.316	0.116	0.228	0.026	13.129	23.756
Median	0.034	0.080	1.140	0.074	0.216	0.019	12.863	22
2009								360
Mean	0.042	0.065	1.405	0.118	0.224	0.025	13.226	23.811
Median	0.028	0.077	1.230	0.080	0.200	0.016	12.969	22

Notes: This table shows the averages and medians for the variables in each year of the period 2005-2009 across CF, DIV and SIZE. Analytical definitions for all the variables are provided in table 2.1.

The financial crisis officially started in July 2007, however firms usually respond or adjust to such an exogenous shock with a delay, thus this year can be treated as a transformation year in terms of the capital market conditions changes. Therefore, to have a balanced view two years before, 2007 is treated as booming time and two years after 2007 is recognized as financial crisis time. Over the financial crisis years: 2008-2009 one can see a drop in capital expenditures for both firms' groups after firm's different divisions, especially in year 2009. Cash flow is positive over all five years for positive cash flow, dividend paying, mature and large firms, while it is negative for their counterparts firms. The level of future expected investment opportunities is much higher for negative cash flows, nil dividend paying, quickly growing, young and small firms than it is to their mature counterparts firms. The difference between a firms' groups in terms of cash savings is pretty high, firms with negative cash flows, not paying dividends, young and small save much higher (approximately twice as much) levels of cash than opposite firms. On the other hand, groups of small, young, negative cash flow and not paying dividend firms are characterized by smaller levels of leverage in comparison with their corresponding firms' groups. Around double difference appears also in dividend payout ratio between both firms' groups for small versus large firms' division criteria. As expected negative cash flow firms hardly pay any dividends. Also negative cash flow and non dividend payout firms are smaller and younger. Division of firms according to sales growth shows different features in comparison with other division's measures. The capital expenditures ratio seems to be around same level of 4% for both corresponding groups apart from year 2009 when the ratio drops substantially for slowly growing firms to 2.7%. The cash flow variable is negative for firms growing

slowly and positive for firms growing quickly during years 2006, 2007 and 2009. In 2005 cash flow is positive for both groups, while in 2008 it is negative for both groups. As expected, Tobin's Q is consistently higher for firms with higher sales growth and smaller for firms with lower sales growth. Quickly growing firms have higher level of cash holding in each year in comparison to their counterparts firms. The ratio of total debt is smaller for firms growing quickly up to the year 2008. In year 2009 these firms have higher level of leverage in comparison with slowly growing firms. This suggests that well growing firms relied more on internal finances during booming time but when the financial crisis appeared they increased their debt level and decreased their cash savings. Firms with higher sales growth pay relatively less dividends than firms with smaller sales growth in each year.

In general, the impact of the financial crisis is most visible in year 2009 where all financial characteristics are importantly different from years of economic growth. Also financially constrained firms are more affected by the crisis period than financially unconstrained firms. A meaningful drop in the proxy for the demand side for capital is well presented next to a drop in the firms' cash flow. Interestingly small firms increased their dividend payout ratio in year 2008, while large firms decreased it. In the same year, the firms' size variable is higher in comparison with previous years suggesting that many small firms could have gone out of business due to the financial crisis explosion.

Overall, the summary statistics demonstrate that the direction of UK listed non-financial firms' behavior has changed critically. Most importantly, mean and median of cash flow plummeted drastically, which is to certain extent a result of growing number of firms with persistently negative cash flow and increase in the number of firms especially small and young. Also the number of listed firms in general increased sharply, implying higher use of public equity issues, followed by its easier access in recent decades.

2.5 Empirical results

This chapter begins by demonstrating the effects of the investment model of Equation 1 by using the OLS method. We then look at the GMM regression outcomes based on the Equation 2 capturing cash savings and TD. We also recheck the association of ICFS by splitting the sample into groups of financial constrained and unconstrained firms according to age, size, dividend payout, sales growth and cash flow sign.

2.5.1 ICFS over time

Table 2.5 shows the estimation results for the year by year cash flow and growth opportunities sensitivity of physical investment based on the OLS regression described by Equation 1. Industry dummies are included but are not presented. The residuals (errors) are identically and independently distributed. The standard errors presented in brackets are heteroskedasticity-consistent and clustered at the firm level.

For the first year of the sample, 1980, the ICFS is 0.253. It is statistically significant at the 1% confidence level. The economic magnitude is easy to interpret: a one-dollar increase in cash flow increases investment by 25.3 cents. However, the investment-cash flow sensitivity declines over time, and in 2007 it is equal to 0.0156. Interestingly in 2008 ICFS is equal to 0.016 and in 2009 it is equal to 0.0217, which implies that firms' ICFS is getting stronger due to the financial crisis. All these estimates are statistically indistinguishable from zero, however the proxy controlling for future expected investment opportunities becomes statistically insignificant in years 2008 and 2009, indicating that the demand for capital is in a bad state in those years. These results are what we would have expected from this financial period.

Table 2.05 Cross-Sectional Regressions by Year

DV:INV	CF		Q		Obs.	Adj. R-sq.
1980	0.253***	(3.25)	0.022***	(2.69)	203	0.333
1981	0.235***	(3.10)	0.028***	(2.82)	211	0.397
1982	0.397***	(4.51)	0.020**	(2.39)	222	0.373
1983	0.508***	(5.38)	0.009	(1.21)	238	0.398
1984	0.603***	(8.57)	0.002	(0.36)	299	0.413
1985	0.164**	(2.38)	0.021***	(3.38)	342	0.264
1986	0.159**	(2.21)	0.019**	(2.55)	365	0.168
1987	0.398***	(4.68)	0.006	(0.89)	347	0.239
1988	0.238***	(5.40)	0.026***	(3.80)	327	0.248
1989	0.264***	(3.01)	0.009	(1.22)	309	0.190
1990	0.164***	(5.06)	0.012***	(3.06)	866	0.123
1991	0.152***	(6.67)	0.007*	(1.80)	905	0.121
1992	0.132***	(7.21)	0.004	(1.62)	932	0.151
1993	0.095***	(7.33)	0.002	(1.19)	997	0.116
1994	0.094***	(4.61)	0.006***	(2.85)	1046	0.090
1995	0.111***	(5.57)	0.004**	(2.29)	1040	0.093
1996	0.099***	(5.08)	0.004**	(2.38)	1051	0.102
1997	0.088***	(3.83)	0.004**	(2.13)	979	0.087
1998	0.104***	(7.01)	0.004***	(3.43)	847	0.135
1999	0.114***	(6.54)	0.001	(0.58)	698	0.112
2000	0.025*	(1.83)	0.002*	(1.66)	855	0.040
2001	0.012*	(1.91)	0.003**	(2.01)	936	0.057
2002	0.013**	(2.31)	0.002**	(2.05)	1026	0.053
2003	0.019***	(2.95)	0.001	(1.10)	1085	0.037
2004	0.020**	(2.26)	0.002**	(2.38)	1084	0.050
2005	0.026***	(3.27)	0.002**	(1.99)	1074	0.067
2006	0.026***	(3.79)	0.003***	(3.04)	1045	0.064
2007	0.016*	(1.94)	0.003***	(3.06)	929	0.055
2008	0.016***	(4.00)	0.002	(1.42)	809	0.102
2009	0.022***	(3.39)	0.001	(0.52)	720	0.078
p-Value	0.0024		0.0081			

Notes: This table displays results from the year by year investment regressions in equation 1. Analytical definitions for all the variables are provided in table 2.1. All regressions include industry dummies. P-values are for the null hypothesis that the coefficients are the same between the first (1980) and the last (2009) years. T-statistics are reported in parentheses. ***, ** and * indicate coefficient is significant at the 1%, 5% and 10% respectively. For the estimation we use consistent to heteroskedasticity standard errors.

The estimated investment-cash flow sensitivities for the full sample for each year are plotted in Figure 2.2.

Figure 2.3 Plots of the ICFS over Time
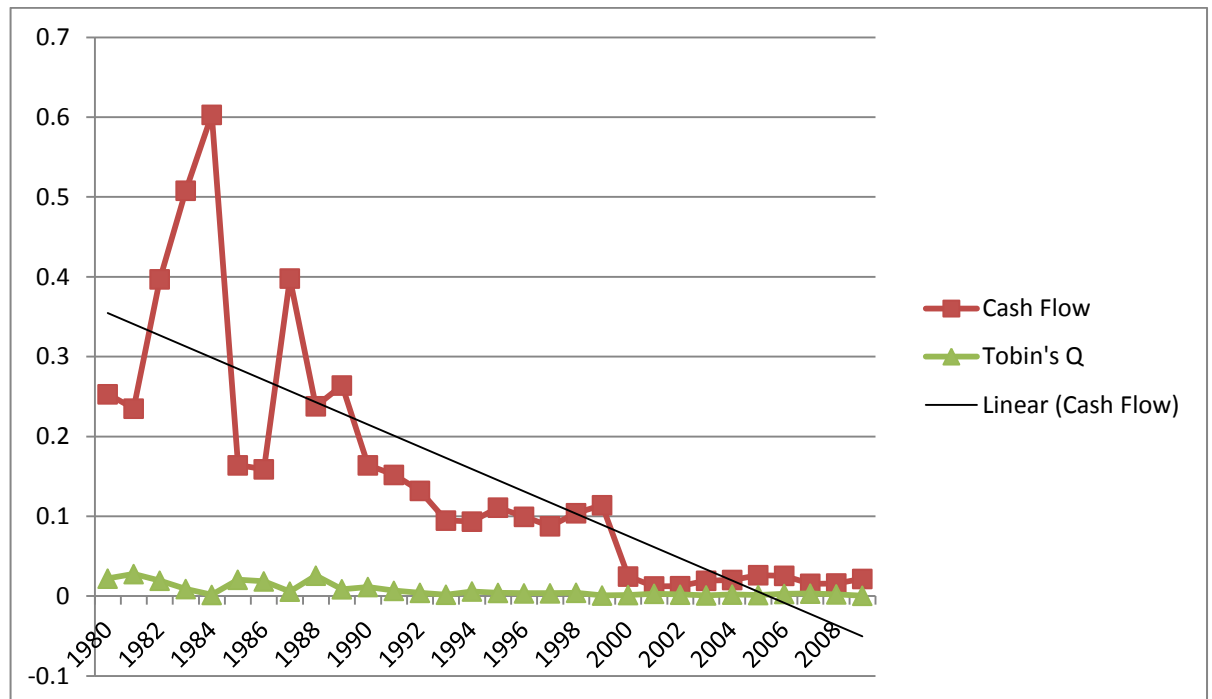
The plot shows that investment-cash flow sensitivities have been fluctuating substantially over time especially during the first subperiod and smoothed mostly in the last subperiod. Overall ICFS show a declining trend over time.

Table 2.6 shows the investigation of the time series pattern of ICFS by running rolling regressions of investment on cash flow and Tobin's Q from 1980 to 2009 for overlapping periods of ten year according to the model described in Equation 1.

The first regression is for the period 1980-1989, the second for the period 1981-1990, and so forth. According to this examination there is a clear and systematic decrease of the ICFS over time. The ICFS drops by 93.8% from 0.281 in the first ten years period to 0.0174 in the last ten years period. Furthermore, the coefficient measuring the impact of Tobin's Q on investment also declines nearly as systematically as the coefficients of cash flows. Specifically Tobin's Q's evolution starts from 0.016 for the first period and end with 0.00194 in the last period, which gives a drop of 87.8 % between these periods. All the coefficients are statistically significant at the 0.1% level.

Table 2.6 Rolling ICFS by Ten Year Periods

DV:INV	CF		Q		Obs.	Adj. R-sq.
1980-1989	0.281***	(8.13)	0.016***	(6.10)	2863	0.269
1981-1990	0.237***	(10.03)	0.015***	(7.24)	3526	0.218
1982-1991	0.203***	(11.68)	0.014***	(7.49)	4220	0.194
1983-1992	0.174***	(13.47)	0.012***	(7.54)	4930	0.194
1984-1993	0.143***	(14.55)	0.009***	(7.19)	5689	0.187
1985-1994	0.126***	(13.94)	0.008***	(7.19)	6436	0.174
1986-1995	0.123***	(14.76)	0.007***	(6.79)	7134	0.161
1987-1996	0.119***	(15.39)	0.005***	(6.44)	7820	0.152
1988-1997	0.114***	(15.54)	0.005***	(6.21)	8452	0.141
1989-1998	0.111***	(16.68)	0.004***	(6.59)	8972	0.135
1990-1999	0.110***	(17.77)	0.004***	(6.35)	9361	0.129
1991-2000	0.091***	(13.94)	0.004***	(6.63)	9350	0.102
1992-2001	0.056***	(10.14)	0.004***	(6.93)	9381	0.081
1993-2002	0.039***	(9.19)	0.003***	(7.53)	9475	0.079
1994-2003	0.033***	(9.28)	0.003***	(7.38)	9563	0.085
1995-2004	0.029***	(8.86)	0.003***	(7.39)	9601	0.091
1996-2005	0.027***	(8.84)	0.003***	(7.19)	9635	0.091
1997-2006	0.024***	(8.88)	0.002***	(7.12)	9629	0.088
1998-2007	0.021***	(8.14)	0.002***	(7.03)	9579	0.081
1999-2008	0.019***	(7.94)	0.002***	(6.13)	9541	0.072
2000-2009	0.017***	(7.81)	0.002***	(5.72)	9563	0.069
p-Value	0.0000		0.0000			

Notes: This table displays results from the rolling ten year investment regressions in equation 1 from 1980 to 2009. Analytical definitions for all the variables are provided in table 2.1. All regressions include time and industry dummies. P-values are for the null hypothesis that the coefficients are the same between the first (1980–1989) and the last (2000–2009) subsample periods. T-statistic values are reported in parentheses. ***, ** and * indicate coefficient is significant at the 1%, 5% and 10% respectively. For the estimation we use consistent to heteroskedasticity standard errors.

2.5.2 Cross sectional analysis

There is robust literature describing the financial crisis which started in July 2007. The substantial losses in subprime loans in 2008 evolved a banking crisis which led to a current recession (Barrell et al., 2008). Without doubt this financial crisis is affecting every firm's investment and financial decisions, and therefore the ICFS is supposedly affected by all changed market conditions but also in this study ICFS is used as a tool in explaining firms' behaviour during financial crisis and the time before the crisis. If a firm is suffering from the current recession, it is possible that this firm experiences significant changes in

investment-cash flow sensitivity. In this paper, we examine whether small, young, non dividend paying, not well growing and negative cash flow firms experience significant change in investment-cash flow sensitivity during the current financial crisis, and compare them respectively with the change in investment-cash flow sensitivity for large, mature, dividend paying, well growing and positive cash flow firms. In all these sample splits firms cannot switch between subsamples because these criteria are calculated averages over all year observations per firm. This makes the criteria more time independent and exogenous in the sense that a longer time period was taken into consideration than just two years. Furthermore, 2007 has been excluded from this pre-crisis and crisis analysis, because it is well known that firms can not adjust to new market conditions as quickly as they would wish because of their previous commitments made before the crisis etc., hence 2007 is treated as transformation year. This way of thinking finds its support also in the previous year by year analysis in table 2.5, where 2007 still shows features of the pre-crisis period and the effect of the crisis starts to be visible in year 2008 rather than in year 2007 when it actually started. Thus we present the cross sectional results for periods 2005-2006 as a pre-crisis period and 2008-2009 as financial crisis. Years 2005 and 2006 are chosen on the basis that they are the same time length as the available financial crisis time period, but also these years show the brightest contrast with years of financial crisis, and this is as expected, because from the point of view of cycle moves in the economy, before every economic downturn there must be an economic growth. Table 2.7 shows cash flow and growth opportunity sensitivity of physical investments based on OLS regression in Equation 1 for financial pre-crisis and crisis periods.

Table 2.07 OLS Estimates of the ICFS over Pre-crisis and Crisis Periods

DV: INV		CF		Q		Obs.	Adj. R-sq.
Panel A							
2005-2006	Full Sample	0.026***	(5.12)	0.002***	(3.69)	2119	0.068
2008-2009	Full Sample	0.018***	(5.34)	0.002	(1.41)	1529	0.098
2005-2006	CF<0	-0.001	(-0.01)	0.001	(0.61)	684	0.032
2005-2006	CF>0	0.172***	(6.66)	-0.001	(-0.39)	1435	0.120
2008-2009	CF<0	0.001	(0.13)	-0.001	(-0.14)	431	0.180
2008-2009	CF>0	0.065***	(3.66)	0.002	(0.93)	1098	0.097
2005-2006	DIV=0	0.003	(0.53)	0.001	(0.33)	623	0.075
2005-2006	DIV>0	0.075***	(4.94)	0.003**	(2.27)	1496	0.086
2008-2009	DIV=0	0.006	(1.52)	0.001	(0.31)	434	0.181
2008-2009	DIV>0	0.049***	(4.52)	0.002	(1.27)	1095	0.086
Panel B							
2005-2006	SIZE<50p	0.013**	(2.35)	0.001**	(2.06)	1060	0.032
2005-2006	SIZE>50p	0.100***	(5.20)	0.002	(1.08)	1059	0.128
2008-2009	SIZE<50p	0.011***	(2.78)	0.001	(0.61)	763	0.058
2008-2009	SIZE>50p	0.036**	(2.54)	0.003	(1.06)	766	0.130
2005-2006	SIZE<25p	0.001	(0.09)	0.001	(0.39)	531	0.009
2005-2006	25p<SIZE<50p	0.050***	(4.37)	0.004**	(2.37)	529	0.092
2005-2006	50p<SIZE<75p	0.107***	(5.33)	0.003	(1.24)	530	0.122
2005-2006	SIZE>75p	0.096***	(2.68)	0.001	(0.68)	529	0.172
2008-2009	SIZE<25p	0.001	(0.26)	0.001	(0.14)	383	0.032
2008-2009	25p<SIZE<50p	0.032**	(2.41)	0.004	(1.43)	380	0.092
2008-2009	50p<SIZE<75p	0.021*	(1.76)	0.006	(1.45)	384	0.136
2008-2009	SIZE>75p	0.105***	(4.07)	-0.004	(-1.30)	382	0.221
Panel C							
2005-2006	AGE<50p	0.021***	(3.57)	0.001	(1.46)	1052	0.061
2005-2006	AGE>50p	0.051***	(4.14)	0.005***	(4.96)	1067	0.108
2008-2009	AGE<50p	0.012***	(3.22)	0.001	(0.68)	748	0.098
2008-2009	AGE>50p	0.049***	(4.91)	0.003**	(2.06)	781	0.108
2005-2006	AGE<25p	0.012	(1.54)	-0.001	(-0.90)	477	0.003
2005-2006	25p<AGE<50p	0.036***	(4.24)	0.003***	(2.81)	575	0.130
2005-2006	50p<AGE<75p	0.041***	(2.69)	0.005***	(4.50)	515	0.105
2005-2006	AGE>75p	0.072***	(4.62)	0.004***	(3.01)	552	0.117
2008-2009	AGE<25p	0.012**	(2.60)	0.003	(0.97)	361	0.111
2008-2009	25p<AGE<50p	0.020**	(2.17)	0.001	(0.28)	387	0.086
2008-2009	50p<AGE<75p	0.036***	(2.89)	0.004*	(1.88)	374	0.123
2008-2009	AGE>75p	0.070***	(3.75)	0.002	(0.88)	407	0.118
Panel D							
2005-2006	SG<50p	0.028***	(3.30)	0.002**	(2.54)	1058	0.060
2005-2006	SG>50p	0.027***	(4.02)	0.002**	(2.42)	1061	0.105
2008-2009	SG<50p	0.014**	(2.55)	0.001	(0.55)	765	0.083
2008-2009	SG>50p	0.019***	(4.41)	0.002	(1.04)	764	0.120
2005-2006	SG<25p	0.023***	(3.21)	0.001	(1.51)	530	0.071

2005-2006	25p<SG<50p	0.023	(1.08)	0.003	(1.40)	528	0.038
2005-2006	50p<SG<75p	0.039**	(2.36)	0.003**	(2.03)	533	0.111
2005-2006	SG>75p	0.020**	(2.56)	0.001	(1.38)	528	0.104
2008-2009	SG<25p	-0.003	(-0.33)	-0.001	(-0.51)	381	0.063
2008-2009	25p<SG<50p	0.036***	(3.03)	0.001	(0.83)	384	0.117
2008-2009	50p<SG<75p	0.028	(1.60)	0.004	(1.10)	382	0.108
2008-2009	SG>75p	0.009**	(2.21)	0.002	(0.88)	382	0.174

Notes: This table presents the OLS estimation results of the investment model in equation 1. The estimations use pre-determined firms selection into two or four catergories. Constraint category assignments employ ex ante criteria based on firm dividend payout, size, age and sales growth. Analytical definitions for all the variables are provided in table 2.1. All regressions include industry and time dummies. T-statistic values are reported in parentheses. ***, ** and * indicate coefficient is significant at the 1%, 5% and 10% respectively. For the estimation we use consistent to heteroskedasticity standard errors.

The first two columns of table 2.7 in panel A report the ICFS for the full sample during the above mentioned periods, and the next columns show results for the following classifications, negative versus positive cash flow firms and non-dividend paying and dividend paying firms. We find that both the cash flow and Tobin's Q coefficients are statistically significant and much higher during financial boom time in comparison with financial crisis period, this is the case for both the full sample as well as positive cash flow firms and dividend paying firms, while negative cash flow firms and firms not paying dividends show positive increase in ICFS during financial crisis period. Moreover, for the period 2008-2009 Tobin's Q coefficient is not statistically significant. In summary, negative versus positive cash flow classification and non-dividend paying and dividend paying firms' classification show that both positive cash flow firms and dividend paying firms groups have much stronger ICFS relationship during financial boom time in comparison with financial crisis period.

The Panel B shows the results when the sample is firstly divided according to the median of firms' averaged size, and then the sample is categorized into four smaller groups according to 25th, 50th and 75th percentiles of a firms' averaged size. When the sample is divided into small and large groups according to the median of a firms' averaged size, we find that the ICFS is higher and statistically significant for large firms in both periods, while the proxy for future expected profitability is significant only for the small firms during financial boom time. However, during financial crisis period the ICFS is weaker for both groups, below and above size the median. To learn more about constrained and

unconstrained firms during boom time and crisis time the sample is divided once more and this shows that if the period of economic growth and only large firms (above median) are taken into consideration then one can align these results with results of FHP (1988), where the smaller firms in the group of large firms have higher ICFS than larger firms in the same group of large firms. The division of the full sample during financial crisis into four small groups according to size shows opposite results, i.e. it is unconstrained firms (the largest firms in the firms' distribution) which have much higher ICFS than constrained firms, while the coefficient for Tobin's q is insignificant for every subsample.

In general, the sample split according to age in panel C shows that ICFS grows monotonically with the direction from constrained firms odds to unconstrained firms for both subperiods. In other words, the more mature a firm is, the higher the ICFS, this is in line with KZ (1997) argument. However, the coefficient for investment growth is statistically significant only in the case of economic growth with the exception of one subsample of the most constrained firms, while it is completely insignificant during the financial crisis period. Also the CFS measure declines over time, in particular its size is consistently smaller during financial crisis period in comparison with financial boom period.

In Panel D the firms are divided according to sales growth. In the first firms' classification according to the sales growth median, ICFS is higher in the subsample of constrained firms and less sensitive for unconstrained firms, while coefficients for Tobin's Q are significant and show opposite strength of sensitivity during economic growth. However, during economic downturn the opposite is observable. When the sample is classified further into more precise subsamples, we can observe similar results but with sharper evidence.

All in all, this cross sectional analysis suggests that firms overinvest during economic growth time and during recession time they underinvest.

2.5.3 OLS analysis

This section covers the investigation of ICFS over time. The OLS regressions for capital expenditures are reported in table 2.7, these demonstrate the results returned from the estimation of our baseline regression model - equation 1 over time based on the three subperiods: 1980-1989, 1990-1999 and

2000-2009, where the investment is regressed on cash flow and growth opportunities. These results provide additional meaningful evidence which supports the decline of ICFS over time.

Table 2.08 OLS Estimates of the ICFS over Time

DV: INV	2000-2009	1990-1999	1980-1989
Full Sample			
CF	0.017***	0.110***	0.281***
	(7.81)	(17.77)	(8.13)
Q	0.002***	0.004***	0.016***
	(5.72)	(6.35)	(6.10)
Obs.	9563	9361	2863
Adj. R-sq.	0.069	0.129	0.269

Notes: This table presents the OLS estimation results over time of the investment model in equation 1. The sample includes all UK firms. Analytical definitions for all the variables are provided in table 2.1. All regressions include industry and time dummies. T-statistic values are reported in parentheses. ***, ** and * indicate coefficient is significant at the 1%, 5% and 10% respectively. For the estimation we use consistent to heteroskedasticity standard errors.

The ICFS together with the proxy for growth opportunities decrease systematically and significantly over time.

2.5.4 GMM analysis

The next step of our analysis is to test ICFS in the presence of other financial variables according to Equation 2. In the spirit of the existing literature on agency costs and corporate performance, the corporate leverage should have a negative impact on investment. This follows the attitude that this variable may function as an effective corporate governance device and therefore is expected to lower agency costs. Corporate governance is about investor protection. The better the investors are protected the more likely they will be willing to invest and the more possible it is that they will be willing to accept lower return on investments, due to the fact that the risk is lower. If corporate governance can achieve that, in other word if corporate governance can reduce the expected return by investors, it means that it is able to reduce the cost of capital to firms. The lower the cost of capital the higher the amount of profitable investment there

is. Financial analyst's employ the Capital Asset Pricing Model (CAPM), which estimates the cost of capital that is used in practice and gives the required rate of return, which can be interchangeable with the expected rate of return. CAPM comes from the relationship between risk and return. Corporate governance has implications for the risk incorporated in that model. In other words, the lower the risk, the lower the required rate of return, and this is good information for everybody. The lower the required rate of return means the lower cost of capital. Researchers like McConnell and Servaes (1995) or Harvey et al. (2004) have proved that leverage may work as an effective corporate governance device by decreasing the agency costs of free cash flow.

In Table 2.9 we report the outcomes regarding the empirical determinants of a firms' investment for the full sample of non-financial firms having a complete panel of data. Based on Equation 2, dynamic GMM regressions with cash holdings and debt finances are reported in table's 2.9 and 2.10, 2.11, 2.12 and 2.13. All financial variables are instrumented with lags dated t-1 and t-2. The GMM results in Tables 2.9-2.13 demonstrate that our model captures the dynamics in firms' investment decisions. The significant but less than unit coefficients of the lagged dependent variable (LDV) suggests a costly and non-instantaneous adjustment process. The GMM estimates show a common pattern in the adjustment speed [θ = 1 - (coefficient of LDV)]. The adjustment process is quicker as time goes pass. In other words, the adjustment coefficients of the capital expenditures ratio indicate that the UK firms become quicker over time at adjusting the investment spending towards their desired level. The faster adjustment is made over time by UK firms could be because of the relatively low adjustment cost or the cost of being off the target is substantial. Overall, the results show that firms attempt to trade-off between the cost of being off-target and the cost of adjustment.

Table 2.9 GMM Estimates of the ICFS

DV: INV	2000-2009	1990-1999	1980-1989
Full Sample			
L.INV	0.340***	0.295***	0.304***
	(10.30)	(9.83)	(4.05)
CF	0.040**	0.019	0.147
	(2.22)	(0.41)	(1.26)
Q	0.005**	0.016**	0.013
	(2.50)	(2.29)	(1.18)
CASH	-0.024	0.011	0.062
	(-1.00)	(0.31)	(0.70)
LEV	-0.035**	-0.056**	-0.075
	(-2.33)	(-2.00)	(-0.74)
Obs.	6799	6893	2093
Firms	1382	1234	385
Sargan	0.131	0.042	0.069

Notes: This table presents the GMM estimation results over time of the investment model in equation 2. The sample includes all UK firms. Analytical definitions for all the variables are provided in table 2.1. All regressions include time dummies. T-statistic values are reported in parentheses. ***, ** and * indicate coefficient is significant at the 1%, 5% and 10% respectively. For the estimation we use asymptotic standard errors robust to heteroskedasticity. We report the Sargan test, which is a test of over-identifying restrictions, asymptotically distributed as a $\chi2$ under the null of valid instruments.

For all firms in table 2.9, the coefficient of cash flow is very close to zero and shows decline over time, though this is not systematic. In the second subperiod cash flow coefficient is lower than the cash flow coefficient in the third subperiod, however the cash flow coefficient is statistically significant only in the last subperiod. The debt issue coefficients are negative, small and in second and third subperiods - significant and they show a declining impact of leverage on investment over time. Myers (1977) stated "that leverage could have a negative impact on investment due to an agency problem between shareholders and bondholders. If managers act in the interest of shareholders, they can give in some positive net present value projects because of debt overhang." Researchers, such as Jensen (1986), Grossman and Hart (1982), and Stulz (1990) also claim a negative relationship between leverage and investment, with the exception that their arguments are stated on agency conflicts between

managers and shareholders. They debate "that companies with free cash flow but low (or no) growth opportunities can never invest (overinvest) in that the manager can undertake projects with negative net present value. This sort of strategy is costly to the manager, if the capital market considers such possible prospective, or there is a takeover of the firm by another firm. Hence managers have an incentive to pre-commit and increase leverage and spend cash on interest and principal. These approaches imply a negative interaction between leverage and investment but only for firms with no or little growth opportunities." Leverage can be influenced by expected investment opportunities and in the above regressions we controlled for this impact by including the Tobin's Q variable.

In contrary, cash holdings coefficients are insignificant for all three subperiods and the sign changes over time from positive in second and third subperiod to negative in the final subperiod.

Table 2.010 GMM Estimates of the ICFS if CFSUM>0

DV: INV	2000-2009	1990-1999	1980-1989
Full Sample			
L.INV	0.361***	0.292***	0.290***
	(8.91)	(9.15)	(3.83)
CF	0.071**	-0.031	0.109
	(1.97)	(-0.56)	(0.93)
Q	0.006*	0.020***	0.015
	(1.87)	(2.73)	(1.53)
CASH	-0.005	0.010	0.034
	(-0.16)	(0.30)	(0.41)
LEV	-0.033	-0.061**	-0.139
	(-0.95)	(-2.11)	(-1.45)
Obs.	4854	6259	2082
Firms	906	1087	382
Sargan	0.0722	0.0595	0.0779

Notes: This table presents the GMM estimation results over time of the investment model in equation 2. The sample includes only firms with positive cash flow sum over time. Analytical definitions for all the variables are provided in table 2.1. All regressions include time dummies. T-statistic values are reported in parentheses. ***, ** and * indicate coefficient is significant at the 1%, 5% and 10% respectively. For the estimation we use asymptotic standard errors robust to heteroskedasticity. We report the Sargan test,

which is a test of over-identifying restrictions, asymptotically distributed as a χ2 under the null of valid instruments.

Table 2.10 shows the results for the full sample of firms but only those with positive cash flow sum over available firm year observations. These results are similar to the results for the full sample in table 2.8, however coefficient for cash flow in second subperiod gains negative sign but it is statistically insignificant. Also third subsample looses statistical significance for coefficient of tobin's q and leverage. However leverage shows same direction, namely it has a negative effect on the investment expenditures which decrease over time. There is still a drop in ICFS between third and first subsamples. All this indicates that overall results and particularly the pattern of ICFS over time are not driven mainly by the negative cash flow firms.

Table 2.11 GMM Estimates of the ICFS across Small and Large Firms

DV: INV	2000-2009 Constr. Small	2000-2009 Unconstr. Large	1990-1999 Constr. Small	1990-1999 Unconstr. Large	1980-1989 Constr. Small	1980-1989 Unconstr. Large
L.INV	0.266***	0.428***	0.242***	0.364***	0.226**	0.111
	(6.65)	(9.65)	(6.95)	(8.90)	(2.28)	(0.89)
CF	0.050**	-0.016	0.043	0.015	0.228	0.202
	(2.55)	(-0.64)	(0.92)	(0.37)	(1.37)	(1.28)
Q	0.004**	0.002	0.016***	0.007	0.009	-0.015
	(2.21)	(0.90)	(2.78)	(1.48)	(0.82)	(-0.53)
CASH	0.000	0.041	0.020	0.005	0.024	0.116
	(0.01)	(1.34)	(0.38)	(0.18)	(0.26)	(1.28)
LEV	-0.010	-0.015	-0.036	-0.075**	-0.087	0.082
	(-0.66)	(-0.52)	(-1.19)	(-2.20)	(-0.97)	(0.72)
Obs.	3302	3497	3393	3500	991	1102
Firms	740	642	641	593	219	166
Sargan	0.228	0.015	0.234	0.020	0.500	0.310

Notes: This table presents the GMM estimation results over time of the investment model in equation 2. The estimations use pre-determined firms selection into "financially constrained" and "financially unconstrained" classes. Constraint category assignments employ ex ante criteria based on firm size. The sample includes all UK firms. Analytical definitions for all the variables are provided in table 2.1. All regressions include time dummies. T-statistic values are reported in parentheses. ***, ** and * indicate coefficient is significant at the 1%, 5% and 10% respectively. For the estimation we use asymptotic

standard errors robust to heteroskedasticity. We report the Sargan test, which is a test of over-identifying restrictions, asymptotically distributed as a χ2 under the null of valid instruments.

Table 2.11 shows the results for all three of the subsamples after each subsample division into two equal subsamples according to the size median. Large firms show a more systematic drop in ICFS over time in comparison with their counterpart firms, however only the small firms have a statistically significant cash flow coefficient. Tobin's Q coefficient shows a decline between the second and third subsamples. The cash holdings are insignificant for all subsamples but are consistently positive. Moreover their influence on investment consistently drops over time for small firms. The total debt coefficients decrease in the strength of their negative relationship with capital expenditures with time in terms of each subsample.

Because the full sample which is considered in this study is robustly heterogeneous, meaning it covers all UK listed companies from very small ones to very large ones, from very negative cash flow firms to very positive cash flow firms etc., we decided to divide the firms further, beyond the simple division according to the median value. Thus each subsample after the median classification is divided again according to the median for each median subsample, so that each subsample (e.g. 2000-2009) is split into four equal subsamples according to again size, age and sales growth. However we only present in table 2.12 the sample division according to size in order to save space.

For the first subperiod:1980-1989 only the largest firms group shows significant coefficient for lagged investment, it is as if only these firms adjust investment to their desired one or it is costly for them to be away from their target investment. This group also has a positive and statistically significant coefficient of cash holdings, suggesting that these largest firms finance their investment projects with cash savings. For the very small firms in the same subperiod the total debt coefficient is significant at 5% level and has a negative effect on investment.

In the second subperiod: 1990-1999 the cash flow coefficients are positive but statistically insignificant in every small subsample. Tobin's Q, however, is significant for the three small subsamples apart from very large firms subsample and also the influence of Tobin's Q on investment decreases as the size of firms

grows within the subperiod. This is to be expected, based on the current theory, which claims that large firms are not as rich in growth opportunities as small firms are. Furthermore, within this subperiod, firms with size above the 25th percentile but below the 50th percentile in terms of size measure for the full sample, show negative and significant coefficient for total debt.

Table 2.12 GMM Estimates of the ICFS across SIZE Measure

DV: INV	L.INV		CF		Q		CASH		LEV		Obs.	Firms	Sargan
2000-2009													
Size<25pct	0.216***	(3.64)	0.006	(0.33)	0.004*	(1.70)	0.003	(0.11)	0.022	(0.62)	1610	390	0.036
25<Size<50pct	0.223***	(4.53)	0.045*	(1.93)	0.008**	(2.08)	0.011	(0.39)	-0.017	(-0.54)	1692	350	0.860
50<Size<75pct	0.399***	(6.95)	-0.011	(-0.66)	-0.000	(-0.03)	0.060	(1.61)	-0.002	(-0.05)	1734	326	0.044
Size>75pct	0.452***	(6.99)	0.012	(0.71)	0.004**	(2.20)	-0.000	(-0.00)	-0.063**	(-2.16)	1763	316	0.024
1990-1999													
Size<25pct	0.243***	(5.48)	0.043	(1.05)	0.016**	(2.42)	-0.006	(-0.13)	0.032	(0.79)	1687	327	0.271
25<Size<50pct	0.162***	(3.13)	0.075	(1.09)	0.013*	(1.69)	0.018	(0.24)	-0.069*	(-1.94)	1706	314	0.461
50<Size<75pct	0.324***	(5.66)	0.034	(0.93)	0.011*	(1.86)	0.031	(0.73)	-0.04	(-0.87)	1749	301	0.156
Size>75pct	0.476***	(7.52)	0.038	(0.87)	-0.001	(-0.34)	-0.004	(-0.10)	-0.049	(-1.57)	1751	292	0.157
1980-1989													
Size<25pct	0.100	(1.00)	0.119	(0.51)	0.009	(0.45)	0.106	(0.82)	-0.303**	(-2.42)	482	120	0.660
25<Size<50pct	0.157	(1.06)	0.088	(0.56)	0.017	(1.40)	-0.125	(-1.63)	-0.089	(-1.64)	509	99	0.685
50<Size<75pct	0.015	(0.08)	0.244	(1.55)	-0.028	(-1.02)	0.091	(1.29)	0.124	(1.01)	547	85	0.245
Size>75pct	0.171**	(2.04)	0.153	(1.00)	-0.003	(-0.19)	0.107*	(1.86)	-0.012	(-0.25)	555	81	0.626

Notes: This table presents the GMM estimation results over time of the investment model in equation 2. The estimations use pre-determined firms selection into four classes. Constraint category assignments employ ex ante criteria based on firm size. The sample includes all UK firms. Analytical definitions for all the variables are provided in table 2.1. All regressions include time dummies. T-statistic values are reported in parentheses. ***, ** and * indicate coefficient is significant at the 1%, 5% and 10% respectively. For the estimation we use asymptotic standard errors robust to heteroskedasticity. We report the Sargan test, which is a test of over-identifying restrictions, asymptotically distributed as a χ2 under the null of valid instruments.

In the third subperiod: 2000-2009 the firms' speed of adjustment to their target investment grows monotonically as the size of firms decreases, meaning the smaller the firms are, the faster they adjust their target investment or it is more costly for them to stay away from their target investment. Cash flow coefficient is positive in three small subsamples within this subperiod, the only negative coefficient belongs to firms with size above the 50th percentile and below 75th percentile. Also Tobin's Q coefficient for the latter small group is negative and insignificant. Very large firms show negative and a significant impact of leverage on investment spending. In contrast, the very small firms show positive influence of total debt on investment, as if they finance their investment with external debt funds, which is quite likely because very small firms' access to external finances such as equity funds can be with a limited access, hence they might be forced to rely only on debt and internal finances.

Overall conclusion from this subsamples splits is that ICFS decreases with time and total debt losses its strength in affecting investment expenditures over time.

In the next stage of this analysis we intend to find very constrained and very unconstrained firms through combining classification of all three divisions' measures. Namely, we group firms as constrained ones if their size, age and sales growth are below the median for the full sample within certain subperiod or if their size, age and sales growth is above the median for the full sample, or if their size, age are above and sales growth are below the median for the full sample. We group firms as unconstrained firms when their size, age and sales growth are above the median of the full sample within a particular subperiod. Subsamples sizes drop substantially as expected. The intuition behind this is to find certainly constrained firms and unconstrained firms characterised not by one category but by a few of them. Therefore constrained firms are small, young and quickly or slowly growing firms, they can also be old, mature and slowly growing firms, while unconstrained firm are large mature and quickly growing firms. Owing to this new way of classifying firms, firms which are contradictive in their features with respect to the full sample, (such as e.g. small - old firm), or switching between the classes, (such as e.g. if the sample is categorized according to size one firm might appear in the unconstrained firms' group but if the sample is categorized according to age the same firm might appear in the constrained firms' group), are dropped. Put differently, this classification makes triple sure

that the firm is financially constrained or unconstrained and it controls for firms switching between categories. Thanks to the large sample considered in this paper such a classification is feasible. The results of this sample division are presented in table 2.13 and they are very intriguing.

In terms of ICFS first and second subperiods show similar trends while third subsample seems to be contradictive, which is in line with the fact that the last subsample covers financial crisis which is the most likely cause for opposing results. For the first subperiod: 1980-1989 and second subsample: 1990-1999 ICFS is strongest in the subsample specified as large and mature firms but with slow pace of sales growth. However for this subsample Tobin's Q coefficients are negative and insignificant. This indicates clearly that these firms suffer from overinvestment problems. For the same subperiods ICFS is second strongest in the subsamples of firms characterized by small, young but with a great pace of sales growth. If one compares this subsample with the subsample of truly unconstrained firms then one would conclude that these firms are financially constrained, but if these firms are compared with firms featured as large, matured and slowly growing then the conclusion would be that they are unconstrained. Therefore, we have conflicting results and this example shows that it truly depends on which firms are compared with which. In other words, if this sample of small, young but quickly developing firms are judged by their size and age only they would be classed as constrained firms, however because they are growing fast, one can argue that they are unconstrained or if they are justified on the basis of sales growth ratio only, then they would be grouped in the unconstrained firms' class. This demonstrates the need of categorizing firm by more than one measure, or more specifically it helps if the measure of classifying firms into constrained and unconstrained firms is not only related with asymmetric information problems but also with other financial measures. The bottom line here is that the more robust sample, and more robust information one considers, and more robust measures are applied to the sample the better picture one is able to draw about firms' investment and financial decisions.

Table 2.013 GMM Estimates of the ICFS across SIZE, AGE and SG

DV: INV		L.INV		CF		Q		CASH		LEV		Obs.	Firms	Sargan
2000-2009														
Constr	SIZE,AGE,SG<50p	0.066	(0.92)	0.012	(0.88)	0.000	(0.12)	-0.003	(-0.08)	0.010	(0.42)	724	180	0.081
Constr/Unconstr	SIZE,AGE<50p & SG>50p	0.183***	(2.65)	0.027	(1.41)	0.012***	(2.79)	-0.069	(-1.56)	-0.052	(-0.92)	1344	341	0.257
Constr	SIZE,AGE>50p & SG<50p	0.421***	(7.25)	0.028	(0.77)	0.006	(1.01)	0.067	(1.60)	-0.019	(-0.38)	1480	236	0.099
Uncons	SIZE,AGE,SG>50p	0.346***	(3.16)	0.038	(0.75)	-0.002	(-0.44)	-0.023	(-0.66)	-0.099**	(-2.23)	917	147	0.687
1990-1999														
Constr	SIZE,AGE,SG<50p	0.194***	(3.76)	-0.016	(-0.32)	0.020*	(1.65)	0.083	(0.82)	0.046	(1.02)	734	158	0.508
Constr/Unconstr	SIZE,AGE<50p & SG>50p	0.245***	(3.63)	0.080	(1.27)	0.016*	(1.83)	0.051	(0.90)	-0.012	(-0.29)	1212	248	0.608
Constr	SIZE,AGE>50p & SG<50p	0.337***	(5.74)	0.105**	(2.55)	-0.017	(-1.37)	0.013	(0.36)	-0.067**	(-2.47)	1304	188	0.753
Uncons	SIZE,AGE,SG>50p	0.325***	(3.55)	0.019	(0.24)	0.012	(1.42)	-0.075*	(-1.95)	-0.013	(-0.36)	900	137	0.406
1980-1989														
Constr	SIZE,AGE,SG<50p	-0.094	(-0.58)	0.127	(0.77)	0.055**	(2.14)	-0.154*	(-1.75)	0.000	(0.00)	239	51	0.671
Constr/Unconstr	SIZE,AGE<50p & SG>50p	0.079	(0.84)	0.139	(0.68)	0.001	(0.04)	0.261**	(2.37)	-0.150	(-1.00)	334	83	0.249
Constr	SIZE,AGE>50p & SG<50p	0.088	(0.55)	0.472*	(1.90)	-0.005	(-0.22)	0.097	(0.66)	-0.018	(-0.29)	413	55	0.186
Uncons	SIZE,AGE,SG>50p	0.066	(0.09)	-0.089	(-0.17)	0.018	(0.61)	0.080	(0.50)	-0.050	(-0.21)	240	35	0.993

Notes: This table presents the GMM estimation results over time of the investment model in equation 2. The estimations use pre-determined firms selection into four classes. Constraint category assignments employ ex ante criteria based on firm size, age and sales growth. The sample includes all UK firms. Analytical definitions for all the variables are provided in table 2.1. All regressions include time dummies. T-statistic values are reported in parentheses. ***, ** and * indicate coefficient is significant at the 1%, 5% and 10% respectively. For the estimation we use asymptotic standard errors robust to heteroskedasticity. We report the Sargan test, which is a test of over-identifying restrictions, asymptotically distributed as a $\chi 2$ under the null of valid instruments.

The third subperiod: 2000-2009 demonstrates that ICFS is highest for the subsample of unconstrained firms, which is in agreement with argument that during financial crisis period there is a problem of the availability of external finances, hence only those firms are able to amply invest because they reach for their internal funds, which is the case in this subsample. Also for these unconstrained firms the coefficient of total debt is negative and significant, which we interpret as the more leveraged firm is, the less it invests, and this suggests again a problem with the availability of external finances or higher costs of external funds, hence even unconstrained firms will finance their investment projects with internal funds. The subperiod covering the financial crisis event shows that the ICFS has dropped for mature, large and slowly growing firms in comparison with prior subperiods, suggesting that the financial crisis period partly limited these firms' abilities to overinvest.

Four way split results can be also analysed from a different point of view and that is: the first subsample of firms characterised as small, young and slowly growing are mostly financially constrained in line with the theory, however, deeper investigation of these firms would probably conclude that there is a good share of distressed firms among all firms covered by this subsample. The second subsample of firms described as small, young and quickly growing are most likely to suffer from asymmetric information problems and hence they will be underinvesting. The next subsample made up of large, mature and slowly growing firms shows that these firms are most likely to be facing overinvestment problem. Finally, the fourth subsample of large, mature and quickly growing firms classed as financially unconstrained group of firms is most likely to face underinvestment problems due to agency conflicts.

Table 2.14 reports rolling regressions from 1980 to 2009 for ten year overlapping periods estimated with GMM technique in line with the model described in Equation 2.

Table 2.14 Rolling Regressions for Overlapping Periods

DV: INV	L.INV	CF	Q	CASH	LEV	Obs.	Firms	Sargan
1980-1989	0.304***	0.147	0.013	0.062	-0.075	2093	385	0.069
	(4.04)	(1.26)	(1.21)	(0.70)	(-0.74)			
1981-1990	0.322***	0.123	0.015**	0.045	-0.123	2349	385	0.075
	(5.17)	(1.06)	(1.96)	(0.67)	(-1.42)			
1982-1991	**0.371*****	**0.104**	**0.017****	**0.086**	**-0.112***	**2605**	**385**	**0.115**
	(6.47)	**(1.05)**	**(2.25)**	**(1.36)**	**(-1.65)**			
1983-1992	**0.349*****	**0.144**	**0.015***	**0.035**	**-0.136****	**2213**	**365**	**0.166**
	(5.67)	**(1.10)**	**(1.94)**	**(0.55)**	**(-2.39)**			
1984-1993	0.276***	-0.053	0.027***	0.051	-0.089*	3427	944	0.062
	(6.44)	(-0.67)	(3.49)	(0.73)	(-1.72)			
1985-1994	**0.284*****	**-0.021**	**0.017****	**-0.002**	**-0.076***	**4043**	**968**	**0.112**
	(8.94)	**(-0.43)**	**(2.66)**	**(-0.04)**	**(-1.70)**			
1986-1995	0.295***	-0.023	0.020**	0.003	-0.066*	4600	982	0.008
	(9.19)	(-0.44)	(2.20)	(0.06)	(-1.74)			
1987-1996	0.298***	0.002	0.027**	0.002	-0.039	5121	996	4E-04
	(8.85)	(0.03)	(2.07)	(0.03)	(-1.29)			
1988-1997	**0.299*****	**-0.040**	**0.034****	**0.017**	**-0.066****	**5813**	**1099**	**0.175**
	(10.04)	**(-0.78)**	**(3.06)**	**(0.36)**	**(-2.18)**			
1989-1998	0.298***	-0.004	0.024**	0.025	-0.041	6360	1144	0.032
	(10.01)	(-0.08)	(2.55)	(0.61)	(-1.51)			
1990-1999	0.295***	0.019	0.016**	0.011	-0.056**	6893	1234	0.042
	(9.91)	(0.41)	(2.32)	(0.32)	(-1.99)			
1991-2000	0.310***	0.022	0.017***	0.048	-0.049*	6414	1180	0.009
	(8.10)	(0.49)	(2.77)	(1.32)	(-1.74)			
1992-2001	0.397***	0.078*	0.007	0.058*	-0.017	5953	1129	0.053
	(8.82)	(1.89)	(0.95)	(1.77)	(-0.57)			
1993-2002	0.452***	-0.011	0.007*	0.084**	-0.033	5489	1051	0.02
	(10.37)	(-0.23)	(1.70)	(2.32)	(-1.18)			
1994-2003	0.408***	0.032	0.005*	0.049*	-0.038	5760	1337	0.059
	(9.28)	(1.50)	(1.80)	(1.72)	(-1.17)			
1995-2004	**0.332*****	**0.039***	**0.005***	**0.022**	**-0.046**	**5741**	**1304**	**0.133**
	(9.68)	**(1.89)**	**(1.73)**	**(0.75)**	**(-1.40)**			
1996-2005	**0.316*****	**0.038***	**0.007****	**0.009**	**-0.065***	**5781**	**1267**	**0.198**
	(8.50)	**(1.87)**	**(2.21)**	**(0.27)**	**(-1.75)**			
1998-2007	**0.324*****	**0.043****	**0.003**	**-0.008**	**-0.025**	**6024**	**1169**	**0.487**
	(9.69)	**(2.51)**	**(1.14)**	**(-0.28)**	**(-1.37)**			
1999-2008	**0.325*****	**0.054*****	**-0.000**	**-0.001**	**-0.020**	**6411**	**1280**	**0.144**
	(9.75)	**(3.37)**	**(-0.18)**	**(-0.03)**	**(-1.15)**			
2000-2009	**0.340*****	**0.040****	**0.005****	**-0.024**	**-0.035****	**6799**	**1382**	**0.131**
	(10.28)	**(2.16)**	**(2.17)**	**(-1.01)**	**(-2.38)**			

Notes: This table displays the GMM estimation results from the rolling ten year investment regressions in equation 2 from 1980 to 2009. The sample includes all UK firms. Analytical definitions for all the variables are provided in table 2.1. All regressions include time dummies.

Only those results for which both the identification and the over-identification criteria are satisfied are reported in bold, and as the coefficients are significantly different from 0 the results are in yellow colour. In comparison with the OLS results in Table 2.5, the GMM coefficients on Tobin's Q are mostly larger than their OLS counterparts and this is in agreement with previous literature (see Erickson and Whited, 2000 or Agca and Mozumdar, 2008). However, GMM estimators are more unstable because in a number of years the coefficients on Tobin's Q are statistically insignificant. The GMM coefficients on cash flow show a different pattern to the OLS estimators. The GMM investment-cash flow sensitivities are positive and significant in 10 out of 21 subperiods at minimum 10% confidence level, positive and insignificant in the other 8 subperiods, and negative and insignificant in 3 subperiods. These results show a clear decrease in ICFS over time and coefficients on Tobin's Q also present a declining pattern as times goes on. The cash holdings impact on investment is positive for most of the time but it becomes negative in the last three subperiods examined. The total debt influence on investment is negative all the time and its level is decreasing over time.

To sum up, the cash flow coefficients in table 2.14 are similar to the OLS results presented above. Even though they are insignificant according to the GMM model they still decline with time in relation to the physical investment. In line with hypothesis 8 of this paper, debt exhibits to be more appealing in the physical investment regressions than cash holdings.

All in all, after comparing the results based on Equation's 1 and 2 it is clear to see that after including cash holdings and debt finances in the model, ICFS becomes a little bit sharper in their drop, namely in the OLS regression without other financial variables cash flow coefficients falls from 0.281 in the first period to 0.11 in the second period (60% drop), while in the GMM regression with other financial variable the cash flow coefficient decreases relatively from 0.147 to 0.0187 (87%).

After splitting the sample into different categories according to various measures, ICFS still shows the same pattern, no matter which classification

category we refer to, it is declining over the time. For all firms' groups, total debt becomes less regularly and less negative in relation to the physical investment as time goes by. For positive cash flow firms' the group leverage coefficients fall down over time from -0.139 in the first period to -0.0334 in the last period. The sensitivity of investment to cash flow reduces as size and age increases. We interpret this finding as further evidence that the asymmetric information conflicts have an impact on investment-cash flow sensitivities because larger and older firms are more established and known in the market therefore the external finance becomes cheaper for them. Small firms are generally associated with greater information asymmetries.

2.6 Robustness

The results in the previous chapter are robust to an alternative estimation procedure, namely we run fixed effects regressions based on both equations 1 and 2. The results from these regressions are similar to the previous ones.

As it has been broadly discusses in the literature, Q may not be a good enough control for investment opportunities because of its measurement problems, and hence other financial variables may proxy for investment demand (e.g. Erickson and Whited (2000)). However, for robustness purposes we have run regression with sales growth instead of Tobin's Q in the model and the pattern of ICFS was similar. Therefore issues with Q cannot properly explain why the ICFS decreases so substantially for physical investment over the time. In the same way, measurements problems in Q are not able to explain the differences in the role of financial variables across physical investment. BP (2009) approach this with the possibility that Q started to be a better control for investment demand during their period of study, which they consider in theory as the reason for a decline in the ICFS. They also write that they actually have run their regressions without Q and they still were coming up with the same pattern of ICFS falling down over the time, which implies that their findings are not affected by a reduction in measurement error related with Q. Carpenter and Guariglia (2008) introduce contractual obligations to new investment projects as a helping proxy for information about investment demand. They discover that after incorporating this variable alongside Q in a typical ICFS regression, the cash flow coefficients decline for large firms, but nothing new happens with the cash flow coefficients for small firms, which supports the argument that the significance of cash flow in terms of small firms appears to be because of financing imperfections.

2.7 Conclusions

The corporate finance literature covers very exciting as well as very important debates on financing constraints and investment–cash flow sensitivity. FHP (1988) initiated first the argument backed up by the empirical evidence that in the presence of capital market imperfections, firms facing a higher wedge between internal and external funds should be more severely affected by underinvestment problems when experiencing negative shocks to internal cash. Hence, more constrained firms should show higher investment–cash flow sensitivity. An ample amount of empirical evidence supporting this hypothesis has been provided by many subsequent papers of different authors. However, KZ (1997) and Cleary (1999) introduced new evidence showing the opposite – the least constrained firms exhibit higher investment–cash flow sensitivity. Our analysis provides a partial explanation for this puzzle by taking into account a very heterogeneous sample of firms over a thirty year period and showing that the FHP or KZ/Cleary results may appear depending on the sample selection in terms of the types of firms accepted in the sample as well as time period the sample originates from. The first applies to the problem of data mining, e.g. most of the evidence provided to support the FHP hypothesis is built on a very large firms' sample, and therefore this may lead to a very quick and easy explanation when the phenomenon is actually more complex. The contradictive evidence provided by KZ is explained in detailed by work of Allayannis and Mozumdar (2004) who state that KZ/Cleary results are largely due to firms in distress as proxied by negative cash flow observations. Additionally, their tests suggest that KZ_s results are also affected by a few influential observations in a small sample. When such observations are excluded from their sample, the estimated sensitivities for financially constrained firms are much higher and overall results much closer to those in earlier papers.

The evidence provided in this paper shows that whether the ICFS is higher for constrained or unconstrained firm purely depends on:

1) Sample selection, e.g. if one includes small or large firms only, only positive cash flow firms, only firms with total debt ratio below 1, with Tobin's Q below 10 or with total assets below 10mln or with only positive sales growth and

so on. That sort of criteria function practically in the literature, where some called this "data mining" or "cutting corners"

2)   Which subsamples are compared with which subsamples of firms, which classification criteria is employed for the comparison, because various firms have various features, e.g. if a firm is old it does not necessarily means it is large or the other way round, therefore firms switching between subsamples may affect the results

3)   Time period of the sample, whether the sample covers economic growth or economic downturn

4)   Industry or country selection, different industries have different financial characteristics, different countries have different financial systems differently affecting firms financial and investment decisions and so on.

In this paper we used various empirical models and measures to test how different determinants of firms influence their investment policy over a thirty year time period. Therefore this paper extends earlier empirical analyses on the relationship between investment and other variables in a few important dimensions. Employing a panel of UK publicly traded non-financial firms between 1980 and 2009, we investigate the changes of ICFS over very long period of time, we also test whether financing concerns influence firm investment decisions. By examining the role of cash flows and growth opportunities in determining investment in perfect and imperfect market, we are also able to underline the importance of these characteristics, which has been explored partially in the literature. It seems that cash flow of firms can be used sufficiently for hedging purposes in cases of fluctuations in financial constraints, which limits the ability of firms to undertake profitable investment opportunities.

The obvious conclusion stemming clearly from these results is that the ICFS for physical investment has declined sharply over the time, regardless from controlling for negative cash flow firms, the role of cash holdings and debt financing or splitting sample to two or four contrasting groups according to various measures like age, size, sales growth or dividend payments, and that this decline cannot be explained on the basis of measurement error alone. The results of this paper also reveal an increase in the proportion of small, young and negative cash flow firms.

The closer investigation of cash holdings in recent decades shows that their overall role in the ICFS is insignificant, with the exception of small firms'

subsamples. Whereas the role of leverage is not as substantial as it used to be, its negative impact decreases with time.

The investigation of financial crisis time versus financial boom period provides additional evidence to support the FHP arguments. During periods of financial crisis firms face higher costs or shortage of external funds, in other words, the financial constraints that firms face, are more severe than before, therefore the only way for firms to invest is to employ internal funds if these are available and that is what we can find from studying the results of this paper. During the financial crisis period the ICFS becomes highest for unconstrained firms in contrast with the financial boom time when constrained firms show higher ICFS.

Of course, the outcomes recorded in this work are grounded on the study of companies from only one country. More research will be needed to further investigate the role of different characteristics in determining corporate investment. Particularly we feel that Corporate Governance should become a more relevant issue in the financial world. Although there has been a great chunk of research that shows that there are indeed effective corporate governance tools to reduce the expected agency costs, we know little as to how these governance mechanisms interact with each other. Hence there is still a gap in the literature regarding the exact nature of the relationship between alternative corporate governance mechanisms and their role in determining the firm's financial and investment decisions, especially over long period of time. There is an area for future study on what the research on Corporate Governance has to offer investors, and recommends the incorporation of Corporate Governance issues and their implications for corporate financial management. The extent to which financial and investment decisions influence corporate performance needs to be analyzed.

All in all the analysis in this paper demonstrates that the cash flow coefficient on investment is decreasing with time. We conclude that firms during financial crisis decrease significantly their investment and start to save cash by increasing their cash holdings.

Chapter 3

The R&D Investment – Cash Flow Sensitivity over Time: Evidence from US

and UK

3.1 Introduction

Corporate research and development (R&D hereafter) spending has increased prominently in the last few decades (see, e.g., Brown and Petersen, 2009). The emergence of "high technology" industries such as software and biotechnology as well as the raising importance of innovation to non high-tech industries has fuelled such growth. The goal of raising R&D expenses is to increase firm-level innovation and ultimately firm value. Science and Engineering Indicators (2010) assert that the world's R&D expenditures have been on an 11-year doubling path, growing faster than total global economic output. This indicator of commitment to innovation went from an estimated $525 billion in 1996 to approximately $1.1 trillion in 2007. The steady and large upward trend illustrates the rapidly growing global focus on innovation. Furthermore, according to the Battelle-R&D Magazine (2011) global R&D spending is expected to increase by 3.6 percent in 2011 to $1.2 trillion.

Economists and policy makers have stressed the central role of R&D activities in driving long-term economic growth. Schumpeter (1942) is one of the first economists to emphasize high place of innovations and knowledge accumulation in determining the long run growth. By defending the monopoly power of large corporations, which are able to finance uncertain innovative projects with their past profits, Schumpeter (1942) indirectly refers to the validity of internal finance for innovation. From then onwards the importance of financial factors for firms' investment decisions has been extensively discussed (see Hubbard (1998), Hall (2002) for a review). Also, the impact of the financial system on economic growth has been acknowledged by the literature for a long time (Levine 2002).

There is a large literature concerning the characteristics determining the level of investment in general. In addition to market demand, the centre of attention is usually on the financial sources for the investment and specifically the use of internal funding (retained earnings or cash flow). Typically the studies find a correlation between capital investment and the availability of internal funds (Hubbard 1998). The theoretical explanation for this relation is largely based on information asymmetries between firms and external financiers. Hence, these information asymmetries attribute to market imperfections, namely financial

constraints. Firms' activities are financially constrained if internal finance is deficient and external finance is either relatively costly, carrying an external finance premium, or rationed. Both, agency conflicts and adverse selection problems are relevant (Von Kalckreuth, 2006).

Two strands appeared in the literature in terms of the severity of financing constraints' influence on R&D investment versus physical investment. On one hand, it has been argued by many researchers that financing constraints are more relevant to R&D than to capital expenditures. Since the theoretical explanations for a found correlation between investment in physical capital and the availability of internal funds (Hubbard 1998) is largely based on information asymmetries between the providers of capital and firm owners or managers, the linkage has been assumed to be even more pronounced for R&D investments than for physical investments because R&D investment is more risky than investments in fixed assets. Additionally, it is also more difficult to collateralize. This is also what the empirical literature on the determinants of R&D investments (surveyed by Hall 2002) concludes. Debt poorly substitute internal finances in case of R&D investment due to lack or limited collateral ability of R&D projects to secure firm's borrowing, great rate of risk featuring innovative activities as well as the complications in estimating the expected future prospects of R&D investment. All this is even more manifested in terms of companies described as e.g. small or young, because they are more like to encounter credit constraints due to their "informational opacity" in comparison with their counterparts firms, large or mature, which can deliver detailed financial information or in the latter instance they are already well known to the market.

Debt is not a popular source of funding for R&D. Instead R&D investment is sensitive to cash flow variations and this sensitivity is often greater in market based economies (e.g. US) than in bank based economies (e.g. France, Japan) (Mairesse et al.,1999). This is ascribed to that the information asymmetries are smaller when firms and banks have trustful and long standing relations. Carreira and Silva (2010) states that compared with physical capital, R&D investments face more severe financial constraints. Binz and Czarnitzki (2008) find that the availability of internal funds is more decisive for R&D investment than for capital investment. They assert that R&D is harder to finance through external resources in the first place, which is reflected by the higher sensitivity of R&D to internal financial resources. Binz and Czarnitzki's (2008) results show that the observed

reaction of R&D to financial constraints is lower than for capital investment, which they explain on the basis of argument existing in the literature for a long time that adjusting R&D is more costly than capital investment, which implies that the firms try to smooth R&D spending over time. Furthermore, prior work on R&D investment identifies that R&D investment has high adjustment costs because in a great part it consists of wage payments to highly skilled technology workers. The change of staff working on R&D projects can be very costly due to very large hiring and training costs as well as the problem of unwanted dissemination of proprietary information on innovation efforts. Therefore it is costly for firms to adjust the flow of R&D investment in response to temporary changes in the availability of finance (Brown and Petersen, 2011).

Studies by Fazzari et al., (1988), Hsiao and Tahmiscioglu (1997) and Aghion et al., (2004), demonstrate that firms with a high level of investment in physical capital face more financial constraints, and that these constraints affect their ability to invest in R&D. Pindado et al. (2010) find that capital-intensive firms face greater financial constraints, and as a result, the market valuation of their R&D projects is lower. Capital intensity also has a negative effect on the relationship between firm value and R&D spending due to the greater financial constraints faced by capital-intensive firms. Overall, the sensitivity of R&D investments to cash flow is often seen as a sign of that firms are financially constrained due to financial market imperfections. Himmelberg and Petersen (1994) find that small high-tech firms are particularly vulnerable to such imperfections. This suggests a possible underinvestment in R&D and that research opportunities as a result may not be fully exploited.

On the other hand, Bond et al., (1999) find significant differences between the cash flow influences on R&D and investment for large manufacturing firms in the United Kingdom and Germany. German firms in their sample are insensitive to cash flow shocks, whereas the investment of UK firms not conducting R&D investment does respond. They conclude that financial constraints are important for British firms, but that those which do R&D are a self-selected group that faces fewer constraints. Studies by Himmelberg and Petersen (1994) or Cincera (2003) imply that, given the existence of very high adjustment costs for innovation investment in the sense that a large part of R&D expenditure is wages for highly qualified staff that cannot be hired or fired fast, firms will engage in R&D activities only if they do not expect to be seriously affected by credit constraints. Bond et al.

(2003) do not find cash flow sensitivity for R&D investments either in the UK or in Germany. They argue that innovative firms are not likely to face financial constraints as they are "deep pocket" firms, i.e. they engage in innovation activity when they have plenty of internal financial resources to do so.

The main research question of this study is how capital market imperfections affect firms with respect to their R&D investment decisions. There are at least three reasons why R&D investment is particularly likely to be influenced by capital market imperfections. Firstly, the returns to R&D investment are skewed (see Harhoff et al. (1999)) and greatly uncertain, partly because R&D projects have a low probability of financial success. Mansfield et al. (1977) finds a probability of financial success for R&D projects of only 27%. Secondly, serious asymmetric information problem is likely to exist between firms and potential investors. Thirdly, limited collateral value of R&D investment can importantly magnify the capital market imperfections.

The present study also aims to contribute to the theoretical discussion about determinants of R&D activity, by investigating the R&D investments of the US and UK firms from 1990 until 2010. The motivation for the study is that there are several factors that may potentially counteract the theoretical expectation of cash flow sensitivity. The US and UK economies are classified as a market based systems according to a ranking made by La Porta et al. (1998) or Levine (2002) and that would point towards more sensitivity of cash flow. However, the literature also recognizes a very sharp rise in the proportion of negative cash flow observations (see e.g., Brown and Petersen, 2009) and that would point towards negative cash flow sensitivity. Also, the tax systems of US[16] and UK[17] exhibit some peculiarities that are different between the two countries and that are

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[16] The important issue related with firms' R&D investment decisions is an accounting treatment of R&D expenses, such as the R&D tax allowances, subsidies or tax credits. US government treats the expenditures of R&D as capital expenses, which can be deducted as current business expenses. (See IRS.gov at
http://www.irs.gov/businesses/small/industries/article/0,,id=100123,00.html)

[17] UK has two schemes for claiming R&D relief, depending on the size of the company or organization, that is the Small or Medium-sized Enterprise (SME) and the Large Company Scheme. From 1 August 2008, the tax relief on allowable R&D costs is 175 (150 beforehand) per cent for the SME and 130 (125 beforehand) per cent for the Large firms. SME scheme includes also payable credit of up to £24 for every £100 of qualifying expenditure on R&D to 31 July 2008 and of up to £24.50 for every £100 thereafter, while large company scheme has no payable credit. Both schemes also cover details about subcontractors, employee costs, staff providers, materials, payments to clinical trials volunteers, utilities, software, subcontracted R&D expenditure and capital expenditures. SME scheme also covers particulars about subsidies and grants. (See HM Revenue and Customs, 2011 at http://www.hmrc.gov.uk/ct/forms-rates/claims/randd.htm)

different from many other countries. There are a number of ways to make allocations for future investments that would lower the tax rate. Such allocations and their subsequent use for investments would lower the immediate sensitivity to cash flow. These contingencies call for a closer investigation of determinants of R&D expenditures in the US and UK contexts.

This paper provides additional empirical evidence on the role of financial factors in company R&D investment decisions for US firms' sample and UK firms' sample. Detailed analysis of the impact of cash flows on R&D investment over time by using different measures of cash flows and different time aspects are presented as well. This investigation directly examines the stability of R&D investment-cash flow sensitivity over time. Hence, year by year estimations are presented. For comparison reason, detailed analysis of the impact of cash flows on physical investment over time is demonstrated too. Moreover, this study explores, at micro-level over 21 years period of time, behavior of firms involved in investing in R&D projects. Thus, roles of cash flows, cash reserves, net debt and net stock issues in determining corporate R&D investment expenditures are investigated over two subperiods: 1990-1999 and 2000-2010. Implicitly, characteristics of firms, intensively investing in R&D activities versus firms weakly maintaining R&D investments, are analyzed. More specifically, firms are divided according to an average R&D investment intensity measured with firm's average over time ratio of R&D expense over total assets (small versus high R&D intensity). Additionally, firms are also divided according to the industry they belong to (high-tech versus non high-tech industry).

There are only two papers presenting the changes of R&D investment-cash flow sensitivity over time, Brown and Petersen (2009) and Chen and Chen (2012) based on US firms sample. Brown and Petersen (2009) find that the physical investment-cash flow sensitivity has declined and largely disappeared but if R&D is included as investment, then the investment-cash flow sensitivity is still strong, particularly for firms with positive cash flows. Chen and Chen (2012) demonstrate that during the recent credit crunch, the R&D-cash flow sensitivity is near zero or negative, even for firms with positive cash flows. Moreover, as mentioned above, this study looks not only at year by year R&D investment-cash flow sensitivities over time but also R&D positive firms' capital expenditures-cash flow sensitivities. Brown and Petersen (2009) reports changes of ICFS over time separately for R&D firms sample and capital expenditures firms

sample, hence their R&D firms sample is smaller in size, in comparison with capital expenditures sample. This analysis considers same sample size for R&D and physical investments, thus it presents directly how positive R&D firms invest in capital expenditures. This allows consistent discovery of positive R&D firms' behavior in details. Additionally all analyses are also controlled for negative cash flow firms.

Contrary to prior studies (estimating R&D investment cash flow sensitivity over time) that take into account the US firms this work delivers evidence for both the UK and US markets. To author's knowledge, there is no study of the R&D investment-cash flow relationship through time or study of the physical– cash flow relationship over time based on the UK listed firms. Although, UK and US both have market-based financial systems they do differ, therefore setting them together for a comparison should show interesting results. The US and UK are often described as Anglo-Saxon countries with respect to ownership structures of companies and institutional and legal framework. Despite the fact that the UK and the US are seen as functioning according to a similar "common law" regulatory system (La Porta et.al., 1998)[18], the UK market is substantially different in certain points. For example the weak role of directors' boards and institutions in mitigating agency problems in the UK have been empirically found by researchers such as Faccio and Lasfer (2000), Goergen and Rennebog (2001), Franks et al. (2001) or Short and Keasey (1999). There are distinct corporate features between the US and the UK, which may have important implications with regard to the R&D investment behavior of firms. For instance, as average yearly plots in section 5 suggest the UK total investment composition, defined as a sum of physical and R&D investments, changes in favour of R&D investment 10 years after the US firms. Guarglia (2009) argues that the relatively small amount of venture capital financing, the relative lack of corporate bond and commercial paper markets, and the relative thinness and highly regulated banking and equity markets, seem to make the idea of financing constraints that affect firm behavior much more plausible to European researchers than to the US ones. Therefore, this work adds to the debate on the effects of financial constraints on R&D

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[18] La Porta, Lopez-de-Silanes and Shleifer (1998) describe for 49 countries the level of shareholder-rights protection. On a scale from zero (no protection) to six (high protection), UK and US firms receive a score of five. For purpose of a comparison with other continental-European countries, France, Germany or the Netherlands get low scores for shareholder protection (three, one and two, respectively).

investment over time, with a focus on the UK and the US rather than just the US. This is a valid issue because the controversy about how to interpret the R&D investment cash flow sensitivity is much less developed in the UK than it has been in the US.

Furthermore, this paper contributes to the literature on R&D investment decisions of firms on few more grounds. Firstly, with respect to the main research question set above, features of financially constrained and unconstrained firms are presented in effect of various sample divisions. Following Fazzari et al., (1988), this work employs a comparative approach between classes of firms.[19] Therefore, two samples of UK and US firms considered in this paper are divided according to measures of firm age (young versus mature) and dividend payout ratio (low or none versus high dividend), which proxy for financial constraints.

Secondly, the impact of R&D investment variability on the R&D investment cash flow sensitivity is examined over time in this paper. Samples are divided according to firm's average R&D investment variability over time, measured with the average standard deviation of firm's R&D expenditure over time (small versus high R&D expenses variability). This factor can play an important role for investment decision-making of corporations during the period when firms suffer from serious financial fragility. R&D investment variability assesses how the firm manages its R&D function over time. R&D expenditure variability is a measure of the fluctuation in firm level R&D spending over time. A firm with relatively low R&D spending variability invests about the same amount on R&D each time period and its R&D investment is relatively stable over time, while a firm with relatively high R&D spending variability changes its R&D expenditure frequently and substantially over time and its R&D investment is fluctuating over time. The main objective of this analysis is to show that R&D investment variability is an indication of effective governance of the research and development process and effective corporate finance management. In order to support and continue good progress on innovations, firms may preserve discretionary funds in the form of organizational slack (Bourgeois, 1981) so that they are able to fund immediately

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[19] Since the work of Fazzari et al. (1988) the methodology of sample-splitting has been broadly adopted in the literature on financing constraints and investment, despite the criticism produced by Kaplan and Zingales (1997) and their followers. Kaplan and Zingales (1997) assumes that all firms face binding financial constraints and they supply a counter-example in which a firm that faces greater financial constraints (much higher costs of external finance in comparison with internal funds) could have a lower sensitivity of investment to internal finance. However, also see the response in Fazzari et al., (2000).

promising opportunities as soon as they are discovered. The form of organizational slack can be generating cash holdings or decreasing debt ratio (Bourgeois and Singh, 1983; Bromiley, 1991).

The next contribution lies in the dynamic analysis of the R&D investment decision. In this context the approach this work takes is that market imperfections such as adjustment and transaction costs may prevent firms from rapidly adapting to their desired target R&D investment. A partial target-adjustment model that allows for the possibility of delays in response of firms in adjusting their R&D expenses is employed. Specifically, to formally investigate the behaviour of R&D firms, a dynamic R&D regression is examined that includes cash flow, Tobin's Q, firm size, cash holdings, stock issues and debt issues. By including in one regression cash flow and cash holding, which represent internal finances sources, and stock and debt issues, which represent external finances sources, this research will be able to answer another question, that is which finances are more important for R&D firms. R&D investment regression is estimated with a "system" GMM estimator that accounts for unobserved firm-specific effects and controls for the potential endogeneity of all financial and non-financial (e.g. size) variables. GMM in this study estimate dynamic R&D models that include measures of internal and external finance in order to explore the importance of cash savings, public equity finance and long term debts finance for R&D investment. As pointed out by Brown and Petersen (2010) a large literature investigates the link between internal finance and physical investment, but comparatively few studies consider R&D and even fewer evaluate the role of external finance. For comparison reason, also OLS estimates are reported for basic and augmented models.

Fourthly, this research examines the relationship between finance and R&D over time covering financial crisis period for panels of US and UK listed firms. All the samples' splits stated above are performed for various subperiods in order to observe the changes of firm behaviour over time and over financial crisis period. The following subperiods are created: 1990-1999, 2000-2010, 2000-2007 and 2008-2010, where the last two: respectively, pre-crisis and crisis periods, are specifically created for the purpose of examining the financial crisis period. In other words, this study detects financially constrained and unconstrained firms' behavior before the financial crisis: 2000-2007 and during the financial crisis: 2008-2010. Parsimonious evidence of the financial crisis event should be

included in year by year analysis. However, the deeper analysis is needed to draw any meaningful results. Therefore, the OLS technique is applied to the model. The OLS technique applied in this chapter still attempts to control for potential endogeneity by lagging the regressors one period. GMM technique is not suitable here because of its requirement of minimum 4 consecutive firm year observations. Therefore the financial crisis dummy is created which takes value of 1 for years 2008 to 2010 and value of 0 for years 2000 to 2007 in the second subperiod of US and UK samples. The interaction term between cash flow and financial crisis dummy is included in the R&D investment in order to examine the effect of financial crisis on the sensitivity of R&D investment to fluctuations in cash flow.

The main finding of this paper is the persistently negative relationship between cash flow and R&D investment. Empirical literature on financial constraints finds that, holding investment demand fixed, investment is sensitive to changes in internal funds, and that this sensitivity is stronger for more financially constrained firms (Fazzari et al., 1988). In other words, this negative relationship can be explained with financial constraints theory where more constrained firms suffer from more costly external finances and the lack of external funds when they are required. Therefore, given the presence of financial markets imperfections, firms with negative profits may struggle to get loans, whereas firms with positive profits may not, hence the latter may expand even more.

The negative ICFS found in this paper is almost independent from the measure of cash flow or from dropping or including the negative cash flow firm year observations or firms whose sum of cash flow-to-assets ratio over the sample period is negative in the sample. This negative association between R&D investment and cash flow is much stronger for financially constrained firms, which may indicate that these firms finance their R&D projects with other available funds. Counterparts firms also show negative relationship between R&D investment and cash flow, however their R&D investment-cash flow sensitivity is much weaker and most of the time insignificant, suggesting that these firms are more likely to employ cash flow in the process of financing firms' innovations, or the alternative understanding, is that they do not require as much financing of R&D because they invest relatively less in R&D projects. Similar trend is found for net stock issues coefficients, but on the smaller scale. This is in agreement with

study of Brown and Petersen (2009) who stresses the rising importance of public equity as a source of funds for the time period 1970-2006, particularly for firms with persistent negative cash flows.

As expected, Tobin's Q – proxy for growth opportunities, appears to play a significant role in explaining R&D investment, with a greater economic coefficient for constrained firms defined by classification measure related with asymmetric information conflicts, such as age, but smaller coefficient for firms defined as fixed R&D investment than firms defined as cutting edge R&D investment, both measured by firm's average R&D standard deviation over firm's years observations. This is in line with common belief that financially constrained firms have higher growth opportunities in comparison with unconstrained firms. For the full sample of US and UK firms between 1990-1999 and 2000-2010, we discover a strong positive and most of the time significant link between cash holdings and R&D, but in most cases insignificant and negative or positive link between external finance and R&D and between size and R&D investment. The positive and significant coefficient on cash holdings is greater for so called financially constrained firms than for their corresponding firms. All this suggest that financially constrained R&D firms save up cash stock out of cash flow innovations or stock issues in order to finance their R&D investment, while unconstrained R&D firms' behaviour is indeterminate. This finding is in line with study of Brown and Petersen (2011) who find that firms most likely to face financing frictions rely extensively on cash holdings to smooth R&D, while firms less likely to face financing frictions appear to smooth R&D without the use of costly cash holdings.

When financial crisis period is considered the ICFS is still even more negative and significant, whereas cash holdings coefficients are more positive and significant according to the OLS regression. In line with GMM results cash holding of the full sample of US firms' impact R&D investment negatively during the crisis.

In terms of comparison the US firms with the UK firms we learn that the coefficients for the UK firms are much greater than for the US firms, implying stronger dependence of R&D investment on financial variables in the UK than in the US market.

The robust estimated results highlight that the negative dependence of investment on internal sources cannot be fully attributed to the persistently negative cash flow firms. It appears again that firm cash holdings exerts a

significant impact on the availability of financial sources to be channeled into R&D investment for negative and positive cash flow firms.

This paper's findings also indicate that R&D investment is now an important fraction of corporate investment spending for a significant share of publicly traded firms. According to the sample of this research the share of R&D investment in total investment, measured as the sum of physical and R&D investments, is higher than the share of capital investment for US firms since year 1992 and for UK firms since year 2001.

Overall, the results show that R&D investment has been affected by financial constraints. Lastly this study shows vast range of differences between R&D firms in the US and UK. The most outstanding one is that US firms show to be much more advanced in their R&D investing process.

The remainder of the paper is designed as follows. Section 2 discusses literature review on R&D investment and internal equity finance. Section 3 provides empirical models, hypotheses development and the estimation method. Section 4 delivers a description of the dataset, together with some summary statistics. Section 5 presents empirical results. Section 6 presents robustness checks. Section 7 summarizes the paper.

3.2 R&D investment and its financing – literature review

Literature on R&D investment is dominated by US and UK countries (see e.g., Anagnostopoulou and Levis, 2008).[20] This chapter concentrates on US and UK firms for three reasons. Firstly, the research on R&D investment is well developed in those countries and thus the comparison of this research with other studies is possible. Secondly, the data availability stands behind such well developed R&D research in the US and UK market and also plays its role in choosing these markets for the investigation in this paper. Finally, US market is a leading market in investing in R&D projects.[21] Duesterberg (2010) presents that when measured on a value-added basis, U.S. manufacturing is the global leader in high-technology goods, it holds around a 30% global market share. Moreover, European Commission (2011) demonstrates that the UK outperforms both the EU average and a group of similar countries and nears the United States in a range of indicators such as high quality publications, high quality patents and high share of the population engaged in knowledge intensive activities. On the other hand, the system underperforms in terms of public and private R&D investment and technological performance as measured by the importance of patents in the economy.

3.2.1 Theoretical aspects

Technological progress is recognized by the economy as the central determinant in explaining the process of economic growth, the performance competitiveness between firms and industries, and the evolution of firms' production structure. Economic growth is driven by the products, processes and services born from creative ideas. The expenditures on research and development form the existence and development process of creative ideas. Despite the fact that not all R&D activities are successful to materialize any

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[20] "US were found to have shown the maximum share (43 per cent) of publications (and more than 50 per cent citations share), followed by the UK" (Gupta et al., 2007).

[21] "The United States remained by far the single largest R&D-performing country. Its R&D expenditure of $369 billion in 2007 exceeded the Asian region's total of $338 billion and the EU's (EU-27) $263 billion. The U.S. 2007 total broadly matched the combined R&D expenditures of the next four largest countries: Japan, China, Germany, and France." (Science and Engineering Indicators: 2010, http://www.nsf.gov/statistics/seind10/c0/c0s2.htm).

tangible results, these failures also contribute in creating the corpus of knowledge needed to stimulate the innovation process.

Schumpeter (1942) points out to large firms' role as engines of economic growth, because they generate knowledge in specific technological areas and markets. This recognition is sometimes referred to as "creative accumulation". Aghion and Howitt (1992) among others formalized Schumpeter's views in the field of (endogenous) growth model, which predicts that the effects of incremental changes in the innovation activity are substantial social gains for the entire economy, as the innovation is adapted and diffused. Arrow (1962) also recognizes that the knowledge incorporated in new technologies cannot be fully taken for its creators' own use. To the extent of knowledge being a good with features of non-rivalry (the consumption of one individual does not take away from that of another) and impossible excludability (there is a struggle to keep an individual out from enjoying it) it cannot be kept secret, thus a market failure appears leading to underinvestment in R&D. [22] Griliches (1992) provides empirical support on this approach by demonstrating that the private rate of return on investment in R&D is lower than the social rate.

The presence of a wedge between the private rate of return of R&D investment and the cost of capital when innovators and providers of finance are different entities is also argued by Arrow (1962). Undoubtedly, by means of external finance resources funding R&D intensive activities is difficult owing to the existence of imperfections in capital market. Automatically, this assumption is in contrast with the theorem of Modigliani-Miller (1958) which states that any positive net present value investment project can be financed either internally or externally, since external funds can substitute for internal capital without any costs.[23] A crucial implication stems from the theories of the firm functioning in imperfect capital markets that is firm's investment decisions are determined by financial factors like retained earnings and the availability of new debt or equity. According to Himmelberg and Petersen (1994) in most advanced economies, R&D investment appears to be mainly financed by internally accumulated cash flow. This leads to the question of whether firms finance R&D investment with a

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[22] On the basis of this argument, interventions like government support of R&D, the intellectual property system or R&D tax incentives, are usually justified.
[23] Certain assumptions apply to this theory, such as the simultaneous presence of a perfect informational context, an efficient capital market and the absence of bankruptcy costs.

great share of internal finance due to financial constraints or is it a voluntary strategy. The latter reason can be connected with the "free cash flow" theory introduced by Jensen (1986), which argues that managers overinvest in projects with negative net present value when their interests are not aligned with interest of stakeholders (maximizing corporate value). The former view can be linked with the "pecking order theory" of financing initiated by Myers (1984), which asserts that financial sources firms use are set in a hierarchical order by means of their costs. A difficulty in estimating the right value of future cash flows generated from investment projects by lenders or outside investors creates the wedge in the cost of financial resources, and that result in underinvestment problem, which means that companies are not able to finance all positive net present value projects. Hence firms firstly exhaust internal equity financing and then, if funds are still desired, turn to debt and external equity.

Large number of scholars believes that in most developed economies R&D investment is mainly financed by internally accumulated cash flow, while the evidence on the impact of internal equity finance on R&D is not consistent. Few advantages of internal finances over debt have been pointed out, namely no need for collateral requirements, no need for dealing with adverse selection problems and no need to be concerned about magnifying problems linked with financial distress (Brown et al. 2009). However, two most obvious disadvantages may apply to innovative firms funding their R&D only with internal finance. First, existing profits of innovative firms may not reach the desired level to finance all profitable and socially desirable R&D opportunities. Specifically, this is very relevant to young, fast growing firms. Second, volatile profits associated with business cycles may generate unwanted fluctuations in financing R&D investments, which in contrary require a rather smooth investment path over time.

Prior work on R&D investment also identifies several firm-specific factors that are important for firms' R&D investment decisions. There has been evidence that firm age, size, equity, growth opportunities, and cash flow volatility play a significant role in determining how much firms choose to invest in R&D activities. For example, owing to the research of Brown et al. (2007) who, after investigating a panel of 1,347 US publicly traded high-tech firms from 1990 to 2004, found that supply shifts in equity finance (both internal and external) had an aggregate effect on R&D, thus explaining most of the dramatic 1990s R&D boom in the US. They

conclude that stock markets play a role in economic growth by directly funding innovation.

Recently corporate finance literature has developed and empirically confirmed a view that internal equity finances is preferred to debt or external equity source of funds for R&D investment (see Brown and Petersen, 2011). Firstly, this approach has been explained on the basis of asymmetric information theory. R&D investment suffers more from asymmetric information because innovative projects are not easily understood by outsiders, or there is uneven knowledge about their likelihood of success between entrepreneurs and providers of external funds in favour of entrepreneurs. Asymmetry of information is also very high for R&D activities as the progress in R&D is difficult to follow and the quality of a final product can remain uncertain for several years. Management does not have currently available data that can be used to evaluate or refute project manager claims (Stein, 2003). R&D projects can endure for 10 to 12 years without producing a rent generating patent (Bernardo et al., 2001: 333).

The secrecy of information and incomplete disclosure of the relative efficacy of R&D projects lead to moral hazard and adverse selection problems developed by Jensen and Meckling (1976) and Stiglitz and Weiss (1981). R&D costs are often sunk, patented innovations markets are segmented and often have oligopolistic characteristics, and tacit knowledge and skills of scientists make it difficult to fire them (Trushin, 2011). These interfere with the classical assumptions of Hayashi (1982) that the average Tobin's Q sufficiently characterizes firm's investment opportunities, thus the importance of cash flow emerges naturally.

Secondly, as argued by Leland and Pyle (1977) or Carpenter and Petersen (2002) high-tech investments have a low probability of success, thus the returns on R&D projects are skewed with a high ratio of uncertainty. According to the U.S. Department of Health and Human Services (2004) in the pharmaceutical industry, only 8 percent of drugs that are approved for phase I clinical trials are granted ultimate approval. Inefficient decision-making within the firm may be to certain extent the reason behind this lack of success. It has been noticed that in many firms, senior management is poorly-equipped to recognize the best R&D investment projects. Previous research by Hoskisson and Hitt (1988) and Hoskisson, et al. (1993) suggest that headquarters management in highly diversified firms suffer from the absence of the domain expertise to make

operational and strategic assessments of division-level R&D investments. Furthermore, in a highly diversified firm the R&D of one division is less likely to benefit another division. Milgrom (1988) points out that even if headquarters management has domain expertise, divisional squabbles in such firms decrease firm productivity.

Thirdly, as pointed out by Lev (2001) or Berger and Udell (1990) investments in innovation cover largely intangible assets, such as salary payments which lack collateral value for securing firms' borrowing. Hall and Lerner (2010) states that more than 50% of spending on R&D is directed to the salaries of innovators, who contribute to their firms' future expected earnings in the form of new products and services. Hillier et al. 2010) point out that because a significant proportion of R&D's inherent value comes from the innovators' human capital, this intangible asset may be lost to the company's shareholders if the innovator leaves the firm. Investment in fixed assets is less risky and easier to collateralize than investment in intangible assets, which may be more prone to financing constraints as a consequence. Bester (1985) and Hubbard (1998) demonstrated how the absence of collateral for debt finance may badly influence the possibility to access external finance for innovative firms. [24]

Fourthly, without proper analytical tools it is difficult to estimate the expected future revenues of scientific and technological research because of their uncertainty.[25] Given these issues, the cost of external capital for R&D funding is significantly greater than for other corporate investments and more sensitive to fluctuations in internal cash flow. An important argument worth mentioning here is that of Bhattacharya and Ritter (1985) who highlights firms' reluctance to fund their R&D externally due to their strategic reasons. Firms are not so keen to transparent to outside investors information on their R&D activities, since there is a threat that this knowledge could leak out to competitors. R&D is conducted within competitive environments, hence R&D projects carry higher competitiveness level and therefore they can face problems in situations when the firm looks for external support and is in a risk of information leak to rivals, which could result in a decrease of the prospective value of innovation.

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[24] Mocnik (2001) for a sample of Slovene firms provides support for the hypothesis that firms with a high level of intangible assets should be characterized by a lower debt/equity ratio. Also Berger and Udell (1990) for a large sample of US firms report a negative correlation between leverage and intangible assets.
[25] The CAPM or arbitrage pricing theories fails to do so..

R&D intensive firms seek to innovate better and faster than the competition. Megna and Klock (1993) demonstrates that firm performance is negatively related to the number of patents created by the firm's competitors. Firm performance suffers when competing firms innovate faster (and generate more patents). Thus, the speed of creating innovations faster than the competition is important along with creating valuable innovations themselves.

R&D investment has two very important characteristics, the first one refers to the first stage of launching a R&D programme when R&D requires substantial funds and the second one is linked with big fluctuations in the level of spending in existing research programmes, which are very expensive. R&D spending constitutes mainly of wages of R&D staff, and this usually covers highly skilled workers and their hiring, firing and training costs. Decisions of establishing R&D project are more related to potential financial constraints, than decisions about year to year expenditures in existing research investments. Schumpeter (1942) implied that the R&D participation decision is more for the firms with 'deep pockets', meaning that most of the time firms that do commit to R&D investment are confident they can sponsor them from internal funds, because raising external finance for R&D is very expensive, especially in the UK due to accounting reasons. Thus, it is safer for managers to rely on internal finances to pay for their R&D investments. This preference of managers is possibly even more intense in case of smaller companies which are unable to protect their innovations through complementary assets, such as established distribution networks (Scellato (2007)). Lastly, because there is no secondary innovation market, R&D firms can be particularly badly affected by financial distress due to their concentrated, firm-specific assets, which compose non-redeployable capital. Cornell and Shapiro (1988) assert that market value of innovative firms based on future growth options suddenly declines when these firms face financial distress.

Despite all the problems and difficulties, for knowledge intensive industries R&D is important in creating competitive advantage. Many researchers confirm that R&D investment is a critical source of patents, and the creation of patents is strongly related to the creation of shareholder value. [26] E-mail, fiber optic transmission cables, and breakthrough drugs like Lipitor were created through

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[26] Hall, Jaffe and Trajtenberg (2005), Lev and Sougiannis (1996), Jaffe (1986), Pakes (1985)

private-sector R&D. The temptation of discovering ground-breaking innovations, and the wealth and fame that award such achievement, compel firms to carry on committing to risky R&D.

In summary, issues of asymmetric information problems, greatly diversified corporations, lack of collateral value and lack of the ability to estimate the expected future revenues of R&D investment may make investment in R&D projects more prone to financing constraints as a consequence. Hence the view that internal equity finance is preferred to debt or external equity source of funds for R&D investment is rational. Since R&D investment is so difficult to manage, and since it is such an important precursor to the creation of valuable new knowledge, firms can overinvest or underinvest in R&D. Firms obtain resources that they consider will give competitive advantage, and use those resources in attempts to generate shareholder value. In the case of R&D, this is a uniquely difficult process. The purpose of this chapter is to shed light on the determinants of firms' R&D investment decisions. More specifically, we are interested in what determines firm's ability to fund new R&D projects when they are discovered or firm's ability to maintain the existing R&D activities, regardless of the firm's current operating performance or the obstacles discussed above.

3.2.2 Empirical evidence

Financial Factors and R&D Investment

Investment in R&D is usually considered to be subject to financing constraints due to outcome uncertainty and asymmetric information between borrowers and lenders (Nelson, 1959; Arrow, 1962; Bhattacharya and Ritter, 1983; Myers and Majluf, 1984; Anton and Yao, 2002). Moreover, R&D investment is usually described as an investment with a low inside collateral value because it is sunk once expensed (Alderson and Betker, 1996).

Hall (2002) summarizes several important features of R&D that can be responsible for the higher external capital costs for an R&D project in comparison with the cost of cash generated through a firm's revenue, such as asymmetric information between inventor and investor, moral hazard on the part of the inventor, tax deduction legislation that affects costs of servicing external debts

and incomplete markets as debt-holders prefer physical assets as collateral to secure loans: sunk costs of R&D are usually higher than of physical investment.

The role of financial factors on firms' capital investments has been extensively examined. However, the role of financial factors on firms' R&D investment is not clear. Majority of documents on the association between capital investment and internal finance insist on the important role for internal finance. [27] This is not the case with R&D investments, where the related evidence is mixed (see Hall (2002) for a review). Early papers by Scherer (1965), Mueller (1967) and Elliott (1971) deliver empirical evidence with no relationship between internal finance and R&D. However, a small literature has emerged showing that company R&D spending is sensitive to cash flow, but unsurprisingly the results are often weak in the sense of economic or statistical significance. Himmelberg and Petersen (1994) stress that these analyses took into account only large firms, which usually have more cash flow than they need for investments.

Most of the following studies find significant and positive influence of cash flow on R&D investments (Hall (1992), Hao and Jaffe (1993), Himmelberg and Petersen (1994), Mulkay et al. (2001), but there are also papers where that relationship does not always hold (Bhagat and Welch (1995), Harhoff (1998), Bond et al. (1999), Bougheas et al. (2003)). Adopting an accelerator type model on a large panel of US manufacturing firms Hall (1992) tests the degree of correlation between R&D and cash flow and discovers a strong impact of cash flow on R&D expenses as well as negative correlation between R&D investments and the degree of leverage. By splitting their sample according to firm size Hao and Jaffe (1993) point to internal financial resources as a major determinant of R&D expenditure decisions. They find no liquidity effect for large firms although they find support for the hypothesis that R&D is liquidity constrained. After examining a panel of 179 US small, high-tech firms Himmelberg and Petersen (1994) also point to internal financial resources as a major determinant of R&D expenditure decisions. Harhoff (1998) demonstrates for German small firms a significant sensitivity of R&D investments to cash flow. Hall et al., (1999) find that R&D is much more sensitive to cash flow in U.S. firms than in French and

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[27] Fazzari, Hubbard et al. (1988) in their seminal paper stress the key role of cash flow in investment decisions of firms. According to Almeida, Campello et al. (2004) financially constrained firms save more cash from their own cash flow. See also Hoshi et al. (1991), Devereux and Schiantarelli (1989), Oliner and Rudebusch (1992), Vogt (1994), Chirinko and Schaller (1995) among others.

Japanese firms. According to Mulkay et al. (2001) cash flow has a weaker influence in France than in the United States both for R&D and ordinary investment. Next Hall (2002) delivers a prominent review of the R&D-cash flow literature based not only on the studies in the US and concludes that small and new innovative firms experience high costs of capital and even large firms prefer internal funds for the financing of R&D. For the UK firms Bond et al. (2006) discover that cash flow predicts whether a firm does R&D or not, but not the level of R&D indicating that UK firms that do R&D are a self-selected group that face fewer constraints. Yet, such effects do not apply to German firms. Recent studies by Brown, Fazzari and Petersen (2009) and Brown and Petersen (2011) find a strong association between R&D and *both* internal and external equity finance for young (but not mature) publicly traded U.S. firms.

A comprehensive summary of literature is provided by Hall and Lerner (2010) with a conclusion that it remains an open question whether financing constraints matter for R&D. Such a conclusion is aligned with the mixed results in studies of U.S. firms and the findings of weak or no evidence of financing constraints for non-U.S. (mainly European) firms.

Stock and Debt Issues and Cash Flow Sensitivity

The recent literature considers R&D investment as an "equity-dependent" type of investment. Brown et. al (2007) study the effect of cash flow and external equity on aggregate R&D investment and they provide further support for the view that supply shifts in equity finance are important factors driving economic growth. Firm mainly oriented in investing in R&D are well known to employ little debt. Among other numerous explanations, Cornell and Shapiro (1988) explain this by the poor collateral value of R&D and the aspect that using debt finance may evolve troubles of financial distress that can be especially dangerous for R&D-intensive firms. Bradley et al. (1984), Titman and Wessels (1988), Hall (2002) and Kayhan and Titman (2007) bring on the evidence of negative relation between R&D and leverage. In effect, young firms, especially those with low or negative cash flow, investing in R&D can be strongly relying on the access to financial sources raised from public equity. There are at least two reasons to directly incorporate stock issues when testing for financing constraints on R&D. First, firms rely heavily on stock issues in the years immediately following their IPO (e.g., Rajan and Zingales (1998)), which is also a time period of low (or

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negative) cash flows and high R&D intensity. This negative correlation between stock issues and cash flow should lead to a downward bias in the estimated R&D-cash flow sensitivity in regressions that omit stock issues. Second, including stock issues in the R&D regression (appropriately instrumented) permits tests of whether variation in access to external finance matters for R&D, as it should in a world of imperfect access to external finance (Brown et al., 2011).

As mentioned before R&D is difficult to collateralize because it is an intangible asset. Very restricted collateral value of R&D limits the use of debt, since risky firms typically must pledge collateral to obtain debt finance (Berger and Udell, 1990). Brown and Petersen (2010) add that the nature of the debt contract is poorly suited for the uncertainty and skewness of returns associated with high-tech investment. Success in R&D is highly uncertain, and an R&D-intensive project may be difficult to monitor and assess, exacerbating agency problems (asymmetric information). Thus, R&D intensive industries may have a low ability to raise finance especially in less developed financial systems (Ilyina and Samaniego, 2011).

Carpenter and Petersen (2002) argue that for high-tech firms, the limited collateral value of assets, together with adverse selection, moral hazard, and financial distress should cause the marginal cost of debt to increase rapidly with leverage. Szewczyk et al. (1996) report that average approximation for Tobin‟s Q is statistically significant in explaining abnormal returns connected to R&D projects, and that these returns are higher for leveraged firms. Price to book ratio is a proxy for the average Q, because marginal Tobin's Q is unobservable. McConnell and Servaes (1995) find for US firms with high Tobin's Q that the leverage has a negative impact on corporate value, but a positive impact on the value of firms with low Tobin's Q. Aivazian, et al. (2005) detect for Canadian firms negative relationship between leverage and investment. Ahn et al. (2006) find for diversified firms with high Tobin's Q a negative influence of leverage on investment. Chiao (2002) finds a negative influence of debt on R&D spending in science-based industries, but a positive one in non-science based industries indicating that risk is significantly lower in the latter.

It is clear that R&D-intensive firms make little use of debt finance (e.g., Hall (2002)). Equity is better suited for financing R&D than debt, because with equity financing there are no collateral requirements, shareholders share in upside

returns and additional equity does not magnify problems associated with financial distress, which can be particularly costly for innovative firms. Kim and Weisbach (2008) report evidence suggesting that a main reason for stock issues is funding R&D. They explore IPOs and SEOs across 38 countries and show that in the four years following the stock issue, the cumulative average increase in R&D is more than half the size of the stock issue. However, owing to various reasons external equity is not a perfect substitute for internal finance, such as substantial flotation costs (e.g., Lee et al., (1996)) and the "lemons premium" due to asymmetric information (Myers and Majluf (1984)).

Brown and Petersen (2009, 2010) come to conclusion that public equity finance play important role in the financing of high-tech investment. In detail, they claim that the financing of young high-tech firms occurs as follows: internal finance is typically small and often negative, debt is essentially unavailable, and VC financing is limited in scope, suggesting that public equity is the key marginal source of finance.

Brown and Petersen (2010) points out that R&D firms are mainly public and there are almost no major private high-tech firms. They argue that a plausible reason for this is that the external capital supplied by public equity markets is crucial for the development of young high-tech firms given their limited access to other sources of finance. Internal funds are less costly than public equity, but internal cash flow of small and young firms is usually negative.

3.2.3 Summary

R&D activity can result in either product or process innovations (i.e., increases in the efficiency with which other inputs are used in production). There are several reasons to expect that more R&D-intensive industries have greater need for external finance. R&D may be associated with longer gestation periods because it does not yield immediate results. R&D may be a lumpy type of investment because it may require large start up investments for new firms and also for new projects. R&D investments are likely to be sunk and they are also inherently risky. Burley and Stevens (1997) find that the ratio of new product ideas to new products is 1:1,000. In R&D-intensive industries, a firm's market

niche may be constantly under threat from innovative competitors, so that expected harvest periods may be relatively short (Kamien and Schwartz,1982).

Changes in R&D expenditure are interpreted by numerous researchers as evidence of earnings manipulations (Baber et al., 1991; Bushee, 1998; Elliot et al., 1984). A popular view is that changes in R&D expenditure may cause damaging disruptions in the R&D process (Dierickx and Cool, 1989; Grabowski, 1968; Hambrick et al., 1983; Kor and Mahoney, 2005). Therefore firms that have same level of investment over time are expected to create very little disruption in their R&D labs. In effect, they make the steadiest innovations progress. Kor and Mahoney assert that in order to create sustainable competitive advantage consistent and sustained high levels of R&D investment are required. In addition, Hambrick et al., (1983:759) states "research workers are not perfectly elastic in supply and cannot be fired and rehired as business conditions might warrant". All this implies that firms steer R&D expenditure levels for reasons that could seriously impact progress towards innovation. However, on the contrary firms that "stick with it" may be prevented from terminating bad R&D investments in a timely manner because they suffer from a form of "organizational inertia" (Hannan and Freeman, 1984). Aborting unsuccessful R&D activities can be difficult, because R&D project managers can be motivated to continue their own projects (Bernardo et al., 2001; Stein, 2003). An important point worth mentioning here is that one of Fogel et al., (2008) that suggests that economies that quickly replace declining firms with fast growing firms generate more economic growth than economies that have the same dominant firms over time. Such "creative destruction" (Schumpeter, 1942) may drive superior R&D performance at the firm level as well. Previous literature implies that if underperforming projects are identified and terminated more quickly ("cutting costs"), then some freed-up R&D resources can be invested into new projects. This policy seems to be more effective at creating firm value (Swift, 2008).

3.3 Empirical model

Previous literature shows that cash flow is an important determinant of R&D investment, and that asymmetric information is considerably greater for R&D than for tangible fixed investments. Effectively, the cost of external funds will necessarily be higher for R&D than for tangible investments (Cleary et al., 2007; Domadenik et al., 2008). Ascioglu et al., (2008) find that firms with high cash flow levels are also less averse to R&D activity. Thus cash flow is expected to be positively related to R&D investment. However, Brown and Petersen (2010) find that firms most likely to face financing frictions rely extensively on cash holdings to smooth R&D, while firms less likely to face financing frictions appear to smooth R&D without the use of costly cash holdings. This finding indicate that firms plan their R&D investment and its financing well in advance, hence their R&D investment cash flow relationship can be negative if they are assessed in the same year, while the association between R&D investment and cash holdings is expected to be positive. Also Lerner et al. (2011) claim that R&D expenditures have features typical of long-run investments. In particular, their costs are expensed immediately, yet their benefits are unlikely to be observed for several years.

External financing (i.e., long-term debt) are also more likely to be more costly than internal financing thanks to market imperfections. Because external funds are not perfect substitutes with internal funds, these market imperfections encourage R&D projects to be financed through internal resources (Islam and Mozumdar, 2007). Moreover, the probability of bankruptcy forces firms to rely on retained earnings to finance innovations (Blundell et al., 1999). Accordingly, a negative relation between debt issues and R&D investment and also a negative relation between equity issues and R&D investment are expected. In the spirit of majority of R&D investment literature, which present that strong returns on R&D encourage and incentivize future R&D investment, lagged values of R&D are employed in the model of this work to explain current R&D expenditure.[28]

All above mentioned firm characteristics explain great part of the variation in R&D investment. However, R&D activity is also strongly characterized by

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[28]See Lev and Sougiannis (1996) or Dunlap-Hinkler et al., (2007).

unquantifiable factors, such as corporate strategy, firm culture, and the propensity to innovate (Hillier et al., 2011). Because these factors are impossible to measure, we incorporate them into our empirical model through an individual effect (FIRM$_i$) and time effect (YEAR$_t$), which controls for the unobservable heterogeneity across firms in our analysis; $\varepsilon_{i,t}$ is the random disturbance. Of course, all variables apart from size are scaled by total assets to avoid heteroskedasticity problems.

This section introduces the explanatory variables for three alternative specifications to empirically model the cash flow sensitivity of R&D investment. The first specification is parsimonious. In addition to firm size, it only includes cash flows and investment opportunities. R&D investment is defined as the ratio of R&D expenses to total book assets. CF is defined as the ratio of earnings before extraordinary items plus depreciation and amortization to total book assets. Proxy for investment opportunities, Tobin's Q, is measured by the ratio of book value of total assets minus the book value of equity plus the market value of equity to book value of assets. SIZE is the natural log of total assets. The baseline empirical model can be written as:

$$R\&D_{i,t} = \alpha_0 + \alpha_1 CF_{i,t-1} + \alpha_2 Q_{i,t-1} + \alpha_3 SIZE_{i,t-1} + \varepsilon_{i,t,} \qquad (1)$$

We want to maintain a common scale factor for all regressions therefore we divide by total assets the same as Baker et al. (2003). We also control for industry dummies and time dummies in all regressions, $\varepsilon_{i,t}$ stands for measurement error.

Equation 1 is estimated with OLS technique in which independent variables are lagged one year to control for potential endogeneity problems (see Duchin et al., 2010).

The primary variable of interest in this model is cash flow (CF hereafter). In line with a standard interpretation, a positive and significant coefficient of CF suggests that firms primarily rely on internal rather than external funds for financing investment, which is taken as a signal of financial constraint. On the contrary, an insignificant estimated coefficient of CF is seen as evidence that firms are financially unconstrained (Arslan et al., 2006).

In addition, R&D decisions should also be affected by the attractiveness of future investment opportunities. Noting the difficulty in empirically measuring those opportunities, the baseline model uses Tobin's Q to capture information about the value of long-term growth options that are available to the firm same as work of Almeida and Campello (2010). Importantly previous research has recognized that the estimate returned for α_2 might give less useful information about the effect of financial constraints on R&D policies than the estimate of α_1. Firm size is included in the baseline model because investing in R&D activities may entail fixed costs; on the margin, the larger firms within a given subset of firms could be more favourably predisposed to substitute between internal and external funds due to economies of scale (Almeida and Campello, 2010).

An alternative estimate of the cash flow sensitivity of R&D investment is obtained from a specification in which a firm's decision to change its R&D investment in the face of cash flow innovations takes into consideration the firm's pre-existing *stock* of internal funding and its ex ante financial structure. Following the literature on investment demand (e.g., Fazzari and Petersen (1993), Schiantarelli and Sembenelli (2000)), on liquidity demand (Almeida et al. (2004)), and on capital structure (e.g., Rajan and Zingales (1995)), the annual R&D investment also as a function of the beginning-of-the-year stock of cash and liquid securities (CASH HOLDINGS), net new funds from stock issues and net new long-term debt modelled, where all of these three additional variables are scaled by total assets.

$$R\&D_{i,t} = \alpha_0 + \alpha_1 CF_{i,t} + \alpha_2 Q_{i,t} + \alpha_3 SIZE_{i,t} + \alpha_4 CASH_{i,t-1} + \alpha_5 STOCK_{i,t-1} + \alpha_6 DEBT_{i,t-1} + \varepsilon_{i,t}. \tag{2}$$

The lagged R&D investment term is included in the model 3 due to the presence of adjustment costs of investment.

$$R\&D_{i,t} = \alpha_1 R\&D_{i,t-1} + \alpha_2 CF_{i,t} + \alpha_3 Q_{i,t} + \alpha_4 SIZE_{i,t} + \alpha_5 CASH_{i,t-1} + \alpha_6 STOCK_{i,t-1} + \alpha_7 DEBT_{i,t-1} + \beta_i + d_t + u_{i,t}. \tag{3}$$

We also control for industry and time dummies in this regression, d_t controls for year fixed effects, β_i is a firm specific effect that controls for all time-invariant determinates of R&D at the firm level, and $u_{i,t}$ stands for random error term.

We control for pre-existing stocks of cash holdings because a firm can use these alternative components of internal wealth to accommodate shocks to cash flows. As in previous research of Brown and Petersen (2010), a firm's net new funds from stock issues and net new long-term debt enter as additional determinants of the R&D investment. Stock and debt issues are included in the model to evaluate the changing role of external finance for R&D investment. Debt issues and cash holdings should show a positive relation with R&D in firms that face binding financing constraints, though debt issues are relatively unimportant as a source of funds for the typical R&D firm (see Fig. 1 in section 4.4.3). In contrary, as discussed above, the coefficients on cash flows and stock issues should share a negative relation in firms that rely on cash reserves to finance R&D.

To formally test whether a firm's financial characteristics are significant in determining its R&D expenses during the financial crisis period the following model is estimated:

$$R\&D_{i,t} = \alpha_1 R\&D_{i,t-1} + \alpha_2 CF_{i,t} + \alpha_3 Q_{i,t} + \alpha_4 SIZE_{i,t} + \alpha_5 CASH_{i,t-1} + \alpha_6 STOCK_{i,t-1} + \alpha_7 DEBT_{i,t-1} + \alpha_8 CRISIS + \alpha_9 CRISIS*CF_{i,t} + \alpha_{10} CRISIS*Q_{i,t} + \alpha_{11} CRISIS*SIZE_{i,t} + \alpha_{12} CRISIS*CASH_{i,t-1} + \alpha_{13} CRISIS*STOCK_{i,t-1} + \alpha_{14} CRISIS*DEBT_{i,t-1} + \beta_i + d_t + u_{i,t}. \qquad (4)$$

where a dummy variable for the crisis period, CRISIS which captures the average change of R&D investment over 2008-2010 period is included. The coefficient on CRISIS is expected to be negative if the R&D investment was reduced on average during 2008-2010 period. Each financial variable in the model except for the lagged dependent variable is interacted with the financial crisis dummy in order to capture the effect of financial crisis on the impact of these variables on R&D investment. For instance, an interactive term between cash holdings and the crisis dummy shows whether the impact of cash holdings on R&D changes during the crisis.

3.3.1 Hypotheses

Summary statistics show that the number of firms with negative cash flows grows over time, hence these firms are not so plausible to finance their intangible investments out of them. Allayannis and Mozumdar (2004, p. 902) claims that "negative cash flow is a useful proxy for characterizing firms that are in. . . financially distressed situations," which attenuates their investment response to changes in cash flow. Furthermore there is a substantial increase in firms' R&D investment ratio but substantial decrease in firms' cash flow ratio over the time period this study considers. Also, in Figures 1 A and B we observe two opposite trends, that is the trend of R&D investment increases over time while the trend of cash flows decreases over time.

H1: Given the development of equity market, the increasing share of negative cash flow firms in the sample and the pronounced rise of R&D investment over the last twenty one years, the R&D ICFS for the full sample of firms is expected to be negative and increase in its negativity (the R&D ICFS trend is downward) over the last twenty one years, *ceteris paribus*.

The development of capital market should reduce the marginal cost of external finance, leading to a reduction in the ICFS (Brown and Petersen, 2009). This leads to the following hypothesis:

H2: Other things equal, improvements in capital markets should lower the ICFS for all types of investment.

Hall and Lerner (2010) and Islam and Mozumdar (2007) argue that in the presence of market imperfections, external funds may not provide a perfect substitute for internal funds, given that the premium for external financing will be higher. Financial crisis should increase the marginal cost of external finance, leading to a rise in the ICFS. This leads to the following hypothesis:

H3: Other things equal, financial crisis should increase the ICFS for all types of investment.

In the spirit of Brown and Petersen (2011) we argue that firms seriously involved in investing in R&D activities should be prepared to maintain a smooth path of R&D, due to high adjustment costs related with R&D investment. For financially unconstrained firms, R&D consistency is straightforward, as shocks to one financing source can be offset with other financing sources. But for financially constrained firms relying extensively on volatile sources of finance, R&D smoothing may be much more challenging. One available and certain way to smooth R&D is to finance it from non volatile sources such as build up precautionary cash holdings. Increased capacity of debt, as an alternative form of firms' financial slack, does not really apply to R&D investment, because R&D investment is usually an investment in intangible assets with hardly any collateral value. Cash holdings can be utilized to finance committed R&D investment when there is a negative shock to the availability of either cash flow or stock issues. Brown and Petersen (2011) present similar argument that firms smooth their R&D investment by drawing down cash holdings to offset partially (or completely) a negative shock to the availability of either cash flow or stock issues. We argue differently to Brown and Petersen that firms are more likely to directly finance R&D investment with cash holdings rather than with cash flows or stock issues. Firms build their cash holdings well in advance before they start their commitment to R&D projects. As mentioned before, studies by Cincera (2003) or Himmelberg and Petersen (1994) imply that, given the existence of very high adjustment costs for innovation investment, firms will engage in R&D activities only if they do not expect to be seriously affected by credit constraints. Bond et al. (2003) argue that innovative firms are not likely to face financial constraints as they are "deep pocket" firms, i.e. they engage in innovation activity when they have plenty of internal financial resources to do so. Also R&D investment is usually considered as long term investment, so firms prepare for its financing well in advance, rather than just financing them straight out of volatile cash flows. In order to assure the continuity of R&D investment, firms need to find regular and safe source of funds for them, which in most cases are cash savings, given that readily available cash balances help firms to avoid costly external finance and grant them the ability to take the opportunity of valuable investments. Therefore, firms engaged in R&D

projects will be very concerned about keeping cash holdings on the required level for financing their R&D activities; hence when positive shocks to cash flow appears or when positive shock strikes stock issues, R&D investment is likely to relatively decrease, because firms firstly want to accumulate enough precautionary cash holdings for future R&D investment so that they can finance their R&D project smoothly out of cash holdings. Put differently, when such an increase in cash flows or stock issues appear firms will draw down these financing sources to finance future R&D investment via cash holdings. Higher levels of cash holdings require reductions in cash flows, thus the more cash flow firms draw down for increasing the cash stock the more they are able to safely finance their investment. Thus, firms run down cash flows to expand R&D investment in response to positive productivity shocks. This explanation predicts a negative correlation between changes in cash flows and R&D (as it is in our data) because cash flows fall so that R&D can increase.

H4: Other things equal, cash holdings are positively related with R&D investment given that cash is an effective hedging device.

Stock issue is another source of income like cash flow relevant to R&D investment (see Brown and Petersen, 2009), hence its role in financing R&D investment should be meaningful, that is positive shock to stock issues should complement or substitute financing R&D investment via two channels, either by funding them directly or by building up cash holdings for future R&D investment, same as cash flow. Therefore, the relationship between stock issues and R&D investment is negative when firms smooth R&D investment with stock issues via building up cash holdings or positive when they finance R&D investment directly from positive shocks of equity issues.

H5: Other things equal, stock issues have a positive impact on investment, given the development of equity market.

3.4 Methodology

3.4.1 Cross-sectional estimation

The analysis of this study begins with a focus on the question whether cash flow, investment opportunities and size impact firms' R&D investment. To answer this question, firstly we estimate an OLS year by year cross sectional R&D investment model using past values of each of the firm characteristics to control for the problem of the endogeneity. Secondly, we estimate a three years average OLS cross sectional R&D investment model using the average values of R&D investment as well as each of the firm characteristics over three years in an attempt to mitigate problems that might arise due to short-term fluctuations or extreme values in one year. The R&D investment regression in both cases includes industry dummies that control for industry membership. Past values not only control for endogeneity problem as mentioned above but also reduces the likelihood of observed relations reflecting the effects of R&D investment on firm-specific factors (see Rajan and Zingales, 1995). However, this approach is unable to control for the potential biases that can be caused by the presence of unobserved firm-specific fixed effects. Therefore, panel data techniques are also utilized in the analysis.

3.4.2 Dynamic panel data estimation

This study employs panel data technique. The unquantifiable characteristics of firms, such as strategy, firm culture, and the propensity to innovate are strongly connected with R&D investment. This specificity should be addressed in the methodology. Unlike cross-sectional analysis, panel data methods control for individual heterogeneity. To eliminate the risk of obtaining biased results, firm-level heterogeneity are controlled for by modeling it as an individual effect, β_i, which is then eliminated by taking the first differences of the variables. The time dummy variable, d_t, another component of the error term, measures time-specific effects thus the impact of macroeconomic variables on R&D can be controlled for and u_{it} is the random disturbance term. Hillier et al., (2011) states that from an economic perspective, the explanatory variables can

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be affected by current and past realizations of R&D but must be uncorrelated with any future realization of the error term. In result, augmented models of this paper (equation 2 and 3) are estimated using an instrumental variable (IV hereafter) method to control for the endogeneity problem. The best option is generalized method of moments (GMM), because it embeds all other instrumental variables methods as special cases (Ogaki, 1993). Additionally, both augmented models control for dynamic effects by including a lag of the dependent variable, $R\&D_{i,t-1}$. Hsiao (1986) demonstrates that ordinary least squares (OLS) gives an estimation of the coefficient that is biased upward in the presence of individual heterogeneity. Moreover, Nickell (1981) presents that the within-groups estimator is seriously biased downward, and Alonso-Borrego and Arellano (1999) report that the first-differenced GMM estimator is subject to a weak instruments problem. In detail, the Arellano-Bond (1991) estimator use lagged values of the dependent variable as instruments, and is an internally derived IV approach. However, the lagged values of the dependent variable are often weak instruments (Arellano and Bover 1995, Blundell and Bond 1998). Modifying the test to include lagged values as well as lagged differences may improve the power of the instruments (known as system generalized method of moments, or system GMM).

First differencing the model removes the individual effects (and the possibility of bias due to omitted variables). However, negative consequences can appear after employing only differenced values. In cases where the variable resembles a random walk or a random walk with drift (common in financial data), then the internal instruments derived from a differenced value will poorly represent the data (Bond 2002). In these cases, it is more appropriate to use a system of equations to estimate the model that includes both the original model and the differenced model in system GMM. Blundell and Bond (1998) improved on earlier versions of system GMM estimators by using additional moment conditions to improve the performance of the estimator when the autoregressive parameters are large. Overall, the "system" GMM estimator developed for dynamic panel models by Arellano and Bover (1995) and Blundell and Bond (1998) jointly estimates a regression in differences with the regression in levels, using lagged levels as instruments for the regression in differences and lagged differences as instruments for the regression in levels. The systems estimator addresses the weak instrument problem that arises from using lagged levels of

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persistent explanatory variables as instruments for the regression in differences, but it does require an additional moment restriction to hold in the data: differences of the right-hand side variables in the equation must not be correlated with the firm-specific effect (Blundell and Bond, 1998).

This work uses the system GMM estimator proposed by Blundell and Bond (1998). However, since there is no clear rule to decide between the first differenced GMM and the system GMM, opposite to the OLS and within-groups estimators, this study firstly runs the analysis with Arellano-Bond (1991) technique. Because first difference GMM estimators can very easily create a very large instrument matrix, the number of lags in the instrument matrix is restricted to three. Year dummies are considered exogenous, and all other variables are considered endogenous. Both augmented models described in equations 2 and 3 are estimated with robust errors in the Arellano-Bond models as the robust option produces standard errors that are asymptotically robust to panel heteroskedasticity. A one-period lagged dependent variable is included too. Arellano-Bond (1991) technique provides some doubtful results, e.g. coefficients of Tobin's Q are stubbornly negative. Bond et al., (2001) assert that the first differenced GMM estimator is biased downward due to weak instruments, and the coefficient takes a value close to or below the within-groups estimator. Also Bond (2002) asserts that a within group estimator is often biased downwards in panel data with small time periods, whereas the OLS levels estimator is biased upwards in large samples and this can be used to estimate the possible range for a parameter.

Next, the hypotheses are examined with the Blundell and Bond (1998) system GMM approach, where additional moment conditions are added to improve the reliability of the results under less than ideal error conditions and a consistent estimation of the coefficients in this dynamic panel specification are performed. The system GMM combines the moment conditions for the first difference model with level moments and has less bias if the series are close to a random walk. The key assumption is that u_{it} are independent across firms.

Implementation of the estimations is performed with Stata software. Cash flow, investment opportunities, cash holdings, stock and debt issues are likely to be endogenous due to measurement error and the potential for reverse causality, thus they are treated as such. One-step estimation and standard variance corrected errors are used. "Identifying instruments for endogenous regressors is

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never an obvious task, but the combination of some economic introspection and thorough testing of the validity and relevance of the selected set of instruments will help ensure the reliability of our GMM estimates. Past lags of the included variables will convey only negligible (if any) additional information to what is already contained in the right-hand side of equation (2), yet those same lags should be reasonably correlated with the included regressors" Almeida and Campello (2010).

All financial variables are treated as potentially endogenous and lagged levels dated t-3 and t-4 are used as instruments for the regression in differences, and lagged differences dated t-2 are employed for the regression in levels.[29] Given the improved performance associated with the Blundell-Bond estimator, these results are reported and discussed.

All in all, by using the panel data methodology (specifically, the system GMM estimator), two important and well-known problems in the literature: individual factor heterogeneity and endogeneity are controlled for. Finally, potential misspecifications of the models are also checked. First, the Hansen J-statistic of overidentifying restrictions to test for the absence of correlation between the instruments and the error term is employed. This test is distributed as a χ^2 with r-k degrees of freedom under the null hypothesis of the validity of the r instruments, where k is the number of parameters. To assess instrument validity Arellano and Bond (1991) are followed, who report an AR2 test for second-order autocorrelation in the first-differenced residuals, which, if present, could render the GMM estimator inconsistent. Therefore, first, the AR1 statistic, and second, the AR2 statistic, developed by Arellano and Bond (1991) are also used, to test for a presence of first serial correlation and a lack of second-order serial correlation in the first-difference residuals. As a result of the first-differenced transformation, the error term suffers from first-order serial correlation. However, no second-order serial correlation exists.

The last approach presented in equation 3 and utilized in this study captures potential interaction effects that may be present. The nature of the relationship between financial variables and R&D investment may vary due to financial crisis. To explore that possibility, we firstly interact our proxy for financial crisis (financial crisis dummy) with each financial variable in the R&D investment

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[29] Exactly same set of instruments can be found in paper of Brown and Petersen (2011).

model. In this way, we test for the existence of both *main effects* (the impact financial variables on R&D investment) and *conditional effects* (the impact of financial crisis on the relationship between financial variables and R&D investment).

3.5 Data

The initial sample of this document comprises all listed companies in the United States and the United Kingdom that are included on the Worldscope database for the years 1990-2010. However, observations from financial institutions and utilities firms are disregarded as well as data cleaning procedure are applied. Data selection criteria are similar to that of Almeida et al. (2004 or 2010). Thus, from the raw data those firm-years for which the value of assets is less than $1 million and those displaying asset growths exceeding 100% are discarded.[30] Next, in order to minimize the sampling of distressed firms the request that firm annual sales exceed $1 million is activated.

Variable construction approach follows the study of Brown and Petersen (2009). However, unlike those authors, we do not trim any of the variables at their extreme percentiles. Instead, same as Almeida et al. studies, we set limits on variables' distributions on the basis of economic intuition. Therefore, firm years for which debt exceeds total assets (near-bankruptcy firms) and those whose Tobin's Q, our basic proxy for investment opportunities is either negative or greater than 10 (see Gilchrist and Himmelberg (1995)) are dropped. The latter data cut-off is introduced to address problems in the measurement of investment opportunities in the raw data.[31] Firm years for which research and development expenses exceeds total assets or for which capital expenditures or R&D expenses are negative are also removed. In order to apply GMM estimation method, it is required that firms enter the sample only if they appear for at least four consecutive years in the data, because GMM estimators rely on lagged values of regression variables as instruments. Finally, due to dynamic models all firms with average of R&D ratio over the years equal to zero are removed as well as firms with average of total investment ratio over the years equal zero are also

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[30] The first screen eliminates from the sample those firms with severely limited access to the public markets; the augmented models of this work include the stock issue variable so it requires that the firm have active (albeit, potentially constrained) access to funds from the financial markets. This selection rule eliminates very small firms from the sample, for which linear investment models are likely inadequate (see Gilchrist and Himmelberg, (1995)). The second screen drops those firm-years reporting large jumps in their business fundamentals; these are typically indicative of major corporate events, such as e.g. mergers or reorganizations.
[31] This cut-off for Q reduces the average Q on a small scale and it does not impose bounds on the empirical distribution of Q.

eliminated.[32] The data are selected as an unbalanced panel in preference to a balanced panel approach, because the unbalanced panel database is free from problem of survivorship bias. The sample periods (1990–1999 and 2000-2010) are fairly long, and many companies delisted, merged, or were acquired during the 10 and 11-year period. Imposing a requirement that all firms must have the same number of observations would reduce the sample dramatically, hence the final sample cover firms that ceased to exist. Separate regression results for US and UK firms for four different subperiods: 1990–1999, 2000-2010 and 2000-2007, 2008–2010 are reported. These time periods divide the overall sample firstly into two periods of approximately equal length – ten and eleven years, and secondly the second subperiod is divided into two smaller ones – eight and three years in order to find the effect of financial crisis on R&D investment.

The subperiods samples are also split according to four main measurements: firms age, size, intensity of investing in R&D projects, and total assets growth.

3.5.1 Financial constraints criteria

Investigating the implications of this study models requires separating firms according to *a priori* measures of the financing frictions that they face. There is a broad range of possible firms' divisions into "financially constrained" and "financially unconstrained" categories. However, there are no strong priors in the literature about which classification is best; hence this paper employs a variety of alternative schemes to partition the sample: firm age (young versus mature) and dividend payout ratio (low versus high dividend). Additionally, firms are also divided according average R&D investment intensity measured with firm's average over time ratio of R&D expense over total assets (small versus high R&D intensity), firm's average R&D investment variability over time, measured with the average standard deviation of firm's R&D expenditure over time (small versus high R&D expenses variability) and the industry they belong to (high-tech versus

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32 If firm reports over all their valid year observations considered in the sample, R&D ratio equal 0, then this will disrupt the interferences related with speed of investment adjustment, because this firm R&D investment is not dynamic owing the fact that it does not change from one year to another, therefore these firms are dropped. This elimination criterion was also applied due to a large number of firms reporting 0 R&D investments over their period of existence, which were influencing the results beyond the econometric theory.

non high-tech industry). Firms division according to their age, the number of years since their first market capitalization appears in Worldscope, (however data on UK firms is available only since year 1980, so to keep consistency US data starts from the same year) is based on the argument that firm age is likely to be strongly correlated with asymmetric information problems and has been used as a proxy for the presence of financing frictions in a number of recent studies (e.g., Rauh, 2006; Fee et al., (2009) and Brown et al., 2009, 2011). Firms are classified as young if their first market capitalization after 1980 is reported by Worldscope below the sample median. Firms are not permitted to switch between young and mature within a given subperiod. The division of firms according to dividend payout ratio exercise the intuition of Fazzari et al. (1988), among many others, that financially constrained firms have significantly lower payout ratios, they pay little or no dividends to investors. Fama and French (2002) use payout ratios as a measure of difficulties firms may face in assessing the financial markets. The third firms' division based on R&D investment intensity refers to the fact that firms of small investment have typically great investment opportunities, thus they are classed as financially constrained because they are not able to fulfill all their growth possibilities due to their financial limits. This classification aims also to provide some deeper insight in the behavior of firms intensively investing in R&D projects with the background of firms investing in R&D activities not so intensively.[33] The fourth firms' split leads to idea of firms consistently investing in R&D projects versus firms investing in R&D projects in a very variable manner. The latter type of firms is usually linked with lack of finances, therefore a firms invests in short term R&D projects rather than long term ones. Finally, firms are divided on the basis of industry they belong to: high tech versus non-high tech firms.

3.5.2 Descriptive statistics

Table 3.1 presents variables definitions.

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[33] Bond et al., 2003 measures R&D intensity by ratio of R&D investment to sales. They focus on industries with above median R&D intensity and label these 'high tech' industries.

Table 3.01 Variables Definitions

Variable	Definition
TA	Total Assets
R&D	The ratio of research and development expenditures to total assets
INV	The ratio of capital expenditures to total assets
TINV	Total Investment = The sum of R&D investment plus INV
CF	The ratio of net income before extraordinary items and preferred dividends plus depreciation, depletion and amortization to total assets
GCF	Gross Cash Flow=The sum of CF plus R&D
Q	The ratio of book value of total assets minus the book value of equity plus the market value of equity to book value of total asset
CASH	The ratio of total cash and short term investment to total assets
STOCK	The ratio of sale of common and preferred stock minus purchase of common and preferred stock to total assets
DEBT	The ratio of long term debt issuance minus long term debt reduction to total assets
SIZE	The logarithm of TA
AGE	Number of years firm is publicly listed since 1980
DIV	The ratio of total cash dividend to total assets
S	Sales=Net Sales or Revenues
SG (%)	The ratio of sales growth equal to Δsales over 1-period lagged sales

Notes: This table provides the definitions of the main variables used in our analysis.

Table 3.2 R&D Intensity by Firm Sector and Average Firm Ratio of R&D over Sales

	1990-1999			2000-2010			2000-2007			2008-2010		
	Obs.	R&D/TA	R&D/TINV	Obs.	R&D/TA	R&D/TINV	Obs.	R&D/TA	R&D/TINV	Obs.	R&D/TA	R&D/TINV
Panel A (US)												
Total High-Tech	9279	0.069	0.454	15725	0.089	0.581	11302	0.088	0.573	3734	0.094	0.606
Chemicals	655	0.036	0.321	781	0.036	0.401	573	0.035	0.399	178	0.038	0.405
Drugs,Cosmetics & Health Care	1132	0.103	0.59	2501	0.136	0.698	1744	0.125	0.684	612	0.158	0.728
Electrical	281	0.049	0.425	585	0.062	0.537	421	0.062	0.527	140	0.058	0.566
Elactronics	3309	0.112	0.615	6336	0.119	0.718	4593	0.121	0.716	1496	0.118	0.734
Machinery & Equipment	819	0.039	0.421	1008	0.046	0.522	763	0.046	0.511	218	0.045	0.556
Total High-Tech	6196	0.090	0.545	11211	0.108	0.665	8094	0.106	0.658	2644	0.113	0.688
Total Non High-Tech	3083	0.027	0.274	4514	0.045	0.373	3208	0.043	0.359	1090	0.051	0.408
Firm Mean of RD/Sale>Median	4643	0.119	0.646	7863	0.153	0.789	5650	0.150	0.782	1869	0.164	0.816
Firm Mean of RD/Sale<Median	4636	0.019	0.264	7862	0.027	0.374	5652	0.027	0.365	1865	0.026	0.395
Panel B (UK)												
Total High-Tech	2256	0.034	0.289	2834	0.066	0.496	1924	0.065	0.489	720	0.064	0.505
Chemicals	170	0.017	0.195	165	0.024	0.367	111	0.023	0.351	41	0.027	0.452

Drugs,Cosmetics & Health Care	175	0.071	0.397	282	0.092	0.586	189	0.087	0.592	72	0.094	0.554
Electrical	88	0.022	0.272	73	0.032	0.448	45	0.025	0.454	21	0.052	0.472
Electronics	547	0.066	0.47	1009	0.104	0.688	669	0.111	0.685	266	0.091	0.692
Machinery & Equipment	244	0.021	0.286	209	0.033	0.367	154	0.038	0.391	47	0.015	0.281
Total High-Tech	1224	0.048	0.371	1738	0.083	0.592	1168	0.086	0.591	447	0.077	0.592
Total Non High-Tech	1032	0.018	0.193	1096	0.040	0.345	756	0.034	0.334	273	0.045	0.363
Firm Mean of RD/Sale>median	1132	0.060	0.437	1416	0.118	0.719	961	0.115	0.706	360	0.118	0.745
Firm Mean of RD/Sale<median	1124	0.008	0.140	1418	0.015	0.275	963	0.016	0.274	360	0.012	0.266

Notes: This table presents the averages for the R&D over TA and R&D over TINV ratios of the US and UK sample firms by firm sector and average firm ratio of R&D over sales over the period 1990-2010 and over financial crisis. Analytical definitions for all the variables are provided in table 3.1.

Table 3.2 summarizes information on the R&D activity of the firms' samples. For the first subperiod: 1990-1999 of US firms out of 9,279 firms, 6,196 belong to the high-tech sector, for the second subperiod: 2000-2010 of US firms out of 15,725 firms, 11,211, belong to the high-tech sector, for the first subperiod: 1990-1999 of UK firms out of 2,256 firms, 1,224 belong to the high-tech sector,and for the second subperiod: 2000-2010 of UK firms out of 2,834 firms, 1,738, belong to the high-tech sector. As expected, high-tech firms are more R&D intensive than non-high tech firms in all subperiods. The two most R&D intensive sectors are Drugs, Cosmetics and Health Care and Electronics. As expected, the percentage ratio of R&D expenditures over total investment expenditures (R&D + capital investments) for high-tech companies is nearly twice as high as for the non high-tech sector. The same two sectors mentioned above: Drugs, Cosmetics and Health Care and Electronics, seem to domineer the high tech firms with their percentage ratio of R&D expenditures over total investment expenditures. Over the subperiods distinguishing financial crisis phenomena: 2000-2007 and 2008-2010, ratio of R&D over total assets has dropped slightly for both US high tech and non high tech firms' groups, increased for UK high tech firms and decreased for UK non high tech firms. The percentage ratio of R&D expenditures over total investment expenditures shows same trend for US firms, whereas it decreases for UK high tech firms by only 0.01% and declines for UK non high tech firms. This is consistent with the argument that R&D firms do not adjust instantly their R&D investment in effect of unfavourable changes in financial constraints and that financing R&D activities is planned well in advance, due to its specificity. Thus one can conclude that R&D investment is well hedged. To certain extent financial crisis stopped the growth of R&D investment, but it has not decreased it, this suggests that R&D investment is a sticky decision.

Table 3.3, provides the summary statistics (mean and median) for US firms (Panel A), UK firms (Panel B) small versus large US firms (Panel C) and small versus large UK firms (Panel D). The sample summary statistics are based on annual firm observations. The analysis of this work is based on the differences between small and large firms and changes over time. As discussed previously, all finance and investment values are scaled by beginning-of-period total assets.

Table 3.3 Descriptive Statistics

	1990-1999		2000-2010		2000-2007		2008-2010	
	Mean	Median	Mean	Median	Mean	Median	Mean	Median
Panel A (US)								
R&D	0.069	0.039	0.090	0.054	0.088	0.054	0.095	0.055
R&D/TINV	0.455	0.441	0.581	0.645	0.573	0.627	0.606	0.684
INV	0.060	0.050	0.040	0.028	0.041	0.030	0.036	0.025
CF	0.062	0.098	-0.013	0.068	-0.009	0.069	-0.014	0.068
Q	2.018	1.556	2.145	1.674	2.212	1.733	1.821	1.452
CASH	0.158	0.089	0.257	0.190	0.250	0.182	0.265	0.205
STOCK	0.026	0.001	0.034	0.002	0.037	0.003	0.008	0
DEBT	0.003	0.000	0.000	0	0.001	0.000	-0.003	0
SIZE	8.14	5.37	8.60	5.42	8.55	5.36	8.80	5.66
AGE	19.228	18	15.997	14	16.532	15	15.633	14
DIV	0.013	0	0.010	0	0.010	0	0.012	0
Share obs negative CF	0.162		0.302		0.297		0.303	
Share obs positive DIV	0.494		0.318		0.320		0.330	
Observations	9279		15725		11302		3734	
Firms	1360		2020		1705		1393	
Panel B (UK)								
R&D	0.034	0.016	0.067	0.031	0.066	0.032	0.065	0.028
R&D/TINV	0.289	0.233	0.497	0.507	0.490	0.499	0.505	0.525
INV	0.064	0.056	0.039	0.030	0.041	0.033	0.033	0.023
CF	0.095	0.108	0.018	0.082	0.015	0.082	0.042	0.084
Q	1.839	1.526	1.890	1.513	1.935	1.551	1.632	1.339
CASH	0.130	0.093	0.187	0.118	0.184	0.113	0.180	0.121
STOCK	0.031	0.002	0.047	0.000	0.044	0.001	0.030	0

	Mean	Median	Mean	Median	Mean	Median	Mean	Median
DEBT	0.001	-0.001	-0.005	-0.001	-0.006	-0.001	-0.004	0
SIZE	7.558	5.210	8.122	4.557	8.007	4.684	8.310	4.472
AGE	19.305	20	16.048	14	17.378	16	14.696	12
DIV	0.031	0.029	0.023	0.015	0.024	0.017	0.023	0.012
Share obs negative CF	0.087		0.249		0.250		0.211	
Share obs positive DIV	0.910		0.623		0.649		0.597	
Observations	2256		2834		1924		720	
Firms	290		382		296		263	

Panel C (US)

	Small 1990-1999		Large 1990-1999		Small 2000-2010		Large 2000-2010	
	Mean	Median	Mean	Median	Mean	Median	Mean	Median
R&D	0.095	0.063	0.043	0.027	0.125	0.084	0.055	0.034
R&D/TINV	0.561	0.610	0.349	0.325	0.679	0.788	0.484	0.494
INV	0.054	0.042	0.066	0.059	0.036	0.023	0.044	0.034
CF	0.021	0.082	0.103	0.107	-0.097	0.015	0.071	0.090
Q	2.100	1.563	1.935	1.551	2.241	1.689	2.049	1.662
CASH	0.211	0.139	0.106	0.060	0.311	0.259	0.203	0.141
STOCK	0.051	0.003	0.000	0	0.071	0.005	-0.002	0.000
DEBT	-0.002	-0.001	0.008	0.000	-0.002	0	0.003	0.000
SIZE	4.268	3.836	8.825	7.189	4.222	3.749	9.290	7.356
AGE	16.657	17	21.799	22	13.338	13	18.655	17
DIV	0.008	0	0.019	0.014	0.007	0	0.013	0.001
Share obs negative CF	0.272		0.051		0.472		0.133	
Share obs positive DIV	0.232		0.757		0.130		0.507	
Observations	4640		4639		7861		7864	
Firms	737		623		1075		945	

Panel D (UK)

R&D	0.048	0.026	0.021	0.011	0.091	0.046	0.042	0.020
R&D/TINV	0.359	0.329	0.220	0.180	0.597	0.667	0.396	0.356
INV	0.064	0.053	0.063	0.058	0.036	0.024	0.043	0.035
CF	0.087	0.111	0.103	0.106	-0.040	0.058	0.076	0.094
Q	1.957	1.535	1.721	1.522	2.000	1.451	1.779	1.540
CASH	0.135	0.079	0.125	0.100	0.237	0.169	0.137	0.094
STOCK	0.046	0.001	0.017	0.002	0.084	0.000	0.010	0.000
DEBT	-0.003	-0.002	0.004	0.000	-0.005	-0.001	-0.005	-0.001
SIZE	4.188	3.875	8.232	6.719	3.514	3.247	8.814	6.473
AGE	16.632	16	21.969	22	11.923	10	20.209	22
DIV	0.028	0.027	0.033	0.031	0.014	0	0.032	0.024
Share obs negative CF	0.134		0.041		0.372		0.124	
Share obs positive DIV	0.829		0.992		0.422		0.820	
Observations	1126		1130		1423		1411	
Firms	151		139		206		176	

Notes: This table shows US and UK firms' sample characteristics over the period 1990-2010. Analytical definitions for all the variables are provided in table 3.1.

On average size is growing with time for all subsamples apart from small firms in both countries. The median of size is growing over time for US sample (apart from small firms) but decreasing over time for UK sample, which indicates that more very small firms are able to be publicly listed. In general, the ratio of R&D investment over total assets increases with time. Particularly, on average it nearly doubles in size for UK firms and still grows for US firms even over the financial crisis period (mean equal 0.088 for 2000-2007 subperiod and 0.095 for 2008-2010), while it stays almost the same for UK firms (respectively 0.066 and 0.065). After dividing firms into small and large groups one can learn that the R&D expenses ratio increases substantially over time (approximately doubles in some cases) for both small and large firms groups and for both countries this paper consider. Namely, for US firms the ratio increases on average from 0.095 (median 0.063) to 0.125 (median 0.084) in case of small firms and for large firms it raises on average from 0.043 (median 0.027) to 0.055 (median 0.034). For UK firms the ratio increases on average from 0.048 (median 0.026) to 0.91 (median 0.046) in case of small firms and for large firms it raises on average from 0.021 (median 0.011) to 0.042 (median 0.020). All in all, R&D expenditure ratio is higher in its absolute value for small firms than for large ones but over time it increases more in small firms group for US firms (on average, 31 %) than in large firms group for US firms (on average, 28 %), while opposite occurs for UK firms (89% increase for small firms and 100% for large firms), and also US firms invest in R&D much more than UK firms. To confirm over time changes of R&D investment the percentage ratio of R&D expenditures over total investment expenditures (R&D + capital investments) has been employed again. In contrary with R&D expenditures ratio, the capital expenditures ratio decreases with time and appears to be affected by financial crisis in the sense that it drops even more in the last subperiod in both countries. On average capital expenditure ratio is greater for large firms for both US subperiods and for the second UK subperiod. On average US / UK small firms drop their physical investment ratio by 33% / 44% from first subperiod to the second one and US / UK large firms decline the same investment by 33% / 32% over the same time period. Overall, these statistics illustrate a dramatic change in the composition of investment for publicly traded manufacturing firms in both US and UK.

Turning to sources of finance,[34] on average cash flow has declined dramatically from 0.062 / 0.095 (median 0.098 / 0.108) in the first subperiod: 1990-1999 to -0.013 / 0.018 (median 0.068 / 0.082) in the second subperiod: 2000-2010 for respectively US / UK firms. Interestingly, while cash flow measure falls down even further over the financial crisis period for the US firms, cash flow measure for UK firms increases over the same time period: 0.015 for 2000-2007 subperiod to 0.042 for 2008-2010 subperiod. However, the median level of cash flow stays nearly on the same level for second, third and fourth subperiods for US (0.068) and UK (0.082). Small and large firms differ a lot in their cash flow levels. As expected, large firms have much higher level of cash flow over the time and for both firms' categories the level of cash flows (measured by its mean or median) declines dramatically over time in both countries. Also the share of observations with negative cash flow increased substantially - approximately doubled over the time or more than doubled especially for large firms in both countries. Cash holdings level has increased over the time for all subgroups apart from the UK sample over the financial crisis period, where cash holdings have dropped slightly. Cash savings level is much higher for small firms than for large firms. Equity issues has increased from first to second subperiod but it dropped critically in the fourth subperiod for the US and UK firms. Small firms issue much more stock than large firms, also small firms increased their stock over the time, whereas large firms decreased it in both countries. Debt issues, however, declined over time for all subgroups apart from small US firms, for which on average debt issues stayed the same over time and also average values of debt issues became negative for the fourth US subperiod, the second to fourth UK subperiods, both subperiods of US and UK small firms and last subperiod of large UK firms. The negative debt issues indicate that firms were paying off their debt rather than issuing it. Debt issues are relatively unimportant for all firms in all periods; the only exception seems to exist in the large subgroup of US firms for the subperiod: 1990-1999, where on average stock issue level is equal to zero and debt issue level reaches its maximum of 0.008.

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[34] Brown and Petersen (2009) employs gross cash flow ratio, which is cash flow before total investment plus R&D. In the US R&D expenses have 100% tax allowance, while in the UK only R&D expenses on capital expenditures which typically consist of 10% of total R&D expenses have 100% tax allowance. UK government introduces some tax credits for R&D firms but they still are not comparable with US 100% R&D tax allowance, therefore this paper concentrates on the standard measure of cash flow.

Dividend payment decreases over time for all subperiods over time, e.g. for small UK firms it halves down over time. Dividend payment is much bigger for large firms than small ones. Firms' age has also dropped over time, implying that more young firms appeared on the stock market. And finally proxy for investment opportunities has increased from first to second subperiod for all, small and large UK and US firms, but it dropped down over the financial crisis period. As expected, Tobin's Q is greater for small than large firms' classes.

Summarizing, the descriptive statistics demonstrate that much has changed for publicly traded non financial firms. In the first place, median and mean cash flows have decreased critically. This fall appears to be mainly due to the substantial increase in the amount of small and young firms with persistent negative cash flows and the increase in R&D investment, which can be expensed for accounting purposes.[35] In the second, physical investment has declined sharply and also its share in total investment has dropped too. In the third place, there has been an increase in the use of public equity issues. In the fourth place, the R&D ratio for small firms over the 1990-2010 period and for the full sample over the last decade has risen to the point that it is considerably larger than the capital investment ratio. As discussed in hypotheses 1 and 2, the sharp rise in the R&D investment and the sharp decline in the physical investment together with the sharp decline in the cash flows over time, implies that the ICFS for R&D should be negative and should have risen in its negativity while for physical investment should be positive and should have fallen, other things held constant. As discussed in hypotheses 3 and 4, the substantial rise in cash holdings for every subsample over time suggests the great reliability of R&D firms on cash holdings, which is consistent with hedging policy. Lastly as discussed in hypothesis 6, the increased use of equity finance for small firms (but not large firms) is consistent with improvements in capital markets in recent decades.

3.5.3 Plots of yearly averages

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[35] A large number of US and UK IPOs in recent decades has persistent negative cash flows, while historically IPOs were usually profitable firms (a listing requirement). Fama and French (2004) study this "weaker" quality of IPOs and conclude that a rightward shift in the supply of public equity finance appears to have given unprofitable firms improved access to public equity finance. Also see Ritter and Welch (2002).

Yearly plots of average ratios for the positive R&D samples appear in Fig. 3.1 A - US and B – UK firms.

Figure 3.1 A: US Plots of the Yearly Averages of R&D, INV, CF, CASH, STOCK and DEBT
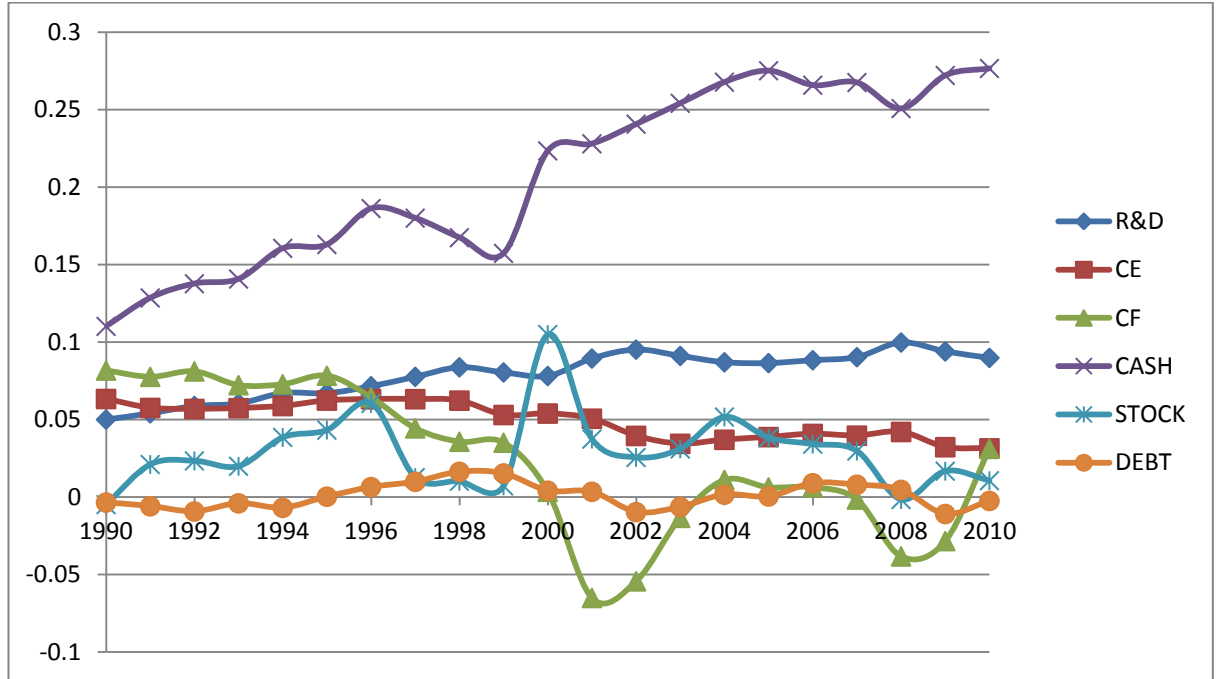
Figure 3.1 B: UK Plots of the Yearly Averages of R&D, INV, CF, CASH, STOCK and DEBT
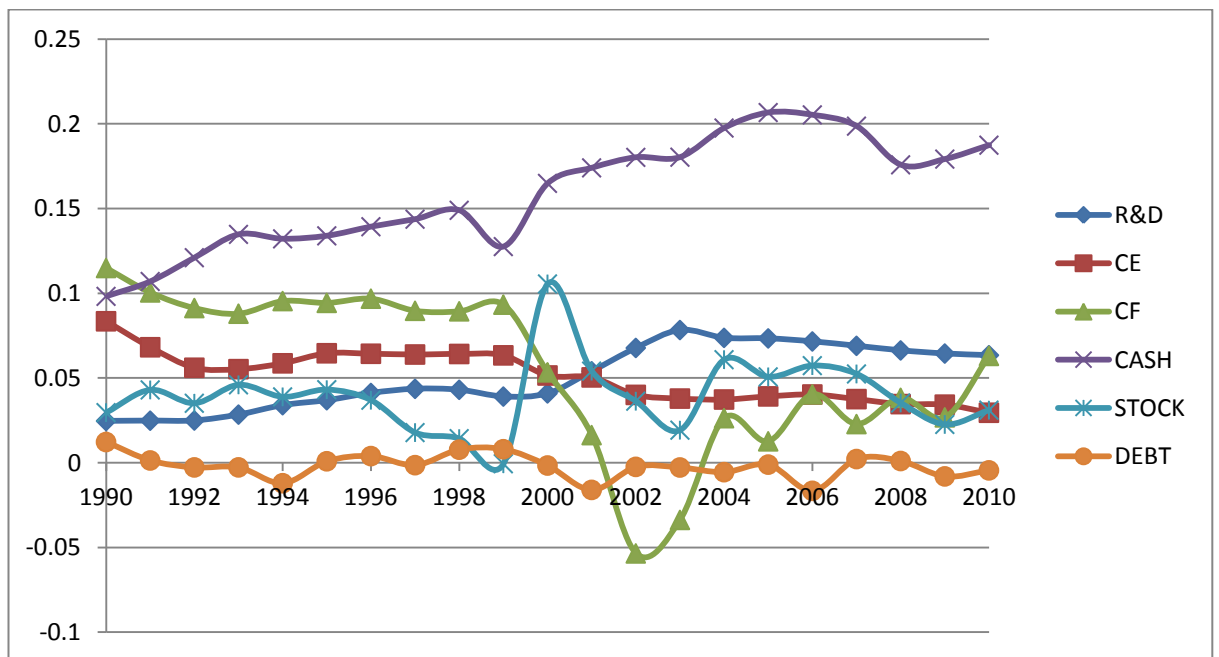
For both US and UK firms debt issues are small in all years, while cash holdings are the main source of finance in nearly all years (only in year 1990 cash flow is higher than cash holdings for UK sample). Cash flow is another source of finances for R&D investment, but it is negative in years 2001 till 2003 and 2007 till 2009 for US firms and in years 2002 and 2003 for UK firms. Stock issues are highly volatile in both UK and US samples. Cash holdings are also volatile, and the sharp swings in average cash holdings line up closely with the sharp swings in stock issues. However, cash holdings have a strong upright trend while stock issues trend seems to be levelled and also it is important to emphasise that the swings in stock issues are much bigger than the swings in cash holdings. Cash holdings seem to be behaving differently than the rest of financial variables. Without a doubt, cash holdings grow distinguishably over time like no other variable. To certain extent the trend line of cash holdings seems to reflect the R&D investment trend line, while the trend line of cash flow reminds the trend line of capital expenditures especially in the first subperiod of UK firms. The line of R&D expenses is pretty stable over time with a visible upward trend for US firms, while in case of UK firms there are two stages of R&D investment, namely it rises steadily up to year 2000, then shoots up until year 2003 and drops smoothly until 2010. The physical investment lines are rather stable over time with downwards trends. An interesting fact is that the line of R&D investment crosses the line on capital investment in year 1992 for US sample and in year 2001 for UK sample. Particularly this means that up to these years firms were investing more in physical investment than in R&D investment and opposite total investment composition appears after these years. This indicates that UK firms' total investment composition gets changed in favour of R&D investment about 10 years after US firms' total investment composition gets changed in favour of R&D investment. US firms have all their investment and financing lines within wider range in comparison with UK firms, which is expectable after taking into account samples' sizes. In other words, UK firms' plots show (consistent with the summary statistics) that they have far smaller average R&D and capital investment, cash flow, cash savings, stock and debt issues compared to US firms. Thus, the plots for UK firms display less of the volatility than US firms. Finally, the plots demonstrate clearly firms' reaction to financial crisis event. In effect of financial crisis US firms' cash flow falls down sharply, the average cash flow plot of UK firms shows two dips in year 2007 and 2009. Firms of both

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countries show decline in net debt issues, also net stock issues decrease severely reaching its dip in 2008 for US firms and in 2009 for UK firms. This is consistent with the argument that during financial crisis external finances become more costly. In year 2008 firms of both countries show a dip in average cash stock plots, which increase again afterwards. The US average plot of R&D expenses presents a small increase in year 2008 and then it falls again slightly, while the UK average plot of R&D expenditures demonstrate steady decrease with time. For both countries, capital expenditure plot declines over financial crisis period. All plots indicate that especially in case of US firms, cash holdings have been drawn down in order to fund firms R&D activities. This is consistent with greater accounting benefits for US firms investing heavily in R&D investment in comparison to UK firms. Put differently, US firms present a rise in investing in R&D projects despite the financial crisis, because they can set their R&D expenses against the tax duties in 100%, while UK firms are able to do so only in fraction. This is an evidence of effective incentive mechanism set by government.

3.6 Empirical results

In what follows we first demonstrate the results for our cross-sectional regressions by focusing on the question of how R&D ICFS changes over time after controlling for the firm-specific determinants. In section 4.5.2 we also consider the differences in R&D ICFS by high tech industries over time. Section 4.5.3 provides results on the dynamic panel data model. In this section, we also concentrate on the question of how capital market imperfections affect firms with respect to their R&D investment decisions.

3.6.1 Cross-sectional regressions by year

This section studies the ICFS across full sample period by estimating a cross-sectional regression of investment on cash flow, Tobin's Q and size in each year separately for R&D investment and capital investment in line with equation 1. The results are reported in Table 3.4.

A declining pattern of the capital ICFS over time is easily noticeable for US firms and with some distortions for UK firms, while for R&D investment the increasing pattern but negative of R&D ICFS is found. In 1991 the R&D ICFS is -0.0297 but statistically insignificant for US firms and -0.0573 and insignificant for UK firms. In 2010, the R&D ICFS is -0.143 and statistically significant for US firms and -0.121 and statistically significant for UK firms. This negative R&D ICFS is significant for all years, except the first one, at minimum 10% level in case of US firms and for 13 years in case of UK firms.

Table 3.4 Cross-Sectional Regressions by Year

DV: R&D	CF		Q		SIZE		Obs.	AR2
Panel A (US)								
1991	-0.030	(-0.98)	0.011***	(2.69)	-0.002	(-1.48)	583	0.302
1992	-0.069*	(-1.81)	0.010***	(3.99)	-0.002**	(-2.11)	643	0.275
1993	-0.121***	(-2.99)	0.011***	(4.43)	-0.003**	(-2.55)	709	0.293
1994	-0.133***	(-3.12)	0.012***	(4.23)	-0.003**	(-2.56)	721	0.296
1995	-0.121***	(-5.09)	0.014***	(5.20)	-0.005***	(-5.03)	981	0.337
1996	-0.118***	(-4.85)	0.014***	(7.50)	-0.004***	(-5.32)	1101	0.366
1997	-0.177***	(-7.06)	0.013***	(5.96)	-0.005***	(-5.49)	1177	0.393
1998	-0.214***	(-7.00)	0.010***	(3.68)	-0.006***	(-5.26)	1086	0.410
1999	-0.155***	(-3.56)	0.011***	(3.37)	-0.010***	(-6.71)	918	0.339
2000	-0.168***	(-3.58)	0.007***	(3.09)	-0.006***	(-4.25)	567	0.384
2001	-0.098***	(-6.30)	0.006***	(3.49)	-0.009***	(-7.41)	1222	0.284
2002	-0.076***	(-4.99)	0.014***	(5.36)	-0.011***	(-9.47)	1362	0.315
2003	-0.086***	(-6.93)	0.010***	(3.60)	-0.010***	(-9.58)	1499	0.298
2004	-0.153***	(-7.48)	0.011***	(5.18)	-0.006***	(-6.67)	1480	0.316
2005	-0.157***	(-6.28)	0.011***	(4.81)	-0.006***	(-5.82)	1471	0.320
2006	-0.097***	(-3.12)	0.011***	(4.73)	-0.008***	(-6.55)	1485	0.280
2007	-0.167***	(-6.61)	0.014***	(5.29)	-0.005***	(-4.09)	1452	0.331
2008	-0.142***	(-5.66)	0.014***	(5.91)	-0.005***	(-4.23)	1393	0.273
2009	-0.136***	(-7.05)	0.021***	(4.77)	-0.007***	(-5.38)	1232	0.276
2010	-0.143***	(-5.65)	0.020***	(4.65)	-0.008***	(-5.75)	1109	0.318
p-value	0.0035		0.1153		0.0002			
DV: INV								
Panel B (US)								
1991	0.093***	(5.91)	0.004	(1.51)	0.002**	(2.52)	583	0.210
1992	0.095***	(5.74)	0.003**	(2.42)	0.003***	(3.12)	643	0.145
1993	0.083***	(4.88)	0.006***	(4.06)	0.001*	(1.65)	709	0.141
1994	0.077***	(6.56)	0.006***	(3.74)	0.000	(0.51)	721	0.122
1995	0.065***	(6.49)	0.007***	(3.66)	0.001	(1.56)	981	0.119
1996	0.045***	(3.71)	0.005***	(3.47)	0.003***	(4.51)	1101	0.0965
1997	0.030***	(3.02)	0.007***	(5.46)	0.002***	(3.64)	1177	0.116
1998	0.038***	(4.84)	0.003***	(2.66)	0.002**	(2.47)	1086	0.108
1999	0.035***	(4.32)	0.004***	(3.35)	0.000	(0.63)	918	0.0967
2000	0.033***	(3.77)	0.005***	(3.46)	0.001	(0.99)	567	0.0964
2001	0.013	(1.49)	0.006***	(5.89)	0.001	(1.18)	1222	0.0558
2002	0.007*	(1.87)	0.004***	(4.30)	0.001**	(2.03)	1362	0.0975
2003	0.012***	(4.99)	0.004***	(4.71)	0.001**	(2.52)	1499	0.104
2004	0.016	(1.62)	0.004***	(3.97)	0.001	(1.36)	1480	0.0823
2005	0.019***	(4.05)	0.002**	(2.58)	0.001**	(2.28)	1471	0.0890
2006	0.019***	(4.95)	0.002***	(3.11)	0.001	(1.19)	1485	0.140
2007	0.020***	(3.02)	0.003***	(3.93)	0.001	(1.22)	1452	0.122
2008	0.009	(1.58)	0.004***	(4.26)	0.001*	(1.89)	1393	0.113
2009	0.012***	(3.51)	0.004***	(2.66)	0.001	(1.29)	1232	0.151

2010	0.015***	(2.79)	0.003**	(2.42)	0.001	(1.25)	1109	0.0919
p-value	0.0000		0.8670		0.1497			

DV: R&D

Panel C (UK)

1991	-0.057	(-0.33)	0.021*	(1.66)	-0.002	(-1.18)	174	0.264
1992	-0.101	(-1.14)	0.019**	(2.25)	-0.001	(-0.91)	201	0.334
1993	-0.011	(-0.33)	0.010***	(2.79)	0.000	(0.00)	220	0.243
1994	-0.036	(-1.05)	0.018***	(3.49)	-0.001	(-0.84)	241	0.347
1995	-0.083	(-1.40)	0.020***	(6.02)	-0.002	(-1.54)	250	0.351
1996	-0.108***	(-2.70)	0.018***	(2.67)	-0.002	(-1.37)	246	0.361
1997	-0.182***	(-4.38)	0.023***	(4.73)	-0.004*	(-1.66)	242	0.431
1998	-0.198***	(-2.77)	0.022***	(3.69)	-0.005**	(-2.40)	214	0.437
1999	-0.133**	(-2.19)	0.016*	(1.88)	-0.006**	(-2.36)	178	0.300
2000	-0.031	(-0.90)	0.008*	(1.95)	-0.005**	(-2.63)	105	0.298
2001	-0.048	(-1.00)	0.011***	(3.28)	-0.006**	(-2.54)	200	0.147
2002	-0.119***	(-4.62)	0.022***	(4.31)	-0.004*	(-1.91)	242	0.428
2003	-0.069**	(-2.50)	0.033***	(2.94)	-0.009***	(-3.52)	266	0.269
2004	-0.064***	(-3.05)	0.022***	(4.61)	-0.007***	(-3.12)	252	0.290
2005	-0.082*	(-1.94)	0.027***	(2.81)	-0.006**	(-2.58)	252	0.362
2006	-0.098*	(-1.78)	0.020***	(2.91)	-0.005	(-1.61)	258	0.222
2007	-0.159***	(-3.34)	0.020***	(3.29)	-0.001	(-0.42)	262	0.295
2008	-0.146*	(-1.97)	0.015**	(1.97)	0.000	(0.13)	263	0.174
2009	-0.132**	(-2.08)	0.014	(1.37)	-0.004*	(-1.87)	246	0.172
2010	-0.121*	(-1.89)	0.036**	(2.20)	-0.003	(-1.12)	211	0.170
p-value	0.7068		0.4316		0.6683			

DV: INV

Panel D (UK)

1991	-0.043	(-0.40)	0.044***	(2.92)	-0.004*	(-1.76)	174	0.262
1992	0.169***	(3.82)	0.002	(0.42)	-0.001	(-0.75)	201	0.236
1993	0.145***	(3.54)	0.004	(0.93)	-0.001	(-0.74)	220	0.182
1994	0.083***	(2.76)	0.015***	(3.53)	-0.002	(-1.60)	241	0.203
1995	0.055*	(1.66)	0.008**	(2.18)	-0.002*	(-1.89)	250	0.106
1996	0.052**	(2.08)	0.011**	(2.56)	-0.000	(-0.16)	246	0.154
1997	0.066***	(3.76)	0.005***	(3.31)	0.000	(0.40)	242	0.123
1998	0.063***	(2.63)	0.007**	(2.29)	0.001	(0.42)	214	0.153
1999	0.060**	(2.35)	0.005	(1.60)	-0.000	(-0.29)	178	0.0206
2000	0.145***	(3.52)	0.005*	(1.81)	-0.003	(-1.35)	105	0.141
2001	0.027	(1.61)	0.001	(0.32)	-0.000	(-0.29)	200	-0.0328
2002	0.012**	(2.47)	0.003**	(2.29)	0.000	(0.54)	242	0.182
2003	0.005	(1.56)	0.003	(1.53)	0.000	(0.12)	266	0.0963
2004	0.013**	(2.55)	0.004	(1.65)	0.002**	(2.29)	252	0.102
2005	0.041***	(2.98)	0.004*	(1.78)	0.000	(0.03)	252	0.0638
2006	0.052***	(3.19)	0.004***	(2.65)	0.001	(0.74)	258	0.157
2007	0.017	(1.43)	0.003	(1.57)	0.000	(0.23)	262	0.111
2008	0.027***	(3.98)	0.003*	(1.91)	0.001	(1.30)	263	0.114

2009	0.032***	(3.04)	0.004**	(2.06)	-0.000	(-0.14)	246	0.0886
2010	0.027**	(2.45)	0.000	(0.10)	0.001	(0.71)	211	0.199
p-value	0.4864		0.0018		0.0416			

Notes: This table displays results from the year by year investment regressions in equation 1. Analytical definitions for all the variables are provided in table 3.1. All regressions include industry dummies. P-values are for the null hypothesis that the coefficients are the same between the first (1991) and the last (2010) years. T-statistic values are reported in parentheses. ***, ** and * indicate coefficient is significant at the 1%, 5% and 10% respectively. For the estimation we use consistent to heteroskedasticity standard errors.

To better explain the R&D ICFS over time two groups of plots for full samples of US and UK firms were created and are demonstrated in Figure 3.2.

Figure 3.2 A: US Cross-Sectional Regressions by Year 1990-2010
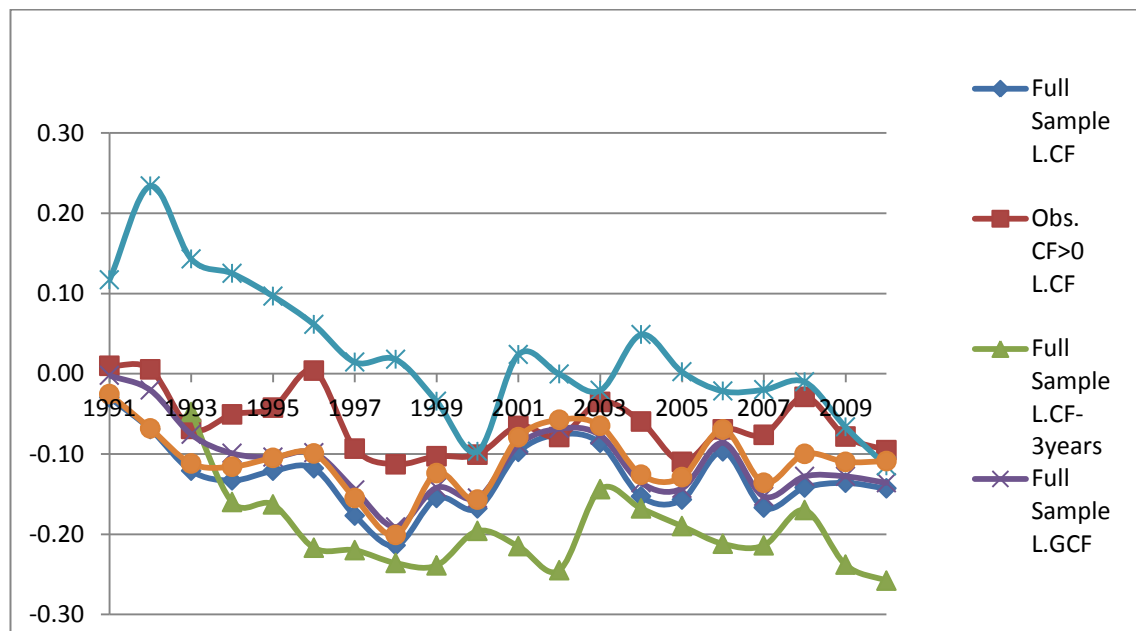
Figure 3.2 B: UK Cross-Sectional Regressions by Year 1990-2010
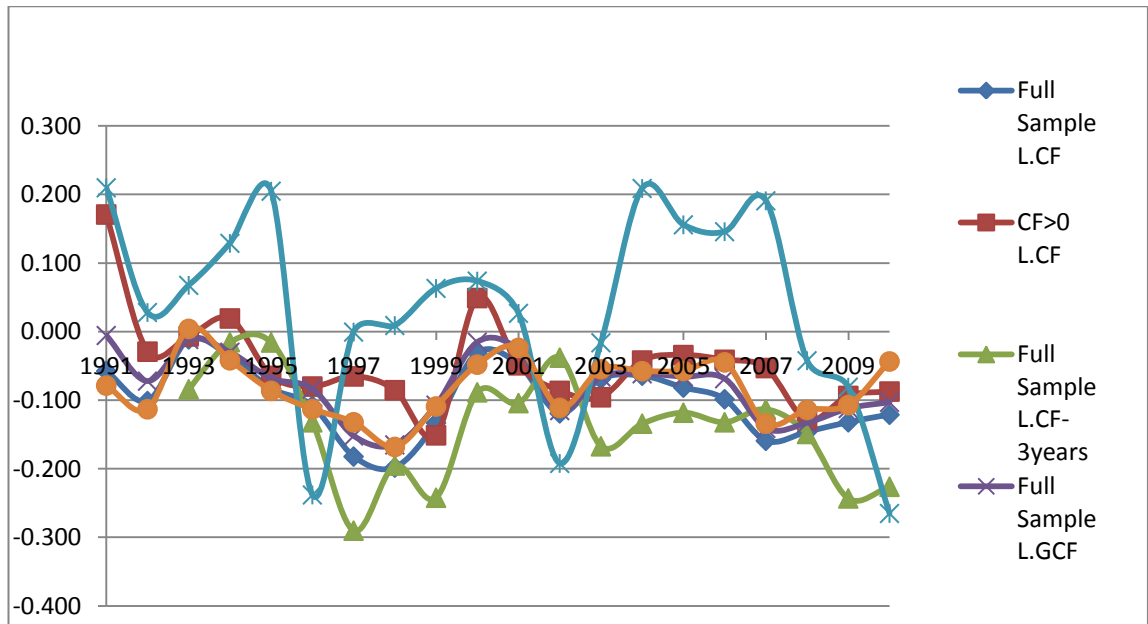
Both groups of plots show that the R&D ICFS for both countries are very volatile over the years and most importantly that their linear trends are downwards. Furthermore, for R&D investment, various OLS estimates show that, even after controlling for negative cash flows firms, there is still an downward negative R&D ICFS trend for US firms and for UK firms the R&D ICFS is interchangeably positive and negative but hardly ever significant (in the last year-financial crisis period, the R&D ICFS is strongly negative and significant). As expected the R&D ICFS is negative (and in most years significant) over time for negative cash flow firms for US.

3.6.2 Baseline empirical findings

In this section we consider the differences in R&D ICFS by high tech industries over time to show that the aggregate picture is not just a function of national high tech industry composition (as one may suspect), but mostly one of firm level differences in R&D spending.

Table 3.5 presents the estimation results for the primary specification in Equation (2) for each of the five high tech industry groups: chemicals; drugs, cosmetics and health care; electrical; electronics and machinery & equipment. The model is estimated with OLS technique due to small number of firm-year observations for the UK sample in each high tech industry. Within each industry

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group, the sample is divided into two consecutive subsample periods and the regression coefficients are estimated for each of them, of course separately for US and UK firms' samples. Time dummies are included but are not reported. The standard errors are heteroskedasticity-robust and clustered at the firm level. The residuals (errors) are identically and independently distributed.

Table 3.5 Cash Flow Sensitivity of R&D Investment by Industry: Augmented Model (OLS)

DV: R&D	Chemicals	Drugs, Cosmetics & Health Care	Electrical	Electronics	Machinery & Equipment
Panel A (US)	1990-1999				
CF	-0.210***	-0.191***	-0.120*	-0.184***	-0.044
	(-3.35)	(-5.72)	(-1.87)	(-11.17)	(-1.53)
Q	0.019***	0.011***	0.012*	0.011***	0.013***
	(4.51)	(5.79)	(1.89)	(8.28)	(4.71)
SIZE	-0.000	0.000	-0.008***	-0.007***	-0.002**
	(-0.45)	(0.25)	(-5.93)	(-9.00)	(-2.51)
CASH	0.015	0.162***	0.067**	0.100***	0.063***
	(0.69)	(7.26)	(2.08)	(12.03)	(3.13)
STOCK	0.036	-0.023	0.011	-0.036***	0.008
	(1.09)	(-1.11)	(0.40)	(-2.73)	(0.44)
DEBT	0.011	-0.051*	-0.035	-0.050*	0.006
	(0.67)	(-1.74)	(-1.12)	(-1.95)	(0.44)
_cons	0.027***	0.045***	0.078***	0.113***	0.027***
	(3.21)	(4.35)	(5.46)	(15.78)	(4.50)
Obs.	566	956	241	2814	705
AR2	0.444	0.447	0.395	0.325	0.0904
Panel B (US)	2000-2010				
CF	-0.041*	-0.220***	-0.076***	-0.099***	-0.038
	(-1.85)	(-7.89)	(-3.14)	(-8.52)	(-1.62)
Q	0.007***	0.012***	0.014***	0.015***	0.006**
	(3.33)	(6.43)	(3.76)	(11.06)	(2.37)
SIZE	-0.004***	0.000	-0.010***	-0.013***	-0.004***
	(-4.30)	(0.10)	(-7.81)	(-18.01)	(-3.16)
CASH	0.077***	0.209***	0.104***	0.083***	0.074***
	(3.85)	(14.55)	(5.65)	(12.84)	(4.63)
STOCK	-0.038	0.006	-0.059**	-0.028**	-0.020
	(-1.07)	(0.27)	(-2.46)	(-2.24)	(-0.85)

DEBT	-0.031	-0.022	-0.041	-0.048***	0.003
	(-1.55)	(-0.88)	(-0.96)	(-3.28)	(0.17)
_cons	0.041***	0.031**	0.063***	0.134***	0.047***
	(4.06)	(2.57)	(5.06)	(20.41)	(4.39)
Obs.	685	2160	509	5544	887
AR2	0.257	0.482	0.424	0.256	0.107

Panel C (UK) 1990-1999

CF	-0.059**	-0.150**	-0.000	-0.131***	-0.043*
	(-2.45)	(-2.31)	(-0.02)	(-3.94)	(-1.88)
Q	0.005***	0.021***	0.002	0.016***	0.012***
	(2.91)	(4.98)	(0.69)	(4.48)	(5.45)
SIZE	-0.002***	0.000	-0.007***	-0.008***	-0.008***
	(-3.87)	(0.05)	(-7.51)	(-4.71)	(-5.59)
CASH	-0.010	0.242***	0.020	0.057***	0.015
	(-0.93)	(5.62)	(0.75)	(2.89)	(1.25)
STOCK	0.005	-0.022	-0.009	0.007	0.006
	(0.29)	(-0.51)	(-0.71)	(0.24)	(0.39)
DEBT	0.002	0.159	-0.033*	-0.018	0.006
	(0.16)	(1.57)	(-1.87)	(-0.56)	(0.51)
_cons	0.029***	-0.014	0.054***	0.062***	0.050***
	(4.79)	(-0.75)	(5.52)	(4.99)	(6.23)
Obs.	148	152	76	475	215
Adj.R2	0.0989	0.701	0.277	0.271	0.277

Panel D (UK) 2000-2010

CF	-0.055***	-0.126***	-0.326***	-0.091***	-0.129***
	(-2.89)	(-6.06)	(-4.78)	(-5.23)	(-3.86)
Q	0.004*	0.018***	0.034***	0.029***	0.023***
	(1.83)	(4.48)	(3.28)	(6.64)	(5.81)
SIZE	-0.001**	0.005***	-0.015***	-0.006***	-0.007***
	(-2.10)	(2.64)	(-5.70)	(-3.33)	(-4.08)
CASH	0.003	0.230***	0.094***	0.077***	-0.011
	(0.24)	(6.28)	(3.40)	(4.05)	(-0.36)

STOCK	0.005	-0.072**	-0.048**	0.020	0.038
	(0.29)	(-2.27)	(-2.18)	(0.93)	(0.65)
DEBT	-0.001	-0.079	0.026	0.020	-0.027
	(-0.07)	(-1.59)	(0.90)	(0.53)	(-0.61)
_cons	0.027***	-0.010	0.047***	0.052***	0.026**
	(4.50)	(-0.37)	(3.45)	(3.57)	(2.40)
Obs.	141	245	64	871	182
Adj.R2	0.404	0.430	0.816	0.291	0.577

Notes: This table presents the OLS estimation results of the R&D investment model in equation 2. The US and UK firms' samples are divided by industry. Analytical definitions for all the variables are provided in table 3.1. All regressions include industry and time dummies. T-statistic values are reported in parentheses. ***, ** and * indicate coefficient is significant at the 1%, 5% and 10% respectively. For the estimation we use consistent to heteroskedasticity standard errors.

For US firms in both subperiods the R&D ICFS is negative for all industries and statistically insignificant only for machinery & equipment. For UK firms in the first subperiod the R&D ICFS is negative and significant for four out of five industries. Electrical industry shows insignificant R&D ICFS. In the second subperiod, UK firms report negative and significant R&D ICFS over all five industries. The economic magnitude for ICFS is highest for UK electrical industry in the second subperiod: -0.326. That is: a one-dollar increase in cash flow decreases R&D investment by 32 cents. Put differently, in economic terms, this estimate suggests that for each dollar of internal cash flow shortfall (normalized by assets), a firm will spend up to 32 cents on new R&D activities. Overall for both countries the ICFS is negative in both subperiods, which is in line with this paper's findings so far.

The next step of this section is estimating equation (2) over the entire sample (pooling together financially constrained and unconstrained firms). This is done in order to verify patterns of R&D investment cash flow sensitivity and that well documented patterns of physical investment cash flow sensitivity. The results are reported in table 3.6.

The coefficient associated with CF displays the usual positive association between capital investment and profitability, and negative association between R&D investment and cash flow. The positive coefficients of cash flow in physical investment regression decreases in its magnitude over time and also the

negative coefficient of cash flow in R&D investment regression declines in its magnitude over time for both countries' samples. The coefficients on the control variables conform to the previous literature. An increase in investment opportunities makes it more likely that both sets of firms: US and UK will invest in both R&D and capital investment, however firms are more likely to invest more in R&D than in capital investment as time goes by.

To summarize, this simple analysis indicates aligned changes in firms' total investment composition policies, respectively R&D investment is going up, and the physical investment is going down. Also, the R&D ICFS is negative with a downward trend but the impact of cash holdings on R&D investment substantially increases over time for both UK and US sample. Also the R&D ICFS sensitivity is higher in size for the US sample than UK one, while the capital ICFS is lower for the US sample than UK one.

Table 3.6 Cash Flow Sensitivity of R&D Investment: Augmented Model (OLS)

Dep. Var:	1990-1999		2000-2010	
	R&D	INV	R&D	INV
Panel A (US)				
CF	-0.163***	0.028***	-0.117***	0.009***
	(-12.21)	(6.32)	(-13.69)	(5.95)
Q	0.011***	0.004***	0.011***	0.003***
	(12.32)	(9.65)	(12.81)	(10.58)
SIZE	-0.003***	0.002***	-0.007***	0.001***
	(-9.69)	(8.36)	(-16.81)	(7.44)
CASH	0.097***	-0.018***	0.127***	-0.019***
	(14.63)	(-5.49)	(24.10)	(-11.72)
STOCK	-0.011	0.031***	0.014	0.016***
	(-1.23)	(5.87)	(1.64)	(5.36)
DEBT	-0.020*	0.024***	-0.024**	0.017***
	(-1.85)	(3.74)	(-2.41)	(3.88)
_cons	0.065***	0.032***	0.075***	0.023***
	(18.41)	(14.87)	(18.71)	(15.33)
Obs.	7919	7919	13705	13705
Adj.R2	0.469	0.101	0.396	0.111
Panel B (UK)				
CF	-0.131***	0.062***	-0.106***	0.013***
	(-6.16)	(5.23)	(-7.79)	(3.32)
Q	0.017***	0.007***	0.023***	0.002***
	(8.58)	(5.83)	(8.54)	(3.30)
SIZE	-0.003***	-0.000	-0.003***	0.001***
	(-6.37)	(-1.20)	(-3.99)	(2.63)
CASH	0.083***	-0.028***	0.104***	-0.013***
	(5.38)	(-3.71)	(7.73)	(-3.57)
STOCK	0.009	0.013	-0.004	0.010*
	(0.68)	(1.28)	(-0.22)	(1.85)

DEBT	0.018	0.035***	0.002	0.008
	(0.82)	(3.16)	(0.11)	(1.14)
_cons	0.025***	0.049***	0.025***	0.022***
	(5.34)	(12.28)	(3.20)	(8.47)
Obs.	1966	1966	2452	2452
Adj.R2	0.460	0.157	0.393	0.136

Notes: This table presents the OLS estimation results over time of the R&D investment model in equation 2. Analytical definitions for all the variables are provided in table 3.1. All regressions include industry and time dummies. T-statistic values are reported in parentheses. ***, ** and * indicate coefficient is significant at the 1%, 5% and 10% respectively. For the estimation we use consistent to heteroskedasticity standard errors.

3.6.3 GMM results

We now proceed to motivate the dynamic model, in order to identify an approach that allows firms to adjust towards the target R&D investment level with the possibility of delays following changes in firm-specific characteristics and/or random shocks. Table 3.7 reports the results obtained from estimating equation (2). Panel A provides estimates of the dynamic R&D regression for full samples of US and UK firms in the two sample periods. Panel B delivers estimates for young and mature firms, panel C for firms with low versus high dividend payout ratio, panel D for firms with the ratio of R&D expenses over total assets below the sample median versus above the sample median, panel E for firms with the average lower versus higher variability of R&D investment, and panel F for firms belonging to High tech industries versus firms belonging to Non high tech industries. In all specifications, all variables are treated as endogenous. Also, time dummies are included among the independent variables under all specifications but they are treated as exogenous.

Table 3.7 Cash Flow Sensitivity of R&D Investment: Augmented Regression Model (GMM)

DV: R&D	1990-1999	2000-2010			1990-1999	2000-2010
Panel A	US - Full Sample				UK - Full Sample	
L.R&D	0.642***	0.805***			0.844***	0.772***
	(10.47)	(19.88)			(11.39)	(12.84)
CF	-0.150***	-0.062***			-0.065***	-0.081***
	(-5.42)	(-2.87)			(-2.93)	(-6.05)
Q	0.008***	-0.001			0.005*	0.008*
	(3.56)	(-0.35)			(1.84)	(1.87)
SIZE	-0.002	-0.002			-0.002	0.004
	(-0.94)	(-1.22)			(-1.08)	(1.36)
CASH	0.068***	0.047***			0.052**	0.052**
	(3.86)	(3.65)			(2.52)	(2.40)
STOCK	-0.047**	-0.008			-0.022	-0.053**
	(-2.09)	(-0.30)			(-0.77)	(-2.02)
DEBT	0.059	-0.036			0.110*	0.013
	(1.11)	(-0.89)			(1.84)	(0.24)
Obs.	7919	13705			1966	2452
Firms	1360	2020			290	382
AR1-p value	9.91e-12	3.40e-15			0.000347	0.00000588
AR2-p value	0.641	0.541			0.148	0.264
Hansen-p value	0.223	0.0446			0.630	0.0391

DV: R&D	1990-1999 Young	1990-1999 Mature	2000-2010 Young	2000-2010 Mature	1990-1999 Young	1990-1999 Mature	2000-2010 Young	2000-2010 Mature
Panel B	US				UK			
L.R&D	0.661***	0.718***	0.774***	0.777***	0.797***	0.790***	0.752***	0.856***
	(9.13)	(9.79)	(16.32)	(17.71)	(9.79)	(15.08)	(12.43)	(9.72)
CF	-0.137***	-0.056*	-0.074***	-0.102***	-0.082***	0.018	-0.081***	-0.062***
	(-4.46)	(-1.82)	(-3.34)	(-4.58)	(-2.99)	(1.12)	(-5.52)	(-3.19)
Q	0.012***	0.000	0.002	0.004	0.007***	0.006***	0.009**	0.004
	(3.28)	(0.05)	(0.58)	(1.32)	(2.66)	(3.79)	(2.01)	(1.31)
SIZE	-0.003	-0.001	-0.003	-0.000	-0.003	-0.002**	0.007**	-0.000
	(-0.89)	(-0.40)	(-1.19)	(-0.03)	(-1.14)	(-1.98)	(1.97)	(-0.09)
CASH	0.051**	0.077***	0.045***	0.026	0.078***	-0.020	0.049**	0.043*
	(2.09)	(4.06)	(2.85)	(1.60)	(2.76)	(-1.50)	(2.23)	(1.89)
STOCK	-0.040*	-0.030	-0.047*	0.052	-0.023	-0.041**	-0.041	-0.047***
	(-1.66)	(-1.18)	(-1.86)	(1.45)	(-0.83)	(-2.23)	(-1.64)	(-4.06)
DEBT	-0.024	0.017	-0.009	-0.062	0.097*	0.029	-0.013	0.006
	(-0.47)	(0.56)	(-0.17)	(-1.20)	(1.81)	(1.04)	(-0.26)	(0.22)
Obs.	3803	4116	6995	6710	1073	893	1227	1225
Firms	842	518	1194	826	180	110	227	155
AR1-p value	5.76e-11	0.00196	1.09e-10	2.30e-09	0.000583	0.0290	0.0000494	0.0297
AR2-p value	0.749	0.396	0.0538	0.126	0.177	0.185	0.105	0.0673
Hansen-p value	0.501	0.118	0.0903	0.0147	0.567	0.998	0.333	0.642
DV: R&D	Low DIV	High DIV	Low DIV	High DIV	Low DIV	High DIV	Low DIV	High DIV

Panel C	USA				UK			
L.R&D	0.588***	0.838***	0.810***	0.758***	0.725***	0.928***	0.743***	0.810***
	(8.84)	(16.79)	(18.75)	(12.81)	(10.35)	(19.24)	(12.25)	(6.07)
CF	-0.164***	-0.038	-0.047**	-0.096***	-0.081***	-0.017	-0.082***	-0.034
	(-5.72)	(-0.95)	(-2.22)	(-4.11)	(-2.90)	(-0.84)	(-5.55)	(-1.05)
Q	0.008***	0.004**	0.002	-0.001	0.006**	0.005	0.010**	0.007
	(2.72)	(2.51)	(0.65)	(-0.22)	(2.13)	(1.64)	(2.01)	(1.36)
SIZE	-0.001	0.000	-0.005*	0.001	-0.003	-0.001	0.008**	-0.003
	(-0.19)	(0.18)	(-1.79)	(0.81)	(-0.77)	(-1.13)	(2.01)	(-0.97)
CASH	0.086***	0.023	0.055***	0.050***	0.101***	0.014	0.060**	-0.004
	(3.95)	(1.02)	(3.35)	(2.84)	(2.92)	(1.48)	(2.56)	(-0.26)
STOCK	-0.055**	0.025	-0.014	0.021	-0.031	0.012	-0.050**	-0.033
	(-2.41)	(0.71)	(-0.49)	(0.68)	(-1.04)	(0.72)	(-1.96)	(-1.12)
DEBT	0.077	-0.005	-0.041	-0.016	0.153**	-0.014	0.009	-0.013
	(1.33)	(-0.12)	(-0.87)	(-0.40)	(2.49)	(-0.74)	(0.20)	(-0.27)
Obs.	3908	4011	7774	5931	982	984	1209	1243
Firms	740	620	1221	799	150	140	207	175
AR1-p value	2.18e-12	0.0165	9.88e-14	6.96e-08	0.000541	0.0133	0.0000104	0.0956
AR2-p value	0.645	0.953	0.640	0.685	0.501	0.0275	0.392	0.218
Hansen-p value	0.157	0.672	0.0859	0.319	0.456	0.785	0.340	0.345
DV: R&D	Rdm<Median	Rdm>Median	Rdm<Median	Rdm>Median	Rdm<Median	Rdm>Median	Rdm<Median	Rdm>Median
Panel D	US	Rdm-mean of R&D			UK			

L.R&D	0.632***	0.548***	0.661***	0.761***	0.748***	0.799***	0.431***	0.731***
	(9.14)	(8.14)	(12.48)	(16.91)	(8.86)	(12.50)	(5.10)	(11.46)
CF	0.005	-0.172***	-0.016**	-0.079***	-0.005	-0.071***	-0.005	-0.081***
	(0.82)	(-5.73)	(-2.27)	(-3.97)	(-0.50)	(-2.94)	(-0.62)	(-6.06)
Q	-0.000	0.007***	0.000	0.001	0.001	0.006**	0.003**	0.008*
	(-0.52)	(2.71)	(0.25)	(0.36)	(1.57)	(2.12)	(2.12)	(1.76)
SIZE	-0.001	-0.002	0.001	-0.003	-0.000	-0.003	-0.001	0.006*
	(-1.28)	(-0.57)	(1.21)	(-1.44)	(-0.96)	(-1.09)	(-1.53)	(1.82)
CASH	0.003	0.073***	0.015***	0.050***	-0.001	0.055**	0.016**	0.054**
	(0.65)	(3.44)	(3.10)	(2.97)	(-0.27)	(2.12)	(2.04)	(2.24)
STOCK	-0.006	-0.052**	-0.022*	-0.009	0.003	-0.031	0.003	-0.044*
	(-0.69)	(-2.15)	(-1.82)	(-0.33)	(0.87)	(-1.14)	(0.35)	(-1.84)
DEBT	0.008	0.048	0.008	-0.057	0.008	0.120	0.009	0.003
	(0.96)	(0.74)	(0.83)	(-1.05)	(1.63)	(1.63)	(1.01)	(0.05)
Obs.	3985	3934	6846	6859	982	984	1228	1224
Firms	660	700	1009	1011	146	144	188	194
AR1-p value	4.39e-08	1.73e-09	5.39e-10	5.44e-14	0.00525	0.000420	0.000251	0.0000164
AR2-p value	0.851	0.624	0.0378	0.523	0.117	0.138	0.0291	0.296
Hansen-p value	0.109	0.255	0.0300	0.230	0.484	0.515	0.362	0.561
DV: R&D	sd<Median	sd>Median	sd<Median	sd>Median	sd<Median	sd>Median	sd<Median	sd>Median
Panel E	US	sd-R&D standard deviation			UK			
L.R&D	0.955***	0.604***	0.906***	0.790***	0.894***	0.808***	0.842***	0.741***
	(38.29)	(9.75)	(46.76)	(18.30)	(31.06)	(11.87)	(19.97)	(12.56)

	High-Tech	Non High-Tech	High-Tech	Non High-Tech	High-Tech	Non High-Tech	High-Tech	Non High-Tech
CF	-0.002	-0.155***	-0.008**	-0.059***	-0.002	-0.070***	0.008	-0.080***
	(-0.29)	(-5.18)	(-2.05)	(-2.67)	(-0.50)	(-2.98)	(1.14)	(-5.74)
Q	0.000	0.007***	0.000	0.001	0.001*	0.006**	0.000	0.010**
	(0.06)	(2.61)	(0.14)	(0.21)	(1.76)	(2.31)	(0.05)	(2.19)
SIZE	-0.000	-0.001	0.001**	-0.005*	-0.000	-0.003	-0.000	0.007**
	(-0.04)	(-0.21)	(2.35)	(-1.83)	(-0.30)	(-1.17)	(-0.48)	(2.19)
CASH	0.004	0.080***	0.009***	0.057***	0.004*	0.060**	0.009**	0.045*
	(1.42)	(4.10)	(3.40)	(3.18)	(1.75)	(2.11)	(2.12)	(1.95)
STOCK	0.008	-0.050**	-0.016***	-0.028	-0.002	-0.031	0.000	-0.053**
	(1.24)	(-2.07)	(-2.83)	(-0.91)	(-0.86)	(-1.15)	(0.03)	(-2.14)
DEBT	-0.003	0.062	-0.007	-0.027	-0.004	0.122*	0.004	-0.021
	(-0.66)	(1.00)	(-1.07)	(-0.54)	(-1.27)	(1.87)	(0.63)	(-0.40)
Obs.	3981	3938	6855	6850	986	980	1236	1216
Firms	663	697	997	1023	146	144	186	196
AR1-p value	4.62e-20	2.70e-10	1.18e-29	1.24e-14	0.00000697	0.000297	2.89e-08	0.00000692
AR2-p value	0.120	0.636	0.0168	0.514	0.178	0.141	0.968	0.266
Hansen-p value	0.0468	0.316	0.128	0.307	0.639	0.443	0.188	0.480
DV: R&D	High-Tech	Non High-Tech	High-Tech	Non High-Tech	High-Tech	Non High-Tech	High-Tech	Non High-Tech
Panel F	US				UK			
L.R&D	0.593***	0.733***	0.771***	0.829***	0.805***	0.862***	0.768***	0.737***
	(9.44)	(8.31)	(19.72)	(10.22)	(12.06)	(12.67)	(12.13)	(11.14)
CF	-0.187***	-0.019	-0.065***	-0.070***	-0.082***	-0.007	-0.090***	-0.091***
	(-6.36)	(-1.24)	(-2.62)	(-3.80)	(-3.11)	(-1.19)	(-6.81)	(-2.97)

Q	0.007***	0.002	0.000	0.003	0.006*	0.004*	0.009**	0.006
	(3.21)	(0.97)	(0.07)	(1.35)	(1.90)	(1.73)	(2.04)	(1.18)
SIZE	-0.000	-0.001	-0.005**	0.003*	-0.002	-0.000	0.006*	0.002
	(-0.14)	(-0.66)	(-2.51)	(1.66)	(-0.51)	(-0.25)	(1.75)	(1.20)
CASH	0.070***	0.024	0.044***	0.043**	0.045**	-0.003	0.040*	0.058***
	(3.68)	(1.42)	(3.07)	(2.10)	(2.17)	(-0.34)	(1.71)	(3.26)
STOCK	-0.064***	0.035*	-0.034	-0.002	-0.010	-0.022***	-0.038	-0.072**
	(-2.59)	(1.66)	(-1.34)	(-0.04)	(-0.32)	(-2.61)	(-1.58)	(-2.44)
DEBT	0.065	0.029	-0.043	-0.009	0.140**	0.040*	-0.021	-0.046
	(1.03)	(1.17)	(-0.88)	(-0.17)	(1.98)	(1.70)	(-0.40)	(-1.25)
Obs.	5282	2637	9785	3920	1066	900	1503	949
Firms	914	446	1426	594	158	132	235	147
AR1-p value	6.45e-10	0.00181	2.92e-17	0.00889	0.000615	0.00241	0.0000744	0.0112
AR2-p value	0.852	0.158	0.383	0.522	0.146	0.111	0.500	0.148
Hansen-p value	0.163	0.417	0.171	0.148	0.696	0.830	0.143	0.893

Notes: This table presents the GMM estimation results over time of the investment model in equation 3. The estimations use pre-determined firms selection into two classes: poor vs. intensive R&D investment firms (Panel E), high vs. low R&D investment variability (Panel F) and high tech vs. non high tech firms (Panel G). Constraint category assignments employ ex ante criteria based on firm age (Panel B), dividend (Panel C) and size (Panel D). Analytical definitions for all the variables are provided in table 3.1. All regressions include time dummies. T-statistic values are reported in parentheses. ***, ** and * indicate coefficient is significant at the 1%, 5% and 10% respectively. For the estimation we use asymptotic standard errors robust to heteroskedasticity. We report the Hansen test, which is a test of over-identifying restrictions. AR1 and AR2 are tests for the absence of first order and second order correlation in the residuals. These test statistics are asymptotically distributed as N (0,1) under the null of no serial correlation.

The results reveal that the dynamic nature of our R&D investment model is not rejected. In all regressions the estimated coefficient of the lagged dependent variable is positive and significantly different from zero. The adjustment speed, given by 1 minus the estimated coefficient of the lagged dependent variable is smaller than about 0.4, possibly providing evidence that firms adjust their R&D investment relatively slowly in an attempt to reach the target R&D investment ratio. This can lend support to the view that firms trade-off between costs of adjustment towards target R&D investment and costs of being off target. One possible explanation for the relatively low value of the adjustment coefficient might be that the costs of deviating from the target are not significant. However, the value of the adjustment coefficient may also be taken as a support to the view that the adjustment process is costly. Specifically, it may suggest that adjustment costs are higher resulting in lower speeds of adjustment. The lower speed of adjustment for R&D investment can be explained by either the fact that R&D investment has very low collateral value, and hence it struggles to rely on debt finances, or the fact that R&D investment has high adjustment costs in the sense that a large part of R&D expenditure is wages for highly qualified staff that cannot be hired or fired fast. Overall, the results lend strong support to the view that firms tend to trade-off between costs of speedy adjustment and costs of delay in achieving the target R&D investment ratio.

The R&D ICFS estimates show the same patterns reported in Table 3.6, as controls for alternative internal and external funding sources are included. The cash flow sensitivity estimates are all negative and significant for the full samples of different subperiods, and for most of constrained and unconstrained firms. The results in panel B and C for both UK and US firms in both subperiods clearly suggest that a negative relation between internal funds and R&D expenditures holds for the subsample of firms that are most likely to face high financing costs, but it is insignificant for unconstrained firms. These findings are consistent to some extent with the theory of Fazzari et al. (1988) stating that unconstrained firms are not expected to be influenced by the adjustment costs argument. The second subperiod: 2000-2010 covers financial crisis period, which usually is expected to produce more pronounced effects. Furthermore, the negative and significant ICFS applies typically to firms with more intensive R&D investment, measured with ratio of R&D to assets. In panel E the variability of R&D expenses clearly divides firms of negative and significant ICFS and negative or even

positive and insignificant ICFS. The first one refers to firms with average R&D variability measure above the median level and of course the latter one to their counterparts. Similar trend can be observed in panel F especially over the first subperiod, where firms belonging to High tech industries show very negative R&D ICFS in contrast to their corresponding firms. In the second subperiod in both countries the R&D ICFS is negative and significant for both subgroups, but of course higher magnitude for High tech firms. In general, the ICFS is positive only in three subsamples, which are for the subsample of mature UK firms from the first subperiod and for the UK firms with small R&D variability from the second subperiod, and for US firms of small R&D investment intensity in the first subperiod, however, none of these coefficients are statistically significant. The coefficients for the other regressors present either statistically insignificant estimates (e.g., Net Debt issues) or significant estimates of the expected sign (e.g., Tobin's Q). The coefficients for Tobin's Q are smaller for US firms than for UK ones and they decline over time. In terms of firms' classifications, the coefficients for Tobin's Q are typically greater in size for firms: young, low dividend paying, more intensively investing in R&D projects, with higher R&D variability and belonging to High tech industry. Size coefficient is negative and significant for some subgroups, particularly UK firms, and positive and significant for some US subgroups, especially in the second subperiod. Cash holdings influence on R&D investment in most cases is positive and significant, thus cash holdings seem to be the most important source of finances for R&D firms, however, its effect declines over time. In terms of constrained and unconstrained division according to e.g., dividend payout ratio, US low dividend payout firms show decreasing cash holdings coefficients over time, while the same coefficients increase over time for high dividend payout firms. The cash holdings coefficients decrease over time for all UK subgroups created on the basis of dividend payout ratio. The cash savings coefficients are higher for UK low dividend payout firms than US corresponding firms and higher for US high dividend payout firms than UK corresponding firms. Interestingly, cash holdings coefficients in the first subperiod is higher for high tech UK and US firms, while in the second subperiod it is higher for non high tech firms UK and US firms again.

In the last three rows of Table 3.6 the diagnostic test statistics associated with the instrumental set are reported. P-values associated with direct tests for first-order (AR1) and second order (AR2) autocorrelation of the differenced

residuals as well as with Hansen's (1982) test suggest that the instruments are mainly valid and relevant for the estimated equations apart from the subsample of US mature firms in the first and second subperiod, where Hansen p-value equals respectively, 0.0931 and 0.0186, US firms with R&D variability over time below the sample median in the first subperiod, US non high tech firms in the second subperiod and UK high tech firms in the second subperiod.

Overall, the results in table 3.7 show a strong, negative relation between cash flow and R&D investment. These negative coefficients on cash flows together with positive coefficient on cash stock imply that firms rely on cash holdings to finance R&D investment, especially the UK firms, but this pattern seem to weaken with time. To certain extent, this supports the evidence provided by Brown and Petersen (2011) on the smoothing role of the R&D financing by cash holding. The pattern of other coefficients included in the model are as expected: as R&D intensity rises, firms' stock and debt issues, and more importantly cash flow level become increasingly volatile, firms hedge their R&D expenses with cash holdings. According to previous literature as well as descriptive statistics of this research the number of firms with persistently negative cash flows increases over time, however these firms can not be the only reason of negative R&D ICFS, which has been shown in Figure 3.2 and also in table 3.7. The R&D ICFS is negative over time and significant especially for financially constrained firms, however, the size of the cash flow coefficients declines over time and that suggest more complex explanation for negative R&D ICFS. The coefficients for financial variables of UK samples are much higher than for US samples. The more intensively a firm invests in R&D the more cash holdings play a stronger role on that investment and finally the more a firm changes its R&D investment the more it hires cash savings to do so. The more cash holdings affect positively R&D investment the more cash flow negatively influences R&D investment. Net stock issues affects negatively R&D investment, while net debt issues show positive effect on R&D investment, however, the latter one is most of the time statistically insignificant.

3.6.4 Financial crisis

Table 3.8 present the OLS results of equation 2 for full samples of US and UK firms during the pre crisis: 2000-2007 and crisis: 2008-2010 subperiods.

Table 3.8 Cash Flow Sensitivity of R&D Investment Covering Financial Crisis Period: Baseline Model

US Dep Var:	2000-2007 R&D	2008-2010 R&D	UK	2000-2007 R&D	2008-2010 R&D
CF	-0.114***	-0.147***		-0.097***	-0.118***
	(-10.62)	(-7.85)		(-6.65)	(-2.78)
Q	0.011***	0.015***		0.024***	0.020**
	(11.03)	(6.06)		(7.81)	(2.44)
SIZE	-0.008***	-0.004***		-0.005***	0.001
	(-16.23)	(-4.75)		(-5.40)	(0.78)
CASH	0.106***	0.157***		0.068***	0.203***
	(18.42)	(11.08)		(4.57)	(5.01)
STOCK	0.014	0.025		0.005	0.038
	(1.30)	(0.88)		(0.30)	(0.51)
DEBT	-0.011	-0.042		-0.013	-0.014
	(-0.99)	(-1.54)		(-0.63)	(-0.23)
Obs.	9597	2341		1628	457
Adj.R2	0.395	0.412		0.441	0.333

Notes: This table presents the OLS estimation results of the R&D investment model in equation 2. The US and UK samples are divided into two partitions: pre-crisis period (2000-2007) and post crisis period (2008-2010). Analytical definitions for all the variables are provided in table 3.1. All regressions include industry and time dummies. T-statistic values are reported in parentheses. ***, ** and * indicate coefficient is significant at the 1%, 5% and 10% respectively. For the estimation we use consistent to heteroskedasticity standard errors.

Given the significant wedge expected between the cost of internal and external finance in the financial crisis period, R&D investment ratios of firms are predicted to display a greater sensitivity to cash flow in the crisis period regardless of the classification variable. Bernanke and Gertler (1989) claim adverse macroeconomic shocks not only interfere with the central function of financial markets but also exacerbate adverse selection and moral hazard problems. As a result, during a financial crisis the hedging role of cash should be

more popular because of the ability of firms to raise external finance is much smaller, due to an increasing wedge between the cost of internal and external funds. Therefore, during financial crisis periods, financially constrained firms should save a higher proportion of their cash flows, whilst unconstrained firm's cash flow policies should not show any systematic changes. Financial crisis works as exogenous shock affecting both the size of current cash flows as well as the relative attractiveness of current investment against the future one. A firms' viability, profitability and cash flow as well as prevalently reduced the expected return on investment opportunities are clearly affected by exogenous shocks coming from economic and financial crises. Hall and Lerner (2010) and Islam and Mozumdar (2007) argue that in the presence of market imperfections, external funds may not provide a perfect substitute for internal funds, given that the premium for external financing will be higher. Financial crisis should increase the marginal cost of external finance, leading to a rise in the ICFS. In the presence of financial crisis cash flows, cash holdings and stock issues are more likely to affect R&D in a more pronounced manner than before.

The ICFS is negative as before for all subgroups and it increases in its negative magnitude during crisis period. This is consistent with the conjecture that cash flows are more binding on investment at times when capital market imperfections are likely to be more severe, which is expected to be the case during a financial crisis period (Arslan et al., 2006). As expected Tobin's Q coefficients are positive and statistically significant for all subgroups and their magnitude increases (decreases) in the crisis subperiods for US (UK) firms. Size variable has negative and significant impact on R&D investment in both US subperiods and first UK subperiod suggesting that R&D investment increases with decline of firms' size, however this trend falls down under the influence of financial crisis. The coefficients of cash holdings definitely increase over the crisis period and they are lower in the UK in case of first pre-crisis subperiod but higher for UK during the crisis period. Stock issues are positive in all subperiods but statistically insignificant. In contrast, debt issues are negative and statistically significant for the US firm during the crisis period. In terms of countries comparison UK firms show greater coefficients than US firms during crisis period in case of cash holdings, Tobin's Q and stock issues. Overall, the empirical findings presented in Table 3.8 support our expectations regarding the relationship between cash holdings and R&D investment. We find that the

hypothesized positive and statistically significant impact of cash savings on R&D investment is observed to be 1.5 and over 3 times greater during the crisis period for US and UK firms respectively. This is consistent with the conjecture that firms focus more on cash holdings at times when capital market imperfections are likely to be more severe, which is expected to be the case during a financial crisis period. Importantly the negative relationship between cash flow and R&D investment becomes even more negative during financial crisis period. This is in line with the expectation because during financial crisis firms should display lower cash flows but R&D investment is not likely to change a lot due to its high adjustment costs.

Table 3.9 reports the GMM system results of regression 3 for full samples (models 1 and 3) and results for partial equation 3 (models 2 and 4)– including only the interaction between financial crisis dummy and cash holdings.

Table 3.9 Cash Flow Sensitivity of R&D Investment: Augmented Regression Model Including Financial Crisis Dummy

DV: R&D	US (2000-2010)		UK (2000-2010)	
L.R&D	0.827***	0.816***	0.778***	0.772***
	(22.03)	(20.48)	(12.77)	(12.85)
CF	-0.057***	-0.061***	-0.084***	-0.081***
	(-3.17)	(-2.92)	(-5.77)	(-5.97)
Q	-0.000	-0.000	0.007	0.008*
	(-0.18)	(-0.19)	(1.42)	(1.84)
SIZE	-0.000	-0.002	0.003	0.004
	(-0.07)	(-1.30)	(1.57)	(1.33)
CASH	0.052***	0.048***	0.054***	0.053***
	(4.66)	(4.02)	(2.80)	(2.72)
STOCK	-0.018	-0.018	-0.033	-0.053**
	(-0.66)	(-0.71)	(-1.20)	(-2.03)
DEBT	-0.008	-0.046	0.032	0.013
	(-0.17)	(-1.14)	(0.59)	(0.23)
CRISIS	0.008	0.005	0.008	0.001
	(0.94)	(1.50)	(0.61)	(0.24)
CASH*CRISIS	-0.036**	-0.025**	0.017	0.005
	(-2.56)	(-2.03)	(0.70)	(0.24)
CF*CRISIS	-0.007		0.028	
	(-0.35)		(0.71)	
Q*CRISIS	0.003		-0.003	
	(1.11)		(-0.40)	
SIZE*CRISIS	-0.001		-0.001	
	(-1.32)		(-0.63)	
STOCK*CRISIS	-0.053		-0.072	
	(-1.21)		(-0.83)	
DEBT*CRISIS	-0.175*		-0.063	
	(-1.82)		(-0.44)	

_cons	0.006	0.022*	-0.021	-0.028
	(0.76)	(1.78)	(-1.51)	(-1.46)
Obs.	13705	13705	2452	2452
Firms	2020	2020	382	382
AR1-p value	6.20e-15	8.76e-15	0.00000773	0.00000571
AR2-p value	0.601	0.624	0.250	0.264
Hansen-p value	0.116	0.0397	0.0582	0.0355

Notes: This table presents the GMM estimation results over time of the investment model in equation 4. Analytical definitions for all the variables are provided in table 3.1. All regressions include time dummies. T-statistic values are reported in parentheses. ***, ** and * indicate coefficient is significant at the 0.1%, 1% and 5% respectively. For the estimation we use asymptotic standard errors robust to heteroskedasticity. We report the Hansen test, which is a test of over-identifying restrictions. AR1 and AR2 are tests for the absence of first order and second order correlation in the residuals. These test statistics are asymptotically distributed as N (0,1) under the null of no serial correlation.

The interaction term in equation 3 tests whether R&D investment is more sensitive to each particular independent variable included in the model during the financial crisis period. The coefficient on the cash flow is negative and significant but the interaction term of cash flow and financial crisis dummy is positive but insignificant in each subsample. Also the model described by equation 3 examines how firms R&D investment was reallocated depending on the firms' cash holding, stock and debt issues ratios. Put differently, the model also checks if the firms' cash holding, stock and debt issues ratios have an impact on the allocation of R&D investment during the crisis period. The coefficients on cash holdings are positive and significant for both countries, however when cash holdings are interacted with the dummy variable the results vary. The interaction term is negative and significant for both cases of US firms and positive but insignificant for both cases of UK firms. In a typical US firm, the estimated coefficient implies that a one percentage point higher cash savings rate is associated with a 0.03 percentage point lower rate of R&D expense. The coefficient on the financial crisis dummy is positive for US and UK firms but insignificant in all subsamples. The stock and debt issue variables (again multiplied by the crisis dummy) resulted with negative coefficients but insignificant in three models apart from the debt issue in model (1). Due to financial crisis US firms decreased their cash savings level, while UK firms possibly increased it. Debt and stock issues declined during financial crisis. The

estimated coefficients of Tobin's Q variable interacted with financial crisis dummy are statistically insignificant in all subsamples and even negative for UK firms. Hence, there is no evidence that investment opportunities were treated in a differential way in terms of investing in R&D projects after the financial crisis.

3.7 Robustness checks

To ensure the validity of our results a set of alternative specifications have been explored. To see if the negative R&D ICFS and the positive and significant relationship between R&D investment and cash holdings persist over time we change our models' specifications. The GMM results are hardly affected if the dynamic investment term is excluded from the regression. The model in equation (2) was augmented with one-year lagged capital expenditure variable for US sample. The overall interpretation presented above remains largely unchanged. Capital expenditures coefficients show in most cases positive effect on R&D investment.

In order to estimate the extent to which the results are sensitive to the way in which cash flow is measured, this study re-estimates its main empirical specification in equation (2) using Brown and Petersen (2009 or 2011) cash flow measure which adds back on the R&D expenses to the cash flow measure. This important robustness check provides broadly the same results. This cash flow measure which adds back on the R&D expenses to the cash flow measure is adequate for US firms but not for UK firms due to accounting reasons. Both cash flow measure and R&D expenses measure come from the same firms' Income Statements. However, R&D expenses in US can be 100% amortized against tax payments while in UK firms may only amortize 100% of capital expenditures linked with R&D investment.

To check whether the earlier findings hold across different sub-samples of the data and the extent to which firm-specific characteristics affect the R&D ICFS we apply to the data alternative sample splits, such as firms' size (small versus large), average R&D investment intensity measured with firm's average over time ratio of R&D expense over sales (small versus high R&D intensity), firm's average over time total assets growth (slow versus fast total assets growth), size matched with age (small and young versus large and mature), dividend payments (no dividend versus positive dividend payout ratio), sales growth (low growth versus high growth), sales growth matched with size (large and low growth versus large and high growth as well as small and low growth versus small and high growth), sales growth matched with age (mature and low growth versus mature and high growth as well as young and low growth versus young and high growth), sales growth matched with size and age (large, mature and low growth

versus large, mature and high growth as well as small, young and low growth versus small, young and high growth) and Tobin's q (high Tobin's q versus low Tobin's q). Moreover, firms are also categorized according the sign of cash flow (negative versus positive sum of cash flow over years for each firm) as well as the median of cash flow (low versus high sum of cash flow over years for each firm). Most importantly, the R&D ICFS for most of subsamples is negative. The sample division according to the sign of the sum of cash flows[36] over a firm year observations also presents the negative R&D ICFS for both subgroups: positive and negative cash flow firms (where applicable due to subsamples' size). This indicates that the negative ICFS is not only due to firms persistently reporting negative cash flow firms over years of their existence. Therefore, the negative ICFS can be also interpreted as positive R&D firms in US and UK finance their R&D expenses through different channels of finances than cash flows. The most likely channel of R&D investment financing is cash savings, because typically when the ICFS is negative and statistically indistinguishable from zero, the cash holdings coefficients are greater and statistically significant. To make sure that this interpretation is appropriate for this paper's sample the sample has been divided according the median of firms' cash flow sum. The ICFS is negative in both US subperiods, whereas in both UK subperiods ICFS is negative for firms with cash flow sum below the sample median and positive for counterpart firms. These findings suggest that US firms do not tie their R&D investment and cash flow as its financing source in contrary to UK high cash flow sums' firms.

Another important check pertains to the GMM estimation technique that the analysis utilizes. Specifically, in order to make sure that the set of instruments we employed in this chapter is the correct one, we employ instruments t-2 to t-3 instead of t-3 to t-4 to estimate GMM dynamic models. The results are quantitatively very similar to those reported in Table 3.6, however the Hansen and AR1 and AR2 test are not so reliable suggesting instrument t-2 to be a weak one.

The robustness tests we have conducted above provide further support for our earlier findings. Specifically, the R&D ICFS is negative over time and cash holding affect positively R&D investment. Overall, our conclusions about the

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[36] The firm cash flow sum variable is calculated in the same way as in Brown et al. (2009).

changes in cash-flow sensitivities across time periods are robust to whether we include or exclude negative cash-flow observations.

3.8 Conclusions

This chapter investigates the changes in the R&D investment – cash flow relationship of non-financial US and UK firms over the period 1990-2010. We examine the role of liquidity and external finance in R&D investment – cash flow regressions by estimating a dynamic investment model that includes measures of cash holdings and stock and debt issues. Also, we compare the corporate R&D investment behaviour among *a priori* financially constrained firms relative to a matched sample of financially unconstrained firms. Furthermore, we examine the relationship between finance and R&D over time covering financial crisis period. Finally, the impact of R&D investment variability on the R&D investment cash flow sensitivity is examined over time in this paper.

The descriptive statistics of this paper demonstrate that great deals of changes are noticeable for publicly traded manufacturing firms over the last 21 years. Cash flows have decreased critically, greatly because off the substantial increase in the amount of small and young firms with persistently negative cash flows, R&D investment has increased sharply, physical investment has declined and the uses of public equity issues as well as of cash stocks have increased. All these changes are reflected in the following models' estimations.

This paper shows that the ICFS for R&D investment is negative and that it increases in its negative magnitude, while the ICFS for physical investment is positive but it decreases in size over time. These trends do not change a great deal even after controlling for negative cash flow firms. We conclude that the increase in the negative relationship between R&D investment and cash flow is robust to various model specifications.

The simplest explanation of this phenomenon is that the more cash flow firms produce, the less they spend on their R&D activities, put differently more profitable firms invest less in R&D investment or R&D investment is attracted more by firms that show lower profitability. However, alternative explanation of this effect can be that firms continue investing in spite of experiencing a shortage of internal liquidity, which indicates that firms finance their R&D investment with other funds, and this explanation seems to be more aligned with the results of this paper.

The estimated results highlight that firms engaged in investing in R&D projects seem to plan its investment well in advance and make sure that they

have enough funds before they activate the project, especially in the case of financially constrained, thus e.g., firms with high R&D expenses variability show significantly negative cash flow coefficients as well as significantly positive cash stock coefficients and both coefficients are greater in size than those of counterparts firms. In general, financially constrained firms show more negative ICFS and at the same time more positive cash holdings coefficients. All the ICFS are negative and robust to various model specifications. GMM results show that the financially unconstrained adjust their R&D investment faster than financially constrained firms. As expected, the coefficient of the lagged R&D investment is positive and significant at the 1% level in all subsamples. The adjustment coefficient is relatively small (it is lower than 0.4 in all cases) and even smaller during financial crisis period, possibly providing evidence that the dynamics implied by our models are not rejected and firms adjust their R&D expenditures ratios relatively slowly in an attempt to have their target R&D investment ratios. One possible explanation for this adjustment speed could be that the costs deviating from the target debt ratio are not so significant and firms' R&D investment ratios are persistent over time. Overall the adjustment coefficient is rather close to 0, especially during financial crisis period suggesting that the costs of adjustment are much bigger than the costs of disequilibrium in firms' trade-off analysis between two different types of costs: costs of making adjustment to their target ratios and costs of being in disequilibrium (being off target).

Chapter 4

Determinants of R&D Investment over Total Investment Ratio, Evidence from US and UK Firms

4.1 Introduction

The theoretical and empirical corporate finance literature shows that the firm's financial position is important for its capital investment and research and development (R&D henceforth) investment decisions under imperfect financial markets (see Hubbard (1998) for a survey). The evidence provided in two previous chapters of this thesis also confirms that financial constraints and the firms' real activity are indeed interrelated. Overall, empirical studies of the firms' physical and R&D investment robustly indicates that changes in net worth and subsequently in the firms' investment decisions evolve from information problems in the financial markets. Among other things both agency problems and adverse selection are important in determining the extent to which firms are subject to capital market imperfections.

In the presence of market imperfections, such as asymmetric information, it is argued that there is no perfect substitution between internal and external funds. Firms that are affected by informational frictions and agency conflicts will have limited access to external finance and insufficient internal funds, and consequently will fail to undertake profitable investment opportunities in some states of the world. These types of firms are classed as financially constrained and their investment is subject to the availability of internal funds.

The hypothesis that the sensitivity of investment expenditures to the availability of internal funds is higher for financially constrained firms than for unconstrained firms has been explored broadly. To test this hypothesis, several firm characteristics such as e.g., size, dividend and age have been presented to identify financially constrained firms. Furthermore, to proxy for internal funds, the firms' cash flow has been employed in order to investigate whether the investment – cash flow sensitivity is an effective measure of financial constraints.[37]

This chapter studies how the R&D investment-total investment ratio (R&D/TINV) should react to variations in net worth for firms that deal with financial constraints. Bear in mind that total investment is a sum of R&D investment and capital investment. To the author's knowledge there is no other

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[37] There is conflicting evidence on whether investment-cash flow sensitivity has a positive relationship (FHP) or negative/non-linear relationship (KZ and other papers) with the financial constraints that a firm faces.

study investigating the impact of capital market imperfections on the R&D/TINV ratio. Our approach tests how sensitive the R&D/TINV ratio is to firm-specific characteristics, and how capital market imperfections can impact the firms' decisions on the R&D/TINV ratio. Therefore, the main objective of this study is to analyze how sensitive the R&D/TINV ratio is for financially constrained high-tech firms.

A great deal of research considers the implications of investment policies from the perspective that there are firms which are subject to market frictions and hence are constrained in accessing external capital. While we acknowledge the importance of similar firms' characteristics in determining investment, we explicitly examine the investment implications by considering firms both in crisis and non-crisis periods. This enables us to examine the firms' investment behavior to some extent independently of the effects of capital markets imperfections, though we do not rule out the role of market imperfections in determining the firms' investment decisions in the first place.

Our paper contributes to the literature on several grounds. First, we study the association between the R&D/TINV ratio and firm-specific indicators. Financial status is a vague term for describing firms' net worth and the literature has employed a number of balance sheet indicators to measure the financial healthiness of firms (see Benito (2005); Benito and Hernando (2007)). We examine the responsiveness of the R&D/TINV ratio to variations in firm-specific characteristics, such as cash flow, cash holding, leverage and equity issues.

Second, we analyze the behavior of constrained and unconstrained firms regarding their decisions on the R&D/TINV ratio. Provided that a firm's choice to invest in capital and R&D projects may reveal its financial position, financial characteristics become a key factor. Thus, it is particularly important to detect the sensitivity of the R&D/TINV ratio to firm-specific characteristics for constrained and unconstrained firms.

Third, this study explores the impact of financial characteristics on the R&D/TINV ratio. A number of recent studies (for example, Brown and Petersen (2009)) have employed external finances (debt and equity issues) to analyze the effects of a change in external finance policy on a firms' investment behavior. But not many studies have included cash holding, leverage and equity issues variables in the same model. Cash holdings and cash flow represent together the internal finances, while leverage and stock issues demonstrate the external

finances that firms use to finance their investment. Including them together in one model allows us to control for both types of finances at the same time and also shed some light on which type of finances play a stronger/weaker role in financing investment.

Finally, we use rich financial dataset to examine the cash flow sensitivity of the R&D/TINV ratio for a sample of US and UK[38] non-financial firms over the period 2000–2011. This data facilitates us with the comparisons of the US against UK firms, the pre-crisis against crisis period, as well as an over time analysis. To our knowledge, this is the first study to present evidence of a link between the R&D/TINV and firm-specific characteristics under the presence of capital market imperfections.

The empirical analysis of this paper provides a set of interesting results. Our major finding is that a firm's industry plays a distinguishing role for the sensitivity of R&D/TINV ratio, especially under the presence of capital market imperfections. It seems that the group of unconstrained non high-tech firms' R&D/TINV ratio exhibits the greatest sensitivity to cash flow changes independently from the time period we measure it. Our analysis also reveals that financially unconstrained firms, identified by using firm characteristics such as size, dividend payouts and age, generally exhibit greater investment–cash flow sensitivity than constrained firms, especially in the crisis period. Also, it seems that the reliance of both financially constrained and unconstrained firms on internal finance increases during the financial crisis. Finally, our results demonstrate that in the pre-crisis period financially constrained firms' R&D/TINV ratio seems to be negatively related to cash flow and positively related to cash flow in the crisis period.

The remainder of the paper is laid out as follows. Section 2 describes the motivation of the study. Section 3 illustrates a preliminary data analysis and presents our classification schemes. In section 4 we present our baseline

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[38] The R&D investment market is well developed especially in the US. The UK is particularly interesting because like the US it has a market-based financial system, but with lower R&D investment intensity. The characteristics of R&D investment such as e.g. higher risk, greater asymmetric information costs or lack of collateral value, suggest that R&D investment policy even in these 2 developed markets relies on the availability of internal funds. Thus discovering the relation between R&D/TINV and cash flow sensitivity in the US and UK is essential. To sum up, the advanced US and UK R&D investment markets provide us with an ideal environment to investigate the relation between R&D/TINV and its determinants.

specifications and our econometric methodology. In section 5 we discuss the estimation results, and Section 6 offers our conclusions.

4.2 Motivation

In this paper, our motivation originates from the simple theoretical argument. We assert that as long as firms invest simultaneously in two types of investment (capital and R&D) and there is some substitutability between them[39], the two decisions need to be studied together. We take into account the following example. Consider two firms: firm 1 and firm 2 that vary in their ability to raise external funds. Suppose that both firms encounter a permanent increase in the demand for their product. Firm 1, which is less likely to be financially constrained, operates at full capacity and increases both investments by utilizing both external finance and internal funds. Thus, we expect that the firm-level R&D/TINV ratio to remain constant. On the other hand, firm 2, which is more likely to be financially constrained, might not be able to raise enough external finances for the R&D investment and might satisfy partially the demand by increasing the capital investment. Constrained firms by definition cannot invest optimally in R&D activities, due to the high adjustment costs, lack of collateral value and high risk. However, their capital investment may also be far from the optimal level, because of lumpiness characteristic to their physical investment and the cost of capital. Overall, based on R&D investment features (e.g., the high cost of adjustment) and prior literature claiming that firms are likely to smooth their R&D investment with cash holdings (Brown and Petersen, 2011), we hypothesize that firms are more likely to increase their capital investment rather than R&D investment due to the effect of cash flow innovations, *ceteris paribus*. Therefore we predict a decline in the R&D/TINV ratio for the financially constrained firms. A research that is concern with the effects of financial factors on both capital and R&D investments' decisions would be able to make the above distinction. How constrained firms allocate their finances across R&D investment and total investment to reach a target R&D/TINV ratio when decisions on both investments will have to be taken simultaneously rather than independently.

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[39] Please see Table 4.3 presenting the Pearson correlation matrix for the variables used in our analysis. The correlation coefficient between R&D and physical investments is equal to -0.11 and statistically significant at the 1% level, confirming the substitutability between these investments.

4.3 Data analysis and classification schemes

This section demonstrates a graphical and descriptive analysis of the data. The data is portrayed in simple graphical form to show variation in the cross-sectional distributions of outcomes and how this has changed over time. This gives a foundation to our more advanced examination of how the R&D/TINV ratio, of various firm categories, acts in response to financial constraints.

4.3.1 Data description and graphical analysis

We obtain our datasets from the Worldscope database. We employ non-financial US and UK publicly listed firms. The panel datasets for this study have been created as follows. First, financial and utility firms were excluded from the samples. Second, similar to e.g., Brown and Petersen (2010) the aerospace industry is excluded from both samples. Third, from the raw data those firm-years for which the value of total assets is below $10 million are discarded. Fourth, the dataset was cleared from outliers by excluding the values of each variable that lie outside the 1st and the 99th percentile range. Fifth, all missing firm-year observations for any variable in the model during the sample periods were dropped. These criteria have provided us with a total of 4,076 US firms, which represent 22,828 firm-year observations and a total of 665 UK firms, which represent 3,382 firm-year observations for the years 2000-2011 respectively.

The core of this document is the firms' financial decisions on the R&D/TINV ratio. A discussion on the R&D investment and the total investment which are employed to form the R&D/TINV ratio is of particular interest here. Firms' simultaneous decisions on R&D and the total investments, and the substitutability of the two investments generate a motive to take into account their evolution across time. Hence, it is crucial to reveal that any changes in the R&D/TINV ratio are not driven by changes in either R&D investment (R&D) or total investment (TINV). Firstly, we illustrate the INV, R&D and TINV changes for US and UK over our sample period.

Figure 4.1 US Plots of the Yearly Averages of R&D, INV and TINV
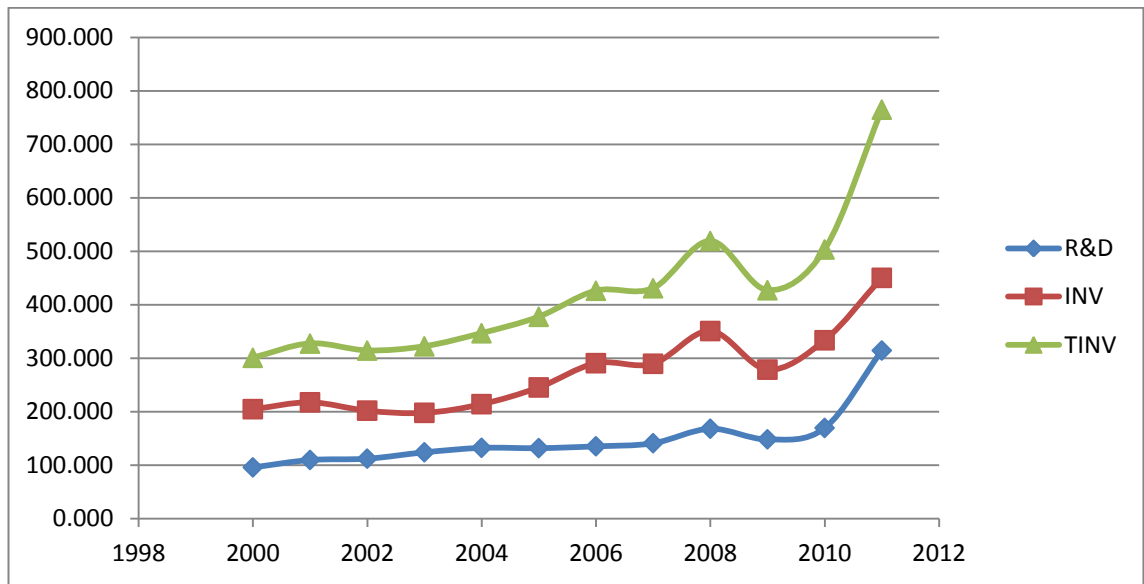
Figure 4.2 UK Plots of the Yearly Averages of R&D, INV and TINV
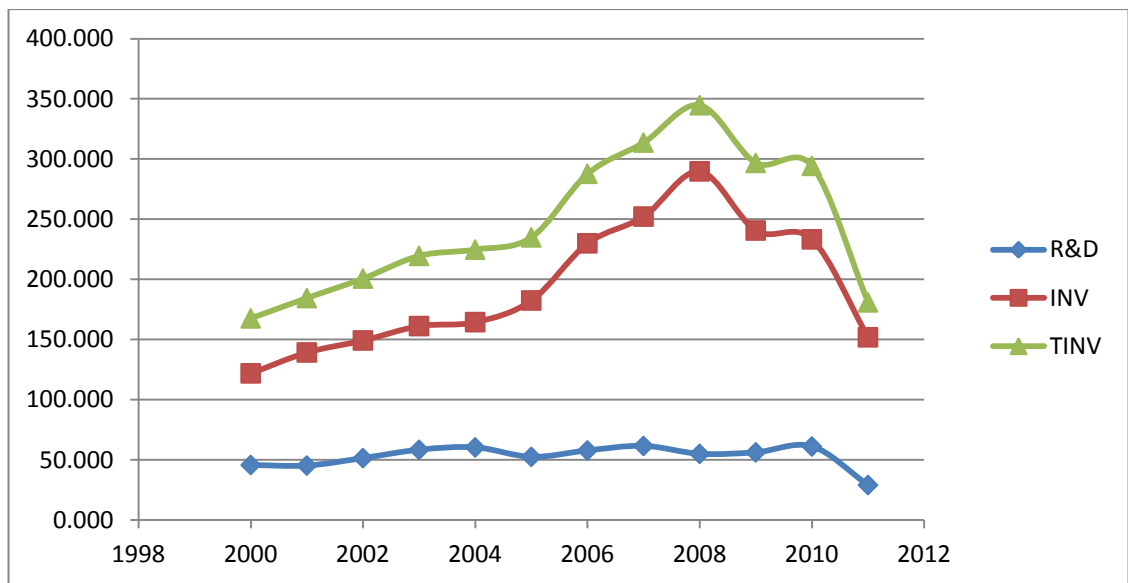
Comparing Figures 4.1 and 4.2 for US and UK firms respectively, we observe that both R&D and TINV follow the same pattern over time. They both display a growing trend, although INV is rising with more fluctuations than R&D investment. This implies that firms are more likely to alter physical investment than R&D investment, which is in line with previous findings in the literature (see Brown and Petersen, 2011). In other words, Figures 4.1 and 4.2 show that firms conduct their capital investment with a greater variability than R&D investment.

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To summarize, these figures depict that both R&D and TINV change over time providing as a result rationalization for their joint inspection.

The last year 2011 in the sample is incomplete in terms of number of firm year observation. Worldscope – the database we use in this chapter is still collecting the data for this year, hence the results might look so different for US and UK.

Figure 4.3 US Plots of the Yearly Averages of R&D/TA, INV/TA and R&D/TINV

Figure 4.4 UK Plots of the Yearly Averages of R&D/TA, INV/TA and R&D/TINV

Figures 4.3 and 4.4 illustrate INV/TA, R&D/TA and R&D/TINV changes for US and UK over our sample period. We observe that the ratio of R&D investment over total assets i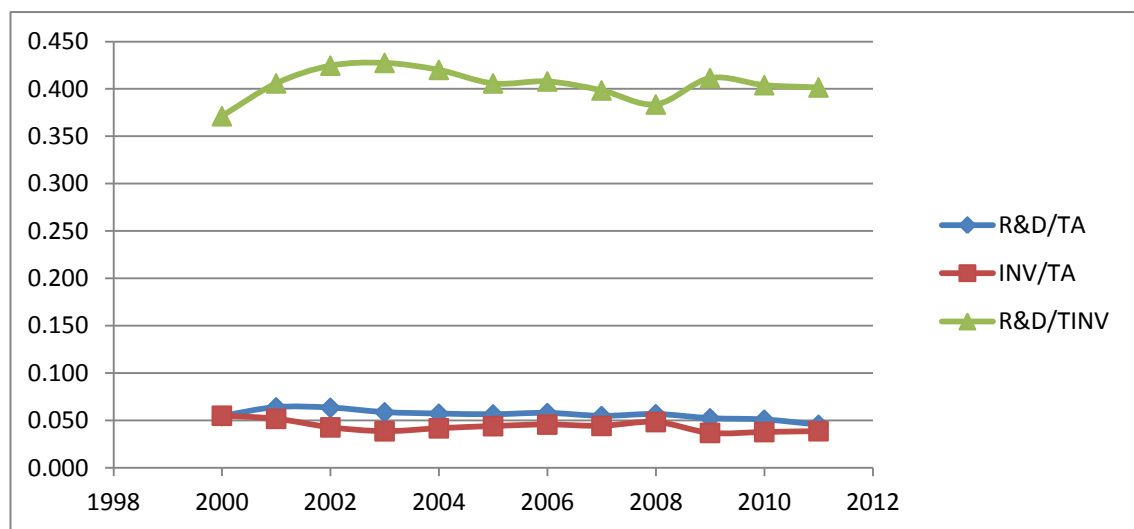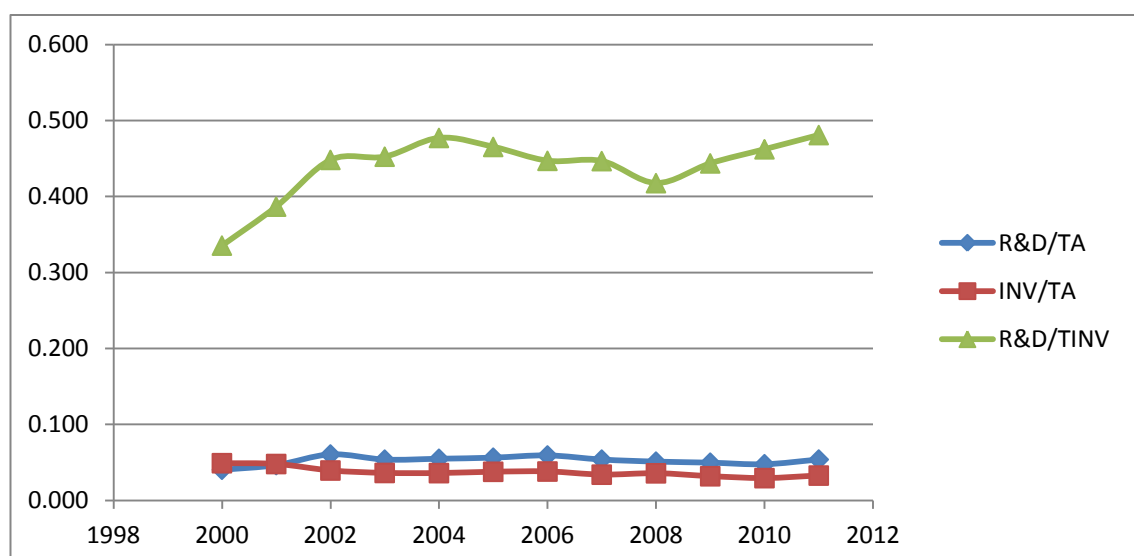s higher than the ratio of physical investment over total assets over time in both countries. The ratios of R&D investment over TINV in US and UK follows a similar pattern over time. They both display a growing trend with a dip in year 2008. However, the UK pattern of R&D/TINV changes is within an approximate 30 to 50% range while the US one is within an approximate 35 to 45% range. This together with Figures 4.1 and 4.2 implies that the UK firms conduct their physical investment with a higher variability than the US firms.

Table 4.1 Variables Definitions

Variable	Definition
TINV	The sum of R&D investment plus INV
R&D/TINV	The ratio of research and development expenses to total investment
R&D/TA	The ratio of research and development expenses to total assets
INV/TA	The ratio of capital expenditures to total assets
CF	The ratio of net income before extraordinary items and preferred dividends plus depreciation plus R&D expenses, deplation and amortization to total assets
Q	The ratio of book value of total assets minus the book value of equity plus the market value of equity to book value of total asset
CASH	The ratio of total cash and short term investment to total assets
LEV	The ratio of total debt to total assets
SIZE	The logarithm of total assets
DIV	The ratio of total cash dividend to total assets
AGE	Number of years firm is publicly listed since 1980
STOCK	The ratio of sale of common and preferred stock minus purchase of common and preferred stock to total assets

Notes: This table provides the definitions of the main variables used in our analysis.

Table 4.2 Descriptive Statistics

2000-2011	Mean	St. Dev.	min	p25	p50	p75	max	Obs.
Panel A (US)								
R&D/TINV	0.405	0.357	0	0	0.386	0.757	0.999	22828
R&D/TA	0.056	0.084	0	0	0.022	0.079	0.584	22828
INV/TA	0.044	0.044	0.000	0.016	0.030	0.056	0.307	22828
CF	0.076	0.172	-1.023	0.037	0.101	0.165	0.481	22828
Q	1.982	1.352	0.479	1.128	1.550	2.340	9.881	22828
CASH	0.222	0.221	0.001	0.047	0.143	0.337	0.919	22828
LEV	0.195	0.198	0	0.010	0.154	0.309	1.063	22828
STOCK	0.035	0.138	-0.227	-0.003	0.001	0.015	0.919	22828
SIZE	5.992	2.207	2.303	4.257	5.784	7.527	13.590	22828
DIV	0.011	0.050	0	0	0	0.010	3.730	22828
AGE	15.158	8.566	1	8	13	20	32	22828
DEBT	0.002	0.099	-1.960	-0.018	-1E-05	0.004	2.202	22828
STD/TA	0.047	0.092	0	0	1E-02	0.052	1.047	22828
Panel B (UK)								
R&D/TINV	0.437	0.326	0	0.123	0.418	0.741	0.998	3382
R&D/TA	0.052	0.079	0	0.004	0.022	0.064	0.553	3382
INV/TA	0.038	0.032	0.000	0.014	0.029	0.051	0.189	3382
CF	0.083	0.158	-0.723	0.038	0.102	0.164	0.541	3382
Q	1.799	1.215	0.512	1.050	1.441	2.092	10.850	3382
CASH	0.179	0.195	0	0.047	0.108	0.244	0.922	3382
LEV	0.156	0.147	0	0.015	0.131	0.252	0.678	3382
STOCK	0.060	0.163	-0.129	0	0.001	0.011	1.008	3382
SIZE	5.213	2.117	2.303	3.509	4.797	6.495	12.524	3382
DIV	0.021	0.048	0	0	0.013	0.030	1.629	3382
AGE	16.274	9.010	1	8	15	24	32	3382
DEBT	-0.002	0.083	-0.965	-0.019	0.000	0.007	0.579	3382
STD/TA	0.055	0.079	0	0.002	0.025	0.075	0.678	3382

Notes: This table shows US and UK firms' sample characteristics over the period 2000-2011. Analytical definitions for all the variables are provided in table 4.1.

Table 4.1 provides the variables' definitions, while table 4.2 reports the summary statistics. Descriptive statistics in table 4.2 present that the average US R&D and physical investment rates are both higher than the UK ones. The average rates of growth opportunities, cash holdings, leverage and size of the US firms are all greater than the for the UK firms. The average rates of cash flows are greater in UK firms. UK firms also pay on average higher dividends than US firms and also average UK firm issues more stock than an average US firm. The average UK firm's age is older than the average US firm by 1 year.

Table 4.3 The Pearson Correlation Matrix

	INV/TA	R&D/TA	R&D/TINV	CF	Q	CASH	LEV	STOCK
INV/TA	1							
R&D/TA	-0.114*	1						
R&D/TINV	-0.368*	0.714*	1					
CF	0.092*	-0.031*	0.034*	1				
Q	0.052*	0.259*	0.218*	0.149*	1			
CASH	-0.162*	0.499*	0.492*	-0.007	0.351*	1		
LEV	0.062*	-0.226*	-0.297*	-0.173*	-0.190*	-0.416*	1	
STOCK	0.012	0.258*	0.166*	-0.266*	0.260*	0.309*	-0.108*	1

Notes: The statistics reported are the Pearson correlation coefficients between all variables used in the analysis. Analytical definitions for all the variables are provided in table 4.1. * indicate correlation coefficient is significant at the 1% levels.

4.3.2 Sample separation criteria

To show how firms react to capital market imperfections, we firstly divide them in accordance with whether they are more or less likely to encounter financial constraints. Following the majority of the relevant literature we pick up three very popular measures of financial constraints, these are: size measured with natural logarithm of total assets, dividend payout ratio measured as dividend payout over total assets and age measure as the number of years a firm is tracked by Worldscope since year 1980. We split each sample in two ways. Firstly we calculate the average of each firm's size, dividend and age over years. On the basis of the median of this average of firms' size, dividend and age measures over time we classify firms as financial constrained and unconstrained. Secondly we compare firms above with those below the median of their size, dividend and age measures. Firms are not allowed to switch across firm categories over time.

The literature contains a long list of scholars who used the size variable as a proxy for capital market access for firms (see e.g., (Gertler and Gilchrist (1994), Himmelberg and Petersen (1994) and Gilchrist and Himmelberg (1995)). Rahaman (2011) argues that firm size is predominantly identified by the extant industrial economics literature as one of the sources of heterogeneity in a firm's growth. The most important issue here is that smaller companies are more likely to be financially constrained as they are subject to higher asymmetric information and agency problems, and hence, have difficulties in obtaining external finance. One of the characteristic and cause identified for the smaller companies is that they struggle to raise outside finance and are enforced to depend on internal finance only therefore their growth is constrained. During financial crisis periods when financial systems do not work correctly this characteristic will be further sharpened.

In terms of the second measure of financial constraints, we follow FHP (1988) theory that dividend paying, as against to non-dividend paying companies, are less likely to be financially constrained since they are able to shorten or stop dividends whenever their ability to access external financing becomes conflicting or impossible. Yet, this variable should be considered with caution due to the fact

that cutting dividends for the sake of liquidity can also have opposite signaling impacts for the firm's stock in the market (e.g. Healy and Palepu, 1988).

In the last scheme firms are grouped according to their age in order to measure the importance of a track record. An old established firm is more likely to have better access in the capital market compared to a young and growing firm. Hence, it is more likely that young firm faces problems of asymmetric information. This classification criterion has been employed by Brown and Petersen (2009) amongst others.

4.4 Methodology

This section depicts the empirical approach and introduces the baseline models. To detect the sensitivity of the R&D/TINV ratio to cash flows (while controlling for growth opportunities) over time (year by year) the following static linear model is estimated.

$$R\&D/TINV_{i,t} = \alpha_{0} + \alpha_{1}CF_{i,t} + \alpha_{2}Q_{i,t} + \varepsilon_{i,t,} \qquad (1)$$

Equation 1 is estimated with OLS technique and industry dummies are also included in the analysis. To investigate the sensitivity of the R&D/TINV ratio to more firm-specific characteristics we estimate the following static linear model.

$$R\&D/TINV_{i,t} = \alpha_{0} + \alpha_{1}CF_{i,t} + \alpha_{2}Q_{i,t} + \alpha_{3}CASH_{i,t-1} + \alpha_{4}LEV_{i,t-1}$$
$$\alpha_{5}STOCK_{i,t-1} + \varepsilon_{i,t} \qquad (2)$$

where we also include industry- and year-dummies. Equation 2 is estimated with OLS technique in which independent variables, such as cash, leverage and stock issues are lagged one year to break their correlation link with cash flow. These variables are the potential substitutors for cash flow outflows. Firms can decide to allocate their positive cash flow shocks into either higher cash reserves, the reduction of their debt level, or to the purchase their stock (Dasgupta et. al., 2011).

In this paper we incorporate in our models the set of financial variables that is consistent with the existing empirical literature. Specifically, we control for pre-existing stocks of cash holdings because a firm can use these alternative components of internal wealth to accommodate shocks to cash flows or to finance their investment. Hubbard (1998) states that "it is important to consider investment and financial policy jointly; firms may, for example, accumulate liquidity as a buffer against future constraints." Cash holdings are employed in the analysis because usually together with investment they account for a substantial portion of cash flow use. Consequently in a firm's financial policy investment, cash and debt may compete against each other. Firms classified as financially constrained tend to hold more cash and this is consistent with the hypothesis that

financially constrained firms significantly benefit from cash savings. Moreover, Brown and Petersen (2011) find that firms most likely to face financing frictions rely extensively on cash holdings to smooth R&D. Thus controlling for cash holdings is important in the investigation of R&D/TINV ratio over time. We should expect cash holdings to be a significant indicator for constrained firms' R&D/TINV ratio.

We also employ leverage as a measure of firms' "tightness" of the firm's balance sheet (Sharpe (1994), Guariglia (1999), Vermeulen (2002)). Lang et al., (1996) assert that leverage may impact investment in a number of ways. The amount of cash that can be employed for investment may be reduced thanks to leverage. Excess leverage may also impair a firm's ability to raise additional capital. Myers (1977) claims that the managers of firms with a great leverage level may forgo positive NPV projects because some or all of the benefits from the investment may be transferred to debt-holders, ie the underinvestment effect. According to Jensen (1986) and Stulz (1990) high leverage in low-growth firms discourages management from undertaking unprofitable investments. A negative relationship between leverage and investment is predicted by these theories.

Hovakimian, Opler, and Titman (2001) find that firms with relatively high leverage ratios are reluctant to issue debt since excessive leverage increases the probability of financial distress. Nevertheless, for a certain category of firms, high leverage may also be understood as high capacity of debt and lower financial constraints Hovakimian (2009).

Similar to research of Brown and Petersen (2009), a firm's net new funds from stock issues enter as an additional determinant of the R&D/TINV ratio. A far-reaching body of the literature reveals the importance of stock issues for investment. Brown et al., (2007) study the effect of cash flow and external equity on aggregate R&D investment and they provide support for the view that supply shifts in equity finance are important factors driving economic growth. R&D investment is considered in the literature as it is likely to be an "equity-dependent" investment. Firm mainly oriented in investing in R&D are well known to employ little debt. Among other numerous explanations, Cornell and Shapiro (1988) explain this by the poor collateral value of R&D and the aspect that using debt finance may evolve troubles of financial distress that can be especially dangerous for R&D-intensive firms. In effect, for small firms, especially those with low or negative cash flow, investing in R&D can leave them relying strongly on

access to financial sources raised from public equity. There are at least two reasons to directly incorporate stock issues when testing for financing constraints on R&D/TINV ratio. Firstly, firms rely heavily on stock issues in the years immediately following their IPO (e.g., Rajan and Zingales (1998)), which is also a time period of low (or negative) cash flows and high R&D intensity. This negative correlation between stock issues and cash flow should lead to a downward bias in the estimated R&D-cash flow sensitivity in regressions that omit stock issues. Second, including stock issues in the R&D regression permits tests of whether variation in access to external finance matters for the R&D/TINV ratio, as it should in a world of imperfect access to external finance (Brown et al., 2011).

Finally we include cash flow in our models. Previous studies demonstrate that the activities of more constrained firms depend on the internal finances such as cash flow (Fazzari et al., (1988); Benito and Hernando (2007)). Recent evidence indicates that only financially constrained firms should exhibit a propensity to save cash (Almeida et al., (2004)). In this paper, we might expect cash flow to be less significant for financially unconstrained firms' R&D/TINV ratio, and in contrast, constrained firms should be willing to retain cash flow thus, implying its significance on a firm' decisions with respect to the R&D/TINV ratio.

4.5 Results

Table 4.4 Year by Year Estimations (OLS)

DV: R&D/TINV

Year	CF		Q		Obs.	Adj. R2
Panel A (US)						
2000	-0.0873**	(-2.53)	0.0121***	(3.30)	2010	0.535
2001	-0.172***	(-5.17)	0.0238***	(5.39)	2020	0.500
2002	-0.143***	(-4.41)	0.0270***	(4.81)	1969	0.542
2003	-0.0711	(-1.53)	0.0287***	(6.09)	1855	0.542
2004	-0.0559	(-1.28)	0.0343***	(7.39)	1923	0.524
2005	-0.0581	(-1.44)	0.0266***	(5.54)	1968	0.498
2006	-0.0762*	(-1.70)	0.0325***	(6.69)	1988	0.479
2007	-0.0171	(-0.40)	0.0233***	(4.50)	2176	0.467
2008	0.00129	(0.03)	0.0374***	(4.81)	1910	0.491
2009	0.0389	(0.91)	0.0344***	(4.99)	1938	0.483
2010	0.115**	(2.51)	0.0378***	(7.06)	2050	0.476
2011	0.267***	(2.64)	0.0233**	(2.28)	1021	0.484
p-value	0.0008		0.2957			
Panel B (UK)						
2000	0.0791	(0.57)	0.0449***	(4.38)	272	0.363
2001	0.0259	(0.24)	0.0442***	(4.38)	298	0.391
2002	-0.0414	(-0.45)	0.0486**	(2.56)	279	0.365
2003	0.0635	(0.58)	0.0580***	(2.82)	268	0.363
2004	0.143	(1.12)	0.0338***	(2.87)	270	0.366
2005	-0.149	(-1.19)	0.0217	(1.24)	291	0.267
2006	0.0836	(0.75)	0.0351**	(2.38)	331	0.283
2007	-0.0515	(-0.49)	0.0480**	(2.54)	323	0.295
2008	0.103	(0.88)	0.103***	(6.83)	318	0.304
2009	0.178	(1.45)	0.101***	(6.27)	296	0.391
2010	0.0897	(0.67)	0.0560***	(2.84)	300	0.290
2011	0.121	(0.69)	0.0500***	(3.46)	136	0.375
p-value	0.8441		0.7615			

Notes: This table displays results from the year by year R&D investment rate regressions in equation 1. Analytical definitions for all the variables are provided in table 4.1. All regressions include industry dummies. P-values are for the null hypothesis that the coefficients are the same between the first (2000) and the last (2011) years. T-statistic values are reported in parentheses. ***, ** and * indicate coefficient is significant at the 1%, 5% and 10% respectively. For the estimation we use consistent to heteroskedasticity standard errors.

Given the significant wedge expected between the cost of internal and external finance in the financial crisis period, R&DTINV ratios of firms are predicted to display a greater sensitivity to cash flow in the crisis period

regardless of the classification variable. Bernanke and Gertler (1989) claim adverse macroeconomic shocks not only interfere with the central function of financial markets but also exacerbate adverse selection and moral hazard problems. As a result, during a financial crisis the hedging role of cash should be more popular because of the ability of firms to raise external finance is much smaller, due to an increasing wedge between the cost of internal and external funds. Therefore, during financial crisis periods, financially constrained firms should save a higher proportion of their cash flows, whilst unconstrained firm's cash flow policies should not show any systematic changes. Financial crisis works as exogenous shock affecting both the size of current cash flows as well as the relative attractiveness of current investment against the future one. A firms' viability, profitability and cash flow as well as prevalently reduced the expected return on investment opportunities are clearly affected by exogenous shocks coming from economic and financial crises. Hall and Lerner (2010) and Islam and Mozumdar (2007) argue that in the presence of market imperfections, external funds may not provide a perfect substitute for internal funds, given that the premium for external financing will be higher. Financial crisis should increase the marginal cost of external finance, leading to a rise in the ICFS. In the presence of financial crisis cash flows, cash holdings and stock issues are more likely to affect R&DTINV in a more pronounced manner than before.

Table 4.4 presents the results of our baseline regression, where R&DTINV is regressed on cash flow and growth opportunities in each year. Our main concern here is the relationship between investment and cash flow. For US firms we find negative R&DTINV-cash flow sensitivity up to year 2007 (the pre-crisis period) and positive since year 2008 onwards (the crisis period). This is consistent with the conjecture that cash flows are more binding on investment at times when capital market imperfections are likely to be more severe, which is expected to be the case during a financial crisis period (Arslan et al., 2006). For UK firms the R&DTINV-cash flow sensitivity is statistically insignificant in all years. The sign change from negative to positive also appears in year 2007 but with lower consistency.

Table 4.5 reports the results of our augmented regression in equation 2. Firstly, we consider the full sample. Secondly, we split firms into high-tech and non high-tech industries. Lastly, we split firms into financially constrained and unconstrained categories with respect to their size, dividend payments and age.

The results are reported for two periods, 2000-2007 (pre-crisis) and 2008–2011 (crisis period). Given the significant wedge expected between the cost of internal and external finance in the financial crisis period, R&DTINV ratios of firms are predicted to display a greater sensitivity to cash flow in the crisis period regardless of the classification variable. To estimate our model we use an ordinary least squares approach with robust standard errors to allow for heteroscedasticity across firms. The residuals (errors) are identically and independently distributed. Also, we control for industry-specific effects and time-specific effects by including industry and time dummies in our empirical specification (industry and time specific intercepts are not reported for brevity).

Starting with the case of all firms (specification 1), we find that the hypothesized negative and statistically significant impact of cash flow on corporate R&DTINV is observed only in panel A (US firms) during the pre-crisis period. The corresponding coefficient for the UK firms is positive but insignificant. During the crisis period the corresponding coefficient for both US and UK firms is positive and significant. This is consistent with the conjecture that cash flows are more binding on investment at times when the capital market imperfections are likely to be more severe and this is to be expected during a financial crisis period.

Moving to the role that the industry of the firm play on the relationship between cash flow and R&DTINV, our results suggest that the hypothesized negative and significant R&DTINV–cash flow sensitivities are supported only in the pre-crisis period by the US non high-tech firms. The corresponding coefficient for the UK firms is positive but insignificant. During the crisis period the corresponding coefficient for both US and UK firms is positive and significant only for the US firms. It is also worth noting that the corresponding coefficient is greater for non high-tech than high-tech firms in every subsample. This suggests that for non high-tech firms cash flow finances are of a greater importance than for high-tech firms.

Next, we consider the role that financial constraints play on the relationship between cash flow and R&DTINV. Our results indicate that the hypothesized negative and significant R&DTINV–cash flow sensitivities of financially constrained firms are supported only in the pre-crisis period by the US subsample. When we split the US firms on the basis of their size, dividend payouts and age, the constrained firms display negative and statistically significant sensitivities, while the unconstrained firms show positive and

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significant sensitivities for the pre-crisis period. Whilst contract to this a significant positive cash flow effect is observed under all classification for the crisis period with greater coefficients for the US unconstrained firms. The UK firms are inconsistent with expectations and show positive cash flow effects in almost all subsamples and the cash flow coefficients are greater in size for unconstrained than constrained firms and during the crisis period.

Finally, we provide evidence of a positive and significant impact of growth opportunities on the corporate R&DTINV ratio of US and UK firms in most of subsamples, in general this impact is greater in size for constrained firms. We also observe positive and significant cash holdings coefficients and in general these are greater in size for constrained firms. In contrast, the leverage coefficients are negative and significant in most of subsamples. The stock issues coefficients throughout are positive or negative but most of the time insignificant. They are only significant for US firms during the pre-crisis period.

Briefly, our first set of results show that R&DTINV ratios of financially unconstrained firms are more sensitive to the availability of internal funds and the sensitivity is stronger during the financial crisis period. The result regarding the main interest of this paper, though, refers to the impact of high-tech industry on R&D/TINV-cash flow sensitivity of firms. After classifying firms into high-tech and non high-tech categories, we find evidence that R&D/TINV ratio of non high-tech firms is more sensitive to internal funds. This is consistent with the argument that high-tech firms usually have greater financial flexibility to exploit investment opportunities when they arise. Our empirical findings significantly support this argument, especially during the crisis period when the fluctuations in cash flow are likely to be large and the cost of external finance is significantly high.

Table 4.5 The Cash Flow Sensitivity of Investment During the Pre-Crisis and the Crisis Periods across Different Subgroups of Firms: Augmented Regression Mode

DV: R&D/TINV	CF		Q		CASH		LEV		STOCK		Constant		Adj.R2	Obs.
Panel A (US): Pre-crisis period (2000-2007)														
1. ALL FIRMS	-0.038**	(-2.06)	0.011***	(5.32)	0.367***	(25.12)	-0.100***	(-7.44)	0.014	(0.72)	0.323***	(38.17)	0.570	11533
2. INDUSTRY														
HIGH-TECH	-0.014	(-0.65)	0.006**	(2.26)	0.338***	(21.25)	-0.141***	(-6.71)	-0.018	(-0.87)	0.520***	(43.64)	0.250	6346
NON HIGH-TECH	-0.090**	(-2.52)	0.021***	(5.35)	0.416***	(13.27)	-0.051***	(-2.94)	0.123***	(3.05)	0.077***	(6.48)	0.261	5187
3.SIZE														
CONSTRAINED	-0.036*	(-1.66)	0.020***	(7.13)	0.341***	(17.91)	-0.081***	(-3.50)	-0.001	(-0.05)	0.358***	(26.97)	0.512	5438
UNCONSTRAINED	0.115***	(3.42)	-0.003	(-0.93)	0.389***	(16.84)	-0.081***	(-5.19)	-0.107***	(-2.98)	0.281***	(27.46)	0.619	6095
4.DIVIDEND														
CONSTRAINED	-0.052**	(-2.55)	0.013***	(4.88)	0.396***	(23.32)	-0.106***	(-5.67)	-0.041*	(-1.88)	0.396***	(33.24)	0.557	6030
UNCONSTRAINED	0.102***	(2.69)	0.010***	(2.62)	0.190***	(6.45)	-0.105***	(-5.52)	0.045	(1.06)	0.248***	(21.18)	0.502	5503
5. AGE														
CONSTRAINED	-0.085***	(-3.53)	0.017***	(5.31)	0.440***	(20.14)	-0.130***	(-5.93)	-0.053**	(-2.20)	0.289***	(20.77)	0.531	4997
UNCONSTRAINED	0.089***	(2.81)	0.004	(1.24)	0.302***	(15.00)	-0.025	(-1.41)	0.122***	(3.10)	0.325***	(30.44)	0.618	5924
Panel A (US): Crisis period (2008-2011)														
1. ALL FIRMS	0.120***	(3.31)	0.017***	(3.74)	0.377***	(14.11)	-0.098***	(-4.09)	0.046	(0.85)	0.294***	(22.25)	0.542	4035
2. INDUSTRY														
HIGH-TECH	0.118***	(2.59)	0.010*	(1.83)	0.358***	(11.61)	-0.143***	(-3.53)	-0.025	(-0.37)	0.500***	(26.90)	0.220	2123
NON HIGH-TECH	0.122**	(2.09)	0.026***	(3.38)	0.397***	(7.73)	-0.061**	(-2.10)	0.169*	(1.95)	0.066***	(3.49)	0.269	1912
3.SIZE														
CONSTRAINED	0.080*	(1.80)	0.014**	(2.42)	0.369***	(10.47)	-0.086**	(-1.98)	0.070	(1.10)	0.342***	(16.67)	0.477	1874
UNCONSTRAINED	0.290***	(4.69)	0.014*	(1.90)	0.369***	(9.10)	-0.071***	(-2.65)	-0.133	(-1.19)	0.240***	(14.24)	0.610	2161

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4.DIVIDEND														
CONSTRAINED	0.113***	(2.71)	0.022***	(4.17)	0.388***	(12.22)	-0.118***	(-3.60)	0.046	(0.75)	0.345***	(18.44)	0.524	2184
UNCONSTRAINED	0.256***	(3.36)	0.004	(0.47)	0.261***	(4.96)	-0.074**	(-2.20)	-0.131	(-1.08)	0.248***	(13.32)	0.518	1851
5. AGE														
CONSTRAINED	0.097*	(1.94)	0.021***	(3.50)	0.422***	(10.61)	-0.139***	(-3.67)	0.036	(0.56)	0.250***	(12.13)	0.512	1732
UNCONSTRAINED	0.168***	(3.15)	0.014**	(2.05)	0.309***	(8.23)	-0.048	(-1.60)	0.084	(0.72)	0.318***	(18.18)	0.589	2066

Panel B (UK): Pre-crisis period (2000-2007)

1. ALL FIRMS	0.049	(1.03)	0.024***	(3.40)	0.420***	(10.55)	-0.234***	(-4.40)	0.004	(0.07)	0.336***	(14.13)	0.461	1648
2. INDUSTRY														
HIGH-TECH	0.015	(0.28)	0.021***	(2.73)	0.383***	(8.75)	-0.127*	(-1.85)	-0.011	(-0.21)	0.447***	(14.95)	0.285	935
NON HIGH-TECH	0.163	(1.64)	0.035**	(2.33)	0.469***	(5.91)	-0.368***	(-4.49)	0.045	(0.41)	0.183***	(4.51)	0.402	713
3.SIZE														
CONSTRAINED	0.042	(0.68)	0.019**	(2.12)	0.433***	(7.83)	-0.235**	(-2.31)	-0.007	(-0.13)	0.419***	(11.21)	0.288	750
UNCONSTRAINED	0.070	(0.91)	0.028**	(2.58)	0.400***	(6.20)	-0.166***	(-2.65)	0.002	(0.03)	0.249***	(8.08)	0.529	898
4.DIVIDEND														
CONSTRAINED	0.112**	(2.02)	0.035***	(3.72)	0.358***	(7.60)	-0.224**	(-2.52)	-0.131**	(-2.45)	0.431***	(12.28)	0.421	747
UNCONSTRAINED	0.432***	(3.51)	0.017	(1.57)	0.357***	(4.49)	-0.102	(-1.54)	0.149	(1.45)	0.192***	(5.94)	0.431	901
5. AGE														
CONSTRAINED	0.148**	(2.45)	0.015	(1.64)	0.393***	(7.27)	-0.375***	(-3.57)	-0.052	(-0.92)	0.459***	(12.24)	0.361	693
UNCONSTRAINED	-0.098	(-1.17)	0.033***	(3.40)	0.361***	(5.35)	-0.162***	(-2.70)	0.111	(1.30)	0.263***	(7.93)	0.488	906

Panel B (UK): Crisis period (2008-2011)

1. ALL FIRMS	0.231**	(2.24)	0.030***	(2.76)	0.465***	(6.75)	-0.255***	(-2.99)	0.081	(0.85)	0.334***	(9.07)	0.457	631
2. INDUSTRY														
HIGH-TECH	0.125	(1.13)	0.029**	(2.29)	0.448***	(5.75)	-0.025	(-0.21)	0.046	(0.41)	0.381***	(8.03)	0.343	346
NON HIGH-TECH	0.322	(1.54)	0.034*	(1.72)	0.509***	(3.63)	-0.444***	(-3.88)	0.063	(0.38)	0.279***	(5.18)	0.399	285

3.SIZE														
CONSTRAINED	0.267**	(2.23)	0.039***	(2.98)	0.437***	(4.43)	0.041	(0.27)	0.083	(0.74)	0.307***	(6.45)	0.384	289
UNCONSTRAINED	0.325	(1.19)	0.007	(0.28)	0.442***	(4.10)	-0.332***	(-2.89)	-0.250	(-1.15)	0.370***	(6.13)	0.521	342
4.DIVIDEND														
CONSTRAINED	0.145	(1.13)	0.030*	(1.90)	0.595***	(6.41)	-0.367***	(-2.75)	-0.030	(-0.28)	0.396***	(7.06)	0.455	286
UNCONSTRAINED	0.886***	(4.86)	0.009	(0.50)	0.201*	(1.84)	-0.069	(-0.62)	-0.195	(-0.78)	0.246***	(4.93)	0.516	345
5. AGE														
CONSTRAINED	0.162	(1.46)	0.037***	(2.95)	0.434***	(4.83)	-0.503***	(-3.80)	-0.033	(-0.31)	0.387***	(7.06)	0.455	284
UNCONSTRAINED	0.681**	(2.55)	-0.037	(-1.40)	0.300*	(1.92)	-0.076	(-0.65)	0.146	(0.33)	0.358***	(7.18)	0.457	316

Notes: This table presents the OLS estimation results of the R&D investment model in equation 2. The US and UK samples are divided into two partitions: pre-crisis period (2000-2007) and post crisis period (2008-2011). The estimations use pre-determined firms selection into two categories. Constraint category assignments employ ex ante criteria based on firm size, dividend payout and age. Analytical definitions for all the variables are provided in table 4.1. All regressions include industry and time dummies. T-statistic values are reported in parentheses. ***, ** and * indicate coefficient is significant at the 1%, 5% and 10% respectively. For the estimation we use consistent to heteroskedasticity standard errors.

So far we have mainly investigated the role of a firms' industry in determining the R&D/TINV ratio of firms. However, a firms' industry may also have a significant effect on the relationship between financial constraints and R&D/TINV ratio–cash flow sensitivity. High-tech firms are mainly focused on R&D investment and given that constrained firms will smooth R&D investment with cash holdings (Brown and Petersen, 2011), the sensitivity of R&D/TINV ratio of financially constrained firms to cash flow should be reduced for high-tech firms. That is, the benefit from increased cash flows will be higher for financially constrained non high-tech firms than for financially constrained high-tech firms. For example, high-tech unconstrained firms that pay dividends to their shareholders are more likely to benefit from large cash flow increases for R&D investment rate purposes. On the contrary, high-tech financially constrained firms with restricted access to external finance are more likely to rely primarily on accumulated cash reserves to finance the R&D investment rate. Consequently, we hypothesise that the sensitivity of the R&D/TINV ratio of financially constrained firms to changes in their cash flows should be more significant for non high-tech firms. As for high-tech firms, the impact of financial constraints on R&D/TINV ratio, should be either significantly reduced or become insignificant.

In Table 4.6 we empirically test such a hypothesis by investigating the R&D/TINV ratio of firms in the pre-crisis and financial crisis periods. Initially, we split the sample into financially constrained and unconstrained groups and each of these group is further divided into high-tech and non high-tech categories of firms. The empirical results support our expectations. Starting with the results of high-tech firms, the coefficient of cash flow for all US high-tech firms in the pre-crisis period is negative but insignificant. In the crisis period the corresponding coefficients are positive and significant. However for the UK sample the coefficient of cash flow for all high- tech firms is positive and insignificant in both periods and greater in size during the crisis period. Furthermore, the same results are observed when we split firms into constrained and unconstrained groups using size, dividend payouts and age.

In line with our *a priori* prediction, we find that the effect of cash flow on R&D/TINV is negative and significant for all US constrained, and positive and significant for all unconstrained non high-tech firms in the pre-crisis period. In the crisis period the corresponding coefficients are positive and insignificant for all

US constrained non high-tech firms and positive and significant for all US unconstrained non high tech firms.

For UK firms in the pre-crisis period the effect of cash flow on R&D/TINV is positive (apart from constrained non high-tech firms in the pre-crisis period) and significant only for all unconstrained non high-tech firms and constrained non high-tech firms only under the age criteria. For UK firms in the crisis period the corresponding coefficients are positive for all groups and significant only for constrained non high-tech firms only under the size and age criteria.

Where non high-tech firms are unconstrained, and are known for not having difficulties in accessing external finance, they seem to be relying highly on their internally generated funds to finance R&D investment rate. Finally, in line with our earlier findings, the results point to a positive and significant relationship between growth opportunities, cash holdings and R&D/TINV ratio and negative and significant relation between leverage and R&D/TINV ratio. The stock issue coefficients are insignificant (apart from one specification).

Overall, the evidence reported in this table supports the view that it does matter which the industry a firm belongs to. High-tech firms seem to act differently from non high-tech firms both during an economic expansion and during an economic recession. Moreover, it seems that the positive cash flow shocks are most valuable for the R&D investment rate of financially unconstrained non high-tech firms.

Table 4.6 The Cash Flow Sensitivity of Investment During the Pre-Crisis and the Crisis Periods across High-Tech and Non High-Tech Subgroups of Firms: Augmented Regression Mode

DV: R&D/TINV	CF		Q		CASH		LEV		STOCK		Constant		Adj.R2	Obs.
Panel A (US): Pre-crisis period (2000-2007)														
1.SIZE														
CONSTRAINED														
HIGH-TECH	-0.020	(-0.94)	0.006**	(2.38)	0.339***	(21.19)	-0.135***	(-6.20)	-0.019	(-0.88)	0.532***	(43.05)	0.204	5959
NON HIGH-TECH	-0.146***	(-3.30)	0.029***	(5.50)	0.451***	(10.61)	-0.076**	(-2.42)	0.061	(1.22)	0.075***	(3.69)	0.282	2087
UNCONSTRAINED														
HIGH-TECH	-0.013	(-0.64)	0.004	(1.49)	0.344***	(21.59)	-0.129***	(-6.10)	-0.022	(-1.03)	0.526***	(43.80)	0.237	6224
NON HIGH-TECH	0.209***	(3.74)	0.002	(0.28)	0.305***	(6.53)	-0.022	(-1.06)	0.028	(0.46)	0.077***	(5.66)	0.265	3100
2.DIVIDEND														
CONSTRAINED														
HIGH-TECH	-0.018	(-0.86)	0.006**	(2.29)	0.343***	(21.45)	-0.133***	(-6.18)	-0.018	(-0.87)	0.532***	(43.00)	0.208	5932
NON HIGH-TECH	-0.154***	(-3.33)	0.018***	(3.28)	0.653***	(15.51)	-0.028	(-1.00)	0.003	(0.06)	0.046**	(2.34)	0.357	2052
UNCONSTRAINED														
HIGH-TECH	-0.016	(-0.77)	0.004*	(1.68)	0.342***	(21.44)	-0.129***	(-6.04)	-0.021	(-0.99)	0.525***	(43.75)	0.235	6251
NON HIGH-TECH	0.129**	(2.37)	0.016***	(3.07)	0.105**	(2.35)	-0.067***	(-3.12)	0.077	(1.04)	0.098***	(7.17)	0.200	3135
5. AGE														
CONSTRAINED														
HIGH-TECH	-0.015	(-0.72)	0.005**	(2.06)	0.341***	(21.32)	-0.139***	(-6.47)	-0.021	(-0.99)	0.529***	(43.08)	0.223	6029
NON HIGH-TECH	-0.147***	(-3.37)	0.025***	(4.71)	0.595***	(14.85)	-0.060**	(-2.26)	-0.005	(-0.10)	0.036**	(1.97)	0.318	2296
UNCONSTRAINED														
HIGH-TECH	-0.014	(-0.69)	0.004	(1.45)	0.345***	(21.65)	-0.116***	(-5.37)	-0.020	(-0.95)	0.529***	(43.70)	0.218	6130
NON HIGH-TECH	0.141**	(2.42)	0.019***	(3.28)	0.034	(0.81)	-0.016	(-0.65)	0.296**	(2.55)	0.102***	(6.63)	0.264	2651

Panel A (US): Crisis period (2008-2011)

1.SIZE

CONSTRAINED

HIGH-TECH	0.115**	(2.50)	0.010*	(1.82)	0.359***	(11.58)	-0.136***	(-3.24)	-0.029	(-0.43)	0.512***	(26.90)	0.177	1998
NON HIGH-TECH	0.065	(0.88)	0.023**	(2.09)	0.438***	(6.21)	-0.012	(-0.21)	0.212**	(2.00)	0.072**	(2.25)	0.243	780

UNCONSTRAINED

HIGH-TECH	0.132***	(2.85)	0.010*	(1.79)	0.362***	(11.80)	-0.127***	(-3.08)	-0.020	(-0.30)	0.498***	(26.59)	0.220	2067
NON HIGH-TECH	0.308***	(3.94)	0.019*	(1.73)	0.349***	(4.82)	-0.074**	(-2.45)	0.036	(0.24)	0.063***	(2.88)	0.339	1132

2.DIVIDEND

CONSTRAINED

HIGH-TECH	0.114**	(2.48)	0.010*	(1.82)	0.372***	(12.19)	-0.133***	(-3.23)	-0.036	(-0.53)	0.506***	(26.71)	0.183	1995
NON HIGH-TECH	0.070	(0.94)	0.025**	(2.14)	0.443***	(6.25)	-0.077*	(-1.72)	0.148	(1.40)	0.089***	(2.82)	0.276	854

UNCONSTRAINED

HIGH-TECH	0.133***	(2.86)	0.010*	(1.80)	0.348***	(11.18)	-0.131***	(-3.14)	-0.012	(-0.17)	0.504***	(26.72)	0.213	2070
NON HIGH-TECH	0.274***	(3.21)	0.020*	(1.91)	0.303***	(3.98)	-0.046	(-1.20)	0.058	(0.40)	0.055**	(2.47)	0.262	1058

5. AGE

CONSTRAINED

HIGH-TECH	0.112**	(2.43)	0.010*	(1.85)	0.356***	(11.46)	-0.132***	(-3.17)	-0.028	(-0.42)	0.510***	(26.91)	0.194	2006
NON HIGH-TECH	0.072	(0.99)	0.022**	(2.26)	0.473***	(7.07)	-0.041	(-0.96)	0.111	(1.09)	0.039	(1.42)	0.261	916

UNCONSTRAINED

HIGH-TECH	0.133***	(2.88)	0.009*	(1.68)	0.366***	(11.91)	-0.124***	(-2.97)	-0.015	(-0.22)	0.500***	(26.48)	0.199	2042
NON HIGH-TECH	0.279***	(2.81)	0.040**	(2.51)	0.229***	(3.02)	-0.072*	(-1.77)	0.209	(1.31)	0.079***	(2.84)	0.292	902

Panel B (UK): Pre-crisis period (2000-2007)

1.SIZE

CONSTRAINED

HIGH-TECH	0.016	(0.31)	0.021***	(2.82)	0.383***	(8.61)	-0.130*	(-1.78)	-0.016	(-0.30)	0.456***	(14.77)	0.254	885

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NON HIGH-TECH UNCONSTRAINED	-0.006	(-0.05)	0.018	(0.82)	0.434***	(3.74)	-0.528***	(-3.77)	-0.018	(-0.14)	0.332***	(4.77)	0.287	245
HIGH-TECH	0.024	(0.45)	0.020**	(2.53)	0.391***	(8.83)	-0.117	(-1.65)	-0.021	(-0.40)	0.449***	(14.60)	0.288	903
NON HIGH-TECH	0.585***	(3.77)	0.056***	(2.83)	0.451***	(3.57)	-0.209**	(-2.00)	0.123	(0.68)	0.026	(0.52)	0.390	468
2.DIVIDEND CONSTRAINED														
HIGH-TECH	0.026	(0.49)	0.021***	(2.77)	0.379***	(8.50)	-0.143*	(-1.94)	-0.016	(-0.30)	0.463***	(14.68)	0.252	860
NON HIGH-TECH UNCONSTRAINED	0.125	(1.02)	0.033	(1.64)	0.512***	(5.25)	-0.363**	(-2.46)	-0.108	(-0.91)	0.249***	(3.74)	0.451	272
HIGH-TECH	0.016	(0.31)	0.018**	(2.39)	0.386***	(8.80)	-0.122*	(-1.76)	-0.018	(-0.33)	0.449***	(15.01)	0.285	928
NON HIGH-TECH	0.787***	(4.73)	0.018	(0.85)	0.177	(1.14)	-0.209*	(-1.90)	-0.038	(-0.19)	0.089*	(1.69)	0.270	441
5. AGE CONSTRAINED														
HIGH-TECH	0.021	(0.40)	0.021***	(2.67)	0.383***	(8.58)	-0.135*	(-1.83)	-0.017	(-0.31)	0.460***	(14.72)	0.253	864
NON HIGH-TECH UNCONSTRAINED	0.236*	(1.88)	0.025	(1.43)	0.446***	(4.19)	-0.649***	(-3.96)	-0.087	(-0.71)	0.334***	(4.85)	0.447	252
HIGH-TECH	0.018	(0.34)	0.019**	(2.43)	0.382***	(8.62)	-0.135*	(-1.91)	-0.017	(-0.31)	0.455***	(14.88)	0.274	914
NON HIGH-TECH	0.342*	(1.78)	0.039	(1.51)	0.142	(0.89)	-0.299***	(-2.82)	-0.115	(-0.59)	0.128**	(2.21)	0.255	430

Panel B (UK): Crisis period (2008-2011)

1.SIZE CONSTRAINED														
HIGH-TECH	0.131	(1.17)	0.029**	(2.18)	0.447***	(5.62)	-0.038	(-0.30)	0.054	(0.48)	0.390***	(7.97)	0.331	332
NON HIGH-TECH UNCONSTRAINED	0.517*	(1.81)	0.051*	(1.95)	0.343	(1.26)	-0.242	(-0.90)	0.212	(0.76)	0.218***	(3.37)	0.406	106
HIGH-TECH	0.170	(1.47)	0.024*	(1.84)	0.407***	(4.95)	-0.063	(-0.49)	0.148	(1.31)	0.407***	(8.21)	0.320	326
NON HIGH-TECH	0.651	(1.59)	-0.048	(-0.84)	0.451**	(2.16)	-0.365**	(-2.57)	-0.314	(-1.12)	0.376***	(3.68)	0.417	179

2.DIVIDEND

CONSTRAINED

HIGH-TECH	0.165	(1.43)	0.028**	(2.13)	0.409***	(5.01)	-0.120	(-0.92)	0.116	(1.03)	0.415***	(8.17)	0.312	321
NON HIGH-TECH	0.330	(1.32)	0.026	(0.82)	0.792***	(4.96)	-0.378**	(-2.03)	-0.201	(-1.03)	0.341***	(3.92)	0.496	134

UNCONSTRAINED

HIGH-TECH	0.149	(1.31)	0.026**	(1.99)	0.425***	(5.18)	0.001	(0.00)	0.084	(0.74)	0.387***	(8.03)	0.341	337
NON HIGH-TECH	0.253	(0.82)	0.088***	(2.83)	-0.105	(-0.40)	-0.468***	(-3.02)	0.496	(1.55)	0.178**	(2.40)	0.326	151

5. AGE

CONSTRAINED

HIGH-TECH	0.134	(1.20)	0.031**	(2.36)	0.438***	(5.52)	-0.073	(-0.57)	0.066	(0.60)	0.391***	(8.05)	0.340	330
NON HIGH-TECH	0.476*	(1.95)	0.036	(1.51)	0.390*	(1.71)	-0.720***	(-3.74)	0.026	(0.12)	0.350***	(4.14)	0.428	122

UNCONSTRAINED

HIGH-TECH	0.170	(1.46)	0.023*	(1.75)	0.415***	(5.05)	-0.051	(-0.39)	0.148	(1.31)	0.408***	(8.15)	0.316	328
NON HIGH-TECH	0.490	(1.03)	-0.087	(-1.36)	0.342	(1.37)	-0.356**	(-2.18)	-0.773	(-1.62)	0.444***	(4.99)	0.376	154

Notes: This table presents the OLS estimation results of the R&D investment model in equation 2. The US and UK samples are divided into two partitions: pre-crisis period (2000-2007) and post crisis period (2008-2011). The estimations use pre-determined firms selection into two categories. Constraint category assignments employ ex ante criteria based on firm size, dividend payout and age. Analytical definitions for all the variables are provided in table 4.1. All regressions include industry and time dummies. T-statistic values are reported in parentheses. ***, ** and * indicate coefficient is significant at the 1%, 5% and 10% respectively. For the estimation we use consistent to heteroskedasticity standard errors.

In Table 4.7 we report new regression results using alternative definitions for R&D investment rate and for the contrary ratio, which is capital investment rate. In the first two specifications we present results for the R&D/TINV ratio and for the contrary ratio of INV/TINV. The next two specifications display results for alternative definition of the dependent variable, which is the natural logarithm of the ratio of R&D investment over physical investment and its inverse ratio. Further, we demonstrate results for the natural logarithm of the ratio of R&D investment growth from one year to another over the corresponding growth of capital investment and its inverse ratio. Lastly we report results for the natural logarithm of the ratio of R&D investment growth from one year to another over the corresponding growth of total investment and its inverse ratio. Note that the number of firm year-observations has declined when the growth specification is included. In general, in both panels, patterns of growth opportunities, cash holding, leverage and stock issues coefficients are similar quantitatively to the previous results (apart from the last four specifications, where the signs of these variables are opposite). That is, growth opportunities and cash remain positive and cash seems to be the main firm characteristic significantly affecting the R&D investment rate. Leverage remains negative and significant, while stock issues do not exert significant influence on the dependent variable. However, the cash flow relationship is insignificant in all US specifications except for the 3rd and 4th ones. However in all UK specifications the cash flow relationship is significant except for the 3rd and 4th ones. Overall, the results suggest that for specifications with growth variables the coefficients are opposite to that with absolute values variables. Also the results indicate that the 3rd and 4th specifications show greatest in size coefficients. Lastly ratios of R&D investment are clearly interchangeable with ratios of capital investment in the sense that the coefficients size is the same, only the sign is changing (the exceptions here are the last two specifications).

Table 4.7 Alternative Definitions of the Dependent Variable

Dep. Var. G=Growth	R&D/TINV	INV/TINV	ln(R&D/INV)	ln(INV/R&D)	ln(GR&D/GINV)	ln(GINV/GR&D)	ln(GR&D/GTINV)	ln(GINV/GTINV)
Panel A (US): (2000-2011)								
CF	0.007	-0.007	-0.864***	0.864***	-0.171	0.171	-0.022	0.131**
	(0.46)	(-0.46)	(-9.79)	(9.79)	(-1.62)	(1.62)	(-0.38)	(2.27)
Q	0.012***	-0.012***	0.027**	-0.027**	-0.008	0.008	0.000	-0.001
	(6.68)	(-6.68)	(2.43)	(-2.43)	(-0.54)	(0.54)	(0.02)	(-0.15)
CASH	0.375***	-0.375***	2.173***	-2.173***	-0.376***	0.376***	0.163***	0.554***
	(30.77)	(-30.77)	(31.87)	(-31.87)	(-3.91)	(3.91)	(3.02)	(10.85)
LEV	-0.097***	0.097***	-0.608***	0.608***	0.182	-0.182	0.027	-0.103***
	(-8.74)	(8.74)	(-6.88)	(6.88)	(1.64)	(-1.64)	(0.36)	(-2.76)
STOCK	0.019	-0.019	-0.093	0.093	0.081	-0.081	-0.006	-0.071
	(1.07)	(-1.07)	(-0.89)	(0.89)	(0.63)	(-0.63)	(-0.08)	(-0.99)
Constant	0.322***	0.678***	-0.058	0.058	-0.843***	0.843***	-0.333***	0.268***
	(35.05)	(73.74)	(-0.98)	(0.98)	(-10.51)	(10.51)	(-6.21)	(8.31)
Adj.R2	0.561	0.561	0.450	0.450	0.021	0.021	0.007	0.118
Obs.	17197	17197	12502	12502	7626	7626	9605	15169

Panel B (UK): (2000-2011)

CF	0.110***	-0.110***	0.208	-0.208	-0.521*	0.521*	-0.383**	0.138
	(2.65)	(-2.65)	(0.83)	(-0.83)	(-1.71)	(1.71)	(-2.10)	(0.78)
Q	0.030***	-0.030***	0.141***	-0.141***	0.015	-0.015	0.042	0.039
	(5.43)	(-5.43)	(4.15)	(-4.15)	(0.29)	(-0.29)	(1.44)	(1.22)
CASH	0.426***	-0.426***	2.698***	-2.698***	-0.418	0.418	0.014	0.666***
	(13.14)	(-13.14)	(12.76)	(-12.76)	(-1.48)	(1.48)	(0.09)	(3.59)
LEV	-0.242***	0.242***	-1.665***	1.665***	0.476	-0.476	0.108	-0.232
	(-5.63)	(5.63)	(-5.70)	(5.70)	(1.29)	(-1.29)	(0.41)	(-1.50)
STOCK	0.000	-0.000	0.252	-0.252	-0.034	0.034	-0.031	-0.075
	(0.01)	(-0.01)	(1.00)	(-1.00)	(-0.10)	(0.10)	(-0.17)	(-0.38)
Constant	0.369***	0.631***	-0.599***	0.599***	-0.843***	0.843***	-0.178	0.496***
	(13.39)	(22.91)	(-3.33)	(3.33)	(-3.72)	(3.72)	(-1.15)	(4.70)
Adj.R2	0.455	0.455	0.481	0.481	0.040	0.040	0.022	0.048
Obs.	2536	2536	2347	2347	1310	1310	1702	2136

Notes: This table presents the OLS estimation results of the R&D investment model in equation 2. The estimations use alternative definitions of dependent variable. Analytical definitions for all the independent variables are provided in table 4.1. All regressions include industry and time dummies. T-statistic values are reported in parentheses. ***, ** and * indicate coefficient is significant at the 1%, 5% and 10% respectively. For the estimation we use consistent to heteroskedasticity standard errors.

4.6 Conclusion

In this paper we analyze how sensitive the R&D/TINV ratio is to fluctuations in net worth and other firm-specific characteristics across different subgroups of firms during the pre-crisis and the crisis periods. By combining the literature on corporate R&D investment with the literature on capital investment, we are able to shed more light on the total investment policy of firms in the US and UK markets. Moreover, by investigating how sensitive the R&D/TINV ratio is for financially constrained high-tech firms especially during a financial crisis period, we are also able to investigate important aspects of high-tech firms' behaviour, which has been explored partially in the literature.

This paper is motivated by the fact that no attention has been devoted to the sensitivity of the R&D/TINV ratio to financial factors which is somewhat surprising given that changes in R&D investment and fixed investment arise, to some extent, due to information problems in the financial markets. We consider the effects of financial factors on both R&D and capital investment decisions in order to examine how constrained and unconstrained firms allocate their funds on R&D and capital when decisions on both inputs have to be taken simultaneously.

The paper has found evidence that a firms' net worth and its R&D/TINV ratio are interrelated. According to our results the R&D/TINV ratio tends to be more responsive to changes in firm-specific indicators. Further, when firms are classified on the basis of their different characteristics we show that financially unconstrained firms face a greater sensitivity of the R&D/TINV ratio in contrast with the constrained firms especially in the crisis period. However, in the pre-crisis period financially constrained firms' R&D/TINV ratio seems to be negatively related with cash flow and positively related with cash flow in the crisis period. This indicate that in the pre-crisis period when the expected wedge between the cost of internal and external finance is lower, constrained firms increase their capital investment when cash flow increases, while in the crisis period when the expected wedge between the cost of internal and external finance is greater financially constrained firms increase their R&D investment when cash flow increase. After dividing firms into constrained high-tech and non high-tech and unconstrained high-tech and non high-tech groups we find that the

group of unconstrained non-high tech firms' R&D/TINV ratio exhibit greatest sensitivity to cash flow changes independently from the time period we measure it. This finding is in line with the argument of Brown and Petersen (2011) that firms intensively investing in R&D projects are more likely to smooth their R&D investment by building up cash savings rather than relying on fluctuating cash flows. In summary, the results strongly suggest that capital market imperfections are the most important consideration in shaping the sensitivity of the R&D/TINV ratio across different firm classes. Our findings also reveal that the impact of financial constraints on R&D/TINV ratio also depends on the firm's industry. Finally, we find that in general the R&D/TINV ratio of US firms' is more responsive to changing conditions than that of UK firms.

Chapter 5

Conclusions

The aim of this thesis has been to provide additional insights into the understanding of a number of issues relating to the impact of market imperfections on corporate investment and financial decisions. The investment cash flow sensitivity (ICFS henceforth) has been debated for a long time. As the literature has shown, the nature of the investment-cash flow relationship is, at best, not completely clear. The motivation of this thesis stems from the lack of consensus on the role of the ICFS. In addition, there is no study in the literature exploring physical and R&D investment simultaneously. Effectively, this thesis tries to expand the *status quo* and to contribute current literature.

The three analytical studies in this thesis analyze corporate financial and investment decisions over time under the assumption of an imperfect market. The three different but related subjects under our study are 1) the relationship between internal cash flow and capital expenditure decisions, 2) the relationship between internal cash flow and R&D investment decisions and 3) the determinants of the R&D/TINV ratio.

There are two schools of thought in the literature on the issue of the ICFS of firms with different levels of financial constraints. The first one originated by Fazzari et al. (1988) (FHP) finds a greater ICFS for firms which are *a priori* more likely to confront binding financing constraints while another group initiated by Kaplan and Zingales (1997) (KZ) displays a greater ICFS for counterpart firms. Chapter 2 is motivated by this disagreement in the literature. Our analysis provides a partial explanation for this puzzle by taking into account a very large and heterogeneous sample of non-financial UK listed firms over the period 1980 to 2009 and showing that the FHP or KZ results may appear depending on the sample selection in terms of types of firms accepted in the sample as well as the time period the sample comes from. The sample selection criteria apply to the problem of data mining, e.g. most of the evidence provided to support FHP hypothesis is build on samples of very large firms, therefore this may lead to very quick and easy explanation, while this phenomenon is more complex. In particular, this study finds that one can set together selected results to be either consistent with the conclusions of Fazzari et al. (1988) or Kaplan and Zingales (1997), subject to financial constraints measure, time period considered, or selected sample.

However, taking into account firms most likely to be financially constrained but not financially distressed (on average firms classified as very constrained according to e.g., size show negative cash flows, especially over the last decade, while firms classified as financially unconstrained show positive cash flows) we find that our results are more in line with the FHP argument (a greater ICFS for financially constrained firms) than with the KZ argument (a greater ICFS for financially unconstrained firms). Especially the investigation of financial crisis time versus booming time provides an additional evidence for the FHP argument. Also, after splitting firms into four different subsamples according to firstly size and then a combined measure of size, age and sales growth, we find that the last combined measure controls better for ICFS size changes, namely the ICFS increases monotonically in size from the sample of very constrained firms to lightly constrained firms in every subperiod.

Nonetheless, the detailed division of large firms' sample helps to explain the previous opposing empirical results in the literature and will further our understanding of the relationship between internal funds and the investment behaviours of firms and help solve the long lasting puzzle.

Further, Chapter 2 reveals that the ICFS for physical investment has declined sharply over the entire sample period, even after controlling for negative cash flow firms, the role of cash holdings and debt financing or after splitting the sample into two or four contrasting groups according to various measures like age, size, sale growth or dividend payments. This decline cannot be explained on the basis of measurement error alone. This work substantially contributes to the existing body of knowledge, by extending and complementing existing US evidence (e.g., Brown and Petersen, 2009) on the evolution of ICFS.

The decline of ICFS over time may indicate either some gradual changes in the capital market influencing investment decisions over recent thirty years[40] or that ICFS sensitivity is an incorrect measure of financial constraints as claimed by Chen and Chen (2012). Intuitively we reject the claim made by Chen and Chen on the basis that diminishing ICFS may stem from unspecified mechanisms or simply from error in capturing financial constraints or in the measurement of investment opportunities.

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[40] Brown and Petersen (2009) explain the decrease of ICFS over time with the rising importance of public equity as a source of funds.

The above findings have implications for an important literature on the role of the cash flow for corporate investment. Dasgupta et al., (2011) find that firms stage their response to increases in cash flow, delaying investment while building up cash stocks and reducing leverage. They find that although, in the long run, investment exhibits substantial sensitivity to cash flows, investment does not absorb the entire cash flow shock. In fact, the tighter the financial constraints, the smaller the fraction of cash flow absorbed by investment and the more by leverage reduction. The descriptive statistics of chapter 2 demonstrate that a great number of changes are apparent for UK firms over the last 30 years. Cash flows have decreased critically, mostly due to the substantial increase in the proportion of small and young firms with persistently negative cash flows. Physical investment has also declined and the uses of total debt as well as of cash holding have increased. More leveraged firms have higher obligations in term of interest payments, hence higher debt level will absorb greater share of cash flows. We also know from the descriptive statistics in chapter 2 that on average firms save double amount of cash in the period 2000 to 2009 to what they were saving in the period 1980 to 1989. This may imply that firms devote greater chunk of cash flows to build up cash reserves over time. Hence we can expect smaller fraction of cash flow available for investment over time and consequently decreasing ICFS over time.

Chapter 3 investigates corporate R&D investment behaviour in the US and UK using data from the period 1990-2010. The descriptive statistics of this paper demonstrate that a great number of changes are apparent for publicly traded manufacturing firms over the last 21 years. On average, cash flows ratio has decreased critically, mostly due to the substantial increase in the amount of small and young firms with persistently negative cash flows, R&D investment ratio has increased sharply, physical investment ratio has declined and ratios of the uses of public equity issues as well as of cash stocks have increased over time.

The findings of this chapter also indicate that R&D investment is an important proportion of the overall corporate investment spending for a significant share of publicly traded firms. According to the sample of this research the share of R&D investment in total investment, measured as the sum of physical and R&D investments, is higher than the share of capital investment for US firms since year 1992 and for UK firms since year 2001.

The main finding of chapter 3 is the persistently negative relationship between cash flow and R&D investment. In particular, this study shows that the ICFS for R&D investment is negative and that it increases in the degree of negativity, while conversely the ICFS for physical investment is positive but the degree of positivity decreases over time. These trends do not change much even after controlling for negative cash flow firms. We conclude that the increase in the negative relationship between R&D investment and cash flow over time is robust to various model specifications. This finding suggests that despite experiencing a shortage of internal liquidity firms continue investing, which indicates that firms finance their R&D investment with other funds.

Chen and Chen (2012) study the evolution of ICFS over the period 1967 to 2009 and find that ICFS has declined over time and has completely disappeared in recent years, even during the 2007–2009 credit crunch. They conclude that ICFS is not a good measure of financial constraints, and that future empirical work should not use this variable as a valid proxy for financial constraints. They assert that if one believes that financial constraints have not completely disappeared, then ICFS cannot be a good measure of financial constraints. We find negative R&D ICFS, which also contradicts the theory of financial constraints. However, bearing in mind that physical and R&D investments greatly differ owing to their characteristics, we conclude that ICFS may not work for R&D investment as a measure of financial constraints.

The estimated results of chapter 3 also highlight that firms who are investing in R&D projects seem to plan the investment well in advance and make sure that they have enough funds before they start the R&D investment project, especially in the case of financially constrained firms. In general, financially constrained R&D firms seem to save up cash stock out of cash flow innovations or stock issues in order to finance their R&D investment, while unconstrained R&D firms' behaviour is not significantly related with cash holdings. This finding is in line with the study of Brown and Petersen (2011) who find that firms who are most likely to face financing frictions rely extensively on cash holdings to smooth R&D, while firms less likely to face financing frictions appear to smooth R&D investment without the use of costly cash holdings.

The financial crisis is well distinguished by the results of chapter 3. We find that R&D ICFS is negative before and during the crisis period and it is increasing in its negativity during the crisis especially for US sample. Interestingly for the US

sample the cash holdings coefficients over the boom period is higher than UK ones, while over the crisis period the same coefficients are higher for the UK firms' sample than the US one. Also UK firms show higher coefficients for growth opportunities over the boom and crisis periods than US firms. Overall, when the financial crisis period is considered the ICFS is still even more negative and significant, whereas cash holdings coefficients are more positive and significant according to the OLS regression. In line with GMM results cash holding of the full sample of US firms' impacts R&D investment negatively during the crisis.

The GMM results of chapter 3 report that the financially unconstrained firms adjust their R&D investment faster than financially constrained firms. The adjustment coefficient is relatively small (it is lower than 0.5 in all cases) and even smaller during the financial crisis period, possibly providing evidence that the dynamics implied by our models are not rejected and firms adjust their R&D expenditures ratios relatively slowly in an attempt to have their target R&D investment ratios. One possible explanation for this adjustment speed could be that the costs deviating from the target R&D investment ratio are not so significant and firms' R&D investment ratios are persistent over time. Overall the adjustment coefficient is close to 0, especially during the financial crisis period suggesting that the costs of adjustment are much greater than the costs of disequilibrium in the firms' trade-off analysis between the two different types of costs: the costs of making adjustment to their target ratios and the costs of being in disequilibrium (being off target).

In terms of comparison between the US and UK firms, one can learn from the results that the coefficients for UK firms are much greater than for US firms, implying a stronger dependence by R&D investment on financial variables in the UK than in the US market. This implies that the UK firms who are actively engaged in R&D investment projects are more financially constrained than US firms. This conclusion is supported by the evidence that the cash holdings coefficients for UK firms are in general higher than for US firms. This explains why UK firms invest in RD activities around half as much as US firms. However this subject could be better understood after incorporating the tax system effects in the model of US and UK firms, which remains a recommendation for future research.

Chapter 4 analyses how sensitive the R&D/TINV ratio is to fluctuations in the net worth and other firm-specific characteristics across different subgroups of firms during the pre-crisis and the crisis periods. This study considers the effects of financial factors on both R&D and capital investment decisions in order to examine how constrained and unconstrained firms allocate their funds on R&D and capital when decisions regarding both inputs have to be taken simultaneously.

In chapter 4 we find that a firms' net worth and its R&D/TINV ratio are interrelated. The year by year analysis shows that the R&D/TINV ratio - cash flow sensitivity is negative over time until year 2007 and since year 2008 it becomes increasingly positive. This implies that taking into account both capital and R&D investments simultaneously better reflects the real investment decisions firms make. During booming period the external financing sources are broadly available and less costly, while during financial crisis external finances shrink in size and turn to be costly for firms, hence during financial crisis firms are more likely to employ internal than external finances, and this is what we observe in chapter 4.

According to our results in chapter 4 the R&D/TINV ratio tends to be more responsive to changes in firm-specific indicators. Further, when firms are classified on the basis of their different characteristics we show that financially unconstrained firms face a greater sensitivity of the R&D/TINV ratio in contrast with the constrained firms especially in the crisis period. However, in the pre-crisis period the R&D/TINV ratio of financially constrained firms' seems to be negatively related with cash flow and in the crisis period positively related with cash flow. This indicates that in the pre-crisis period when the expected wedge between the cost of internal and external finance is lower, constrained firms increase their capital investment when cash flow increases. However during the crisis period when the expected wedge between the cost of internal and external finance is greater financially constrained firms increase their R&D investment when cash flow increases. After dividing the firms into constrained high-tech and non high-tech and unconstrained high-tech and non high-tech groups we find that the group of unconstrained non-high tech firms' R&D/TINV ratio exhibit greatest sensitivity to cash flow changes independently from the time period we measure it. This finding is in line with the argument of Brown and Petersen (2011) that firms intensively investing in R&D projects are more likely to smooth their R&D

investment by building up cash savings rather than relying on fluctuating cash flows. In summary, the results strongly suggest that capital market imperfections are the most important consideration in shaping the sensitivity of the R&D/TINV ratio across different firm classes. Our findings also reveal that the impact of financial constraints on R&D/TINV ratio also depends on the firm's industry. Finally, we find that in general the R&D/TINV ratio of US firms' is more responsive to changing conditions than that of UK firms.

Overall, the results show that capital and R&D investment has been affected by financial constraints. In agreement with previous literature this thesis implies that when operating in a market with a variety of distortions, a firm's investment decision-making process is much more difficult than it is in a market free of frictions. Further, this study shows the vast range of differences between the US and UK R&D firms. The most outstanding one is that US firms appear to be much more advanced in their R&D investing processes.

Brown and Petersen (2009) argue that the changes in the physical and R&D ICFS over time are due to the development of equity markets and the changes in the total investment compositions. Our results in this thesis confirm Brown and Petersen's findings and also extend the topic by highlighting various issues. We warn about the data selection process which may result in biased or confounding outcomes. We also emphasize the role of negative cash flow firms in contrast with majority of the existing literature. Empirical studies that ignore negative cash flows firm-year observations are unlikely to unravel the true nature of the relationship between investment and firm specific characteristics, especially the ICFS.

The new insights provided by our empirical analysis of the R&D/TINV ratio suggests new avenues for future research on the relationship between R&D/TINV ratio, other firm specific characteristics and internal corporate governance devices. One such avenue relates to the determinants of the speed of adjustment towards the equilibrium level of R&D/TINV ratio. Another avenue of future research is to focus on the interaction between the financial status of firms and corporate governance measures in determining R&D/TINV ratio.

Evidently, this research comes with a number of limitations that should be kept in mind. Every model specification in this research was estimated using an augmented Q model of investment because this is clearly the specification most

commonly applied in the literature. However, recent literature experiments with different investment specifications such as sales accelerator models (Hoshi et al., 1991; Kadapakkam et al., 1998), or dynamic neoclassical investment models (Bond et al., 2003; Guariglia, 2008), or specifications that engage in different controls for the investment opportunities bias (Gilchrist and Himmelberg, 1995; Guariglia and Carpenter, 2008). It would be interesting to see whether the results hold for these alternative specifications that have been suggested in the previous literature. Another limitation of the thesis is that we have taken into account only publicly traded UK and US firms that are principally both large and mature. We hope that future work will examine these issues using data from smaller or younger companies, or where differences between more innovative and less innovative firms may be even more significant.

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