The Impact of the Financial Crisis on Innovation and Growth: Evidence from Technology Research and Development

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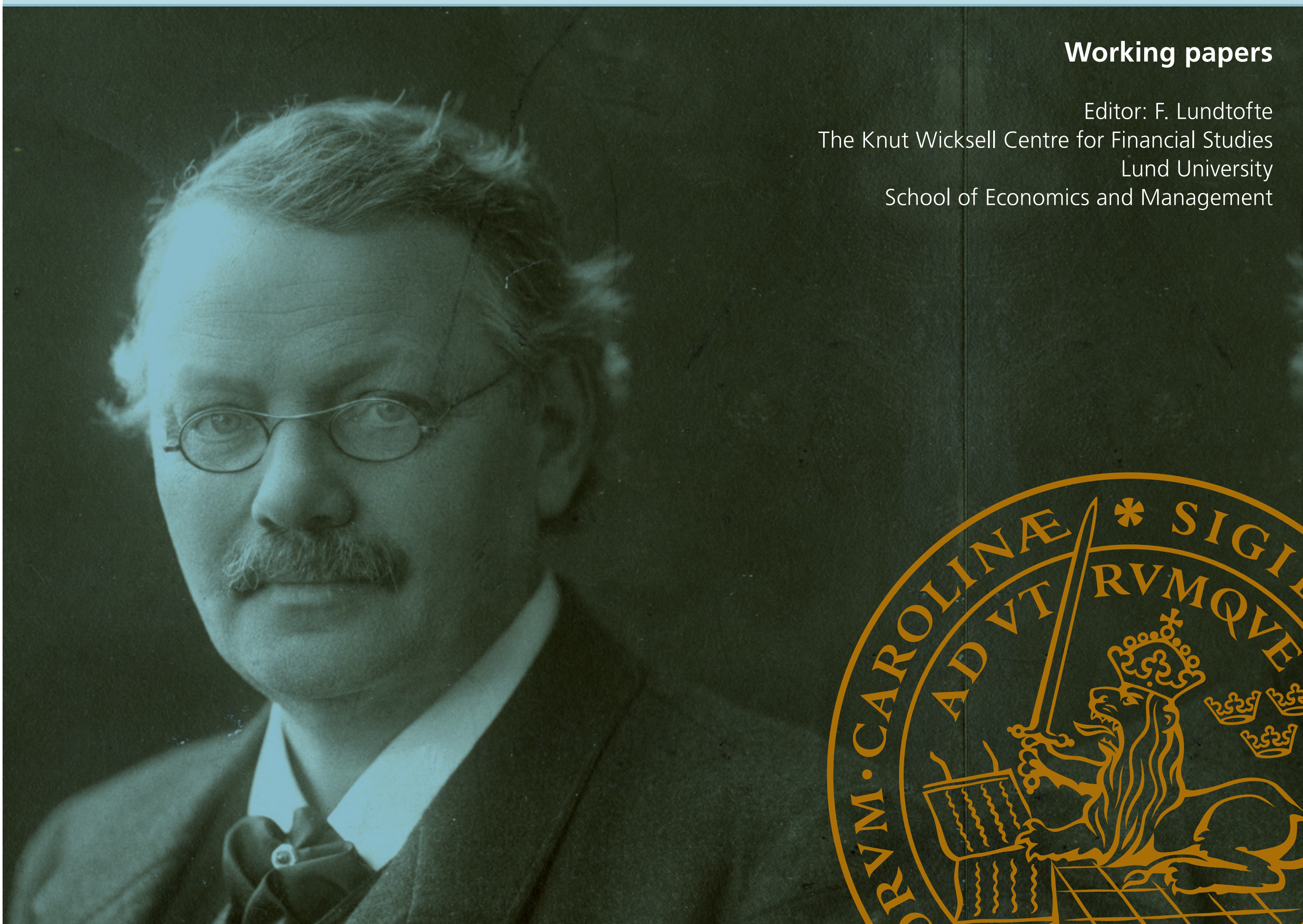
KNUT WICKSELL WORKING PAPER 2014:8



Working papers

Editor: F. Lundtofte
The Knut Wicksell Centre for Financial Studies
Lund University
School of Economics and Management

The Impact of the Financial Crisis on Innovation and Growth: Evidence from Technology Research and Development

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Preliminary Version/Draft: November 2014

Abstract

An increasing body of literature discusses how and to which extent the financial crisis of 2007-2009 transmits to the real economy. This paper investigates the impact of the financial crisis of 2007-2009 on corporate investment, in particular research and development (R&D) expenditures. We measure financial constraints and financial distress of firms and investigate whether those measures have a significant impact on R&D during the financial crisis. We find evidence that financial distress has little impact for our sample of listed technology firms and we argue that the credit supply shock does not play a decisive role as financially constrained firms invest comparatively more than non-constrained firms during the crisis.

JEL classification: G31, G32, G33
Keywords: Financial Constraints, Financial Distress, Financial Crisis, R&D, Investment

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1 Introduction

In this paper we assess the impact of the financial crisis of 2007-2009 on corporate investment, in particular research and development (R&D) expenditures. We measure financial constraints and financial distress of firms and investigate whether those variables have a significant impact on R&D during the financial crisis. We argue that reduced investment due to financial constraints is more detrimental for economic growth and a sign of a credit supply shock, whereas reduced investment owing to financial distress signals a credit demand shock and is a sign of intensified creative destruction during the crisis.

Changes in corporate investment are a crucial driver of macroeconomic fluctuations. While in mature western economies fixed capital spending seldom exceeds 20% of GDP, it is nevertheless considered crucial for future growth and accounts for a considerable part of the fluctuation in overall economic activity. In general, to finance their investment projects firms can use internal funds (cash flow and retained earnings) and external funds (debt or equity). Research on the determinants of investment behavior of firms departs from Modigliani and Miller's (1958) seminal contribution, which states that under certain assumptions the financial structure and financial policies are irrelevant for real investment. A considerable strand of research builds upon the view that external and internal financing are not perfect substitutes and firms' investment and financing decisions are interdependent. According to the pecking order hypothesis of Majluf and Myers (1984) firms prefer internal funds over equity finance and debt financing. Alternatively, the financing of firms is seen as a trade-off weighing the cost of each additional unit of debt against its benefits (cf. Baxter, 1967 and Kraus and Litzenberger, 1973). The most prominently featured examples of costs and benefits of the different forms of financing are transaction costs, tax advantages, agency problems, asymmetric information and fluctuations on credit markets.

Financial innovation has made financial systems as a whole increasingly complex and as some argue more vulnerable to crises. This development increases the odds that turbulences in the financial system are not a result of a downturn in the real economy but, on the contrary, financial crises cause recessions in the real economy. Distressed financial markets may cause a shift in the supply of loans and banks may struggle to access wholesale funding markets. Moreover, due to increasing uncertainty in society, the rate of deposit withdrawals can sharply increase. As a consequence, liquidity and borrowing capacity of banks deteriorate. Many would argue that the recession of 2008 was indeed caused by the financial crisis starting in 2007. An essential question is thus how the financial crisis transmits to the real economy and in particular which type of firms are affected. Gaining further insight into this question helps policy makers to counter the effects of a financial crisis on the real economy.

A large and growing literature examines if the supply frictions on the credit market are relevant for corporate investment during the financial turbulences. Some studies have shown theoretically and empirically that fluctuations on financial markets effect growth of non-financial companies. For example, Duchin et al. (2010), Almeida et al. (2012), and Campello et al. (2010) show that firms reduce capital expenditures due to the negative credit supply shock (a bank lending supply shock or a general credit supply shock). Other researchers (e.g. Kahle and Stulz, 2012; Hetland and Mjos, 2012) find contrasting evidence that the lending supply shock is not necessarily a dominant causal factor for investment policies during the crisis. They show that the level of investment of financially constrained firms is not more affected than the level of investment of unconstrained firms. Thus, given the current state of research it is ambiguous if investment of non-financial firms is decreased due to the decrease of the credit supply or because the economy is in recession and there are not enough viable investment opportunities. This paper contributes to the discussion on corporate investment, in particular R&D, and the effect of the financial crisis on the real economy.

The Schumpeterian idea of creative destruction (Schumpeter, 1939) and basic economic theory on competitive markets predict that recessions provide an opportunity to drive weak and obsolete firms out of business. Thus, a recession should affect businesses already in distress prior to the recession, that is, “weak” businesses. A more negative impact for the economy plays out when a recession affects in principle healthy firms negatively. Economic growth is lost if firms that have viable investment opportunities cannot invest due to a lack of financing. We identify financially “weak” businesses by the degree of financial distress of non-financial firms applying Altman’s Z-scores (Altman, 1968) and financially constrained firms by Whited-Wu index according to Whited and Wu (2006). Financing of R&D is a critical input factor for innovation and growth in modern economies. According to the National Science Foundation (National Science Board, 2012) survey, as of 2009, U.S. R&D growth outpaced GDP growth in the past 20 years. Despite several periods of spending slowdown (including the period of 2007-2009 financial crisis), the rate of R&D to GDP rose from about 0.6% of GDP in 1953 to about 2% in 2009. As the National Science Foundation notes, this increase reflects the growing role of business (privately funded) R&D in the U.S. and the growing prominence of R&D-derived goods and services in the national and global economies.

We focus on high technology industries that are more R&D intensive. The reason for focusing on R&D expenditures instead of capital expenditures is two-fold. First, according to endogenous growth theory, investments in R&D provide new knowledge and increase productivity (Romer, 1990). Thus, R&D spending has a more long-term effect on economic growth and is a more meaningful measure in the framework of our question of how damaging the financial crisis has been to the real economy. Second, since the 1980s R&D spending has become increasingly important compared to capital investment (cf. Borisova and Brown, 2013). Ball et al. (2012) find that the key constraints are the financing of R&D and not capital expenditures. Figure 1 also illustrates that average R&D expenditures are more than double compared to average capital expenditures.

[INSERT FIGURE 1 HERE]

Our main question is how the financial crisis of 2007-2009 affects investment behavior of non-financial firms. Our framework helps get insight into the question whether the financial crisis transmits through decreased credit supply or rather through decreased demand for its products. This paper contributes to the discussion on corporate investment, in particular R&D, and the effect of the financial crisis on the real economy. Our work is distinguished from previous work in the field by the approach we use to test the interdependence between the financial crisis and investment behavior of firms. To our best knowledge, there is no direct comparison between the two groups of firms: financially constrained and distressed. We also contribute to the discussion on whether the supply or demand for funds is the dominant causal factor which determines the investment policies of firms during the crisis.

We find that financial distress plays a minor role, if any, as a determinant of R&D expenditures during the financial crisis. Financial constraints have a substantial impact on R&D expenditures during the crisis. Everything else equal, more constrained firms invest more during the financial crisis. Our result is consistent with the observation that average R&D expenditures were increasing during the financial crisis and in line with the findings of Kahle and Stulz (2012) and Hetland and Mjos (2012) that question whether firms´ investment behavior is affected via a credit supply side shock. From a macroeconomic perspective, it becomes evident that the financial crisis has not affected listed technology firms' R&D investment negatively. This finding is evidence that there is not much long-term damage of the financial crisis for innovation and future growth proxied by R&D expenditures. It also supports the argumentation that the financial crisis transmits rather through a demand-side shock than through a supply-side shock.

2 Financing of Technology Firms, Financial Constraints and Distress

2.1 Financing of Technology Firms

As mentioned in the introduction, the share of R&D expenditures is more than double compared to capital expenditures in non-financial firms included in the Compustat U.S. database. In addition, 70% of the aggregate R&D expenditures in the U.S are concentrated in seven high-tech industries: drugs (SIC 283), office equipment and computers (SIC 357), electronic components (SIC 366), communication equipment (SIC 367), scientific instruments (SIC 382), medical instruments (SIC 384) and software (SIC 737). We only use these seven industries in our analysis following Brown et al. (2009).

In figure 2 we present aggregate R&D and earnings before interest and taxes (EBIT) figures for our sample. The graphs reflect the upward trend in the aggregate value of R&D expenditures. Moreoever, earnings of high-tech firms, measured by EBIT, are also constantly increasing even during the financial crisis. During the dot-com bubble induced recession, despite a slowdown, total R&D investment was still growing in 2001 and stagnated in 2002. During the next macroeconomic shock in 2008, when the collapse of large financial institutions and bailouts of banks by national governments occured, R&D investment contuined to grow. R&D investment slightly declined only in 2009. This intial finding casts doubt on the hypothesis that the slowdown in R&D investment was due to firms' financial constraints in receiving external funds for their investments. Solely based on these findings, we would rather assume that the slowdown in R&D growth is driven by demand side effects. The economy has already been in recession in 2009, thus production and sales could have already been negatively affected.

[INSERT FIGURE 2 HERE]

Our data shows that high-tech firms are able to finance their R&D investment despite the crisis in the financial sector. This means they are able to borrow externally or have enough internal funds to finance their projects. Academic researchers agree that external financing, especially debt, can be more difficult to get for R&D intense firms because R&D investments are more difficult to collatarize and monitor. For example, Hall (2002) notes that "Although leverage may be a useful tool for reducing agency costs in the firm, it is of limited value for R&D-intensive firms. Because the knowledge asset created by R&D investment is intangible, partly embedded in human capital, and ordinarily very specialized to the particular firm in which it resides, the capital structure of R&D-intensive firms customarily exhibits considerably less leverage than that of other firms." However, our data does not confirm this statement. Table 1 illustrates, the mean leverage in high-tech sample (0.599) does not differ considerably from the mean of the entire sample (0.596) in the U.S. Compustat database for the period 1998-2012. Moreover, the average leverage value for all high-tech industries, except for firms with primary SIC 357 (Computer and Office Equipment), is greater than the median (0.168) of the entire sample. This finding suggests that in our sample R&D intense firms rely on debt as much as all other firms despite the theoretical predictions.

[INSERT TABLE 1 HERE]

What is more, as illustrated in figure 3, the leverage ratio for the whole sample in general and high-tech firms in particular was not decreasing during the financial crisis 2007-2009, suggesting that firms were able to borrow during the downturn in the financial sector.

[INSERT FIGURE 3 HERE]

2.2 Financial Constraints

With perfect capital markets, a firm's investment decision is independent of its financial condition, which means investment decisions only depend on demand for investment. However, in the presence of assymetric information, moral hazard and tax considerations, external and internal capital are not perfect substitutes and their costs differ. Adverse selection can also constrain firms with certain characteristics in receiving external financing. For example, small, young firms have less chances to receive funding for the same project than mature and large firms because the creditor has more information about the latter and thus considers their projects less risky. Even in established firms, R&D investment can be disadvantaged due to the uncertainty associated with their output and higher adjustment costs (Hall, 2012).

A plethora of research develops different approaches of testing the financial constraints. Extensive literature is built on the test of the investment equation for liquidity constraints. Thus, Fazzari, Hubbard, and Petersen (1988) address the problem using investment cash flow sensitivities. They demonstrate that financial constraints matter for investment decisions and building upon their findings they argue that financial constraints contribute to macro fluctuations of investment. Building on the work of Kaplan and Zingales (1997), Lamont, Polk, and Saa-Requejo (2001) propose what is commonly referred to as the KZ index. They estimate ordered logit models to determine which balance sheet items optimally predict financial constraints. Although the KZ index has been a popular measure of financial constraint, recent literature casts certain doubts on the validity of the index. Whited and Wu (2006) and Hadlock and Pierce (2009) provide evidence of weaknesses of the KZ index and both propose alternative measures. Rajan and Zingales (1998) construct a simple ratio for the dependence on external finance on a sector level, which measures a different but related phenomenon. In their work, they take the ratio of capital expenditure minus cash flow to cash flow and compare the individual dependencies to the median sector level to determine demand for external financing. Whited and Wu (2006) develop their index optimizing the present discounted value of future dividends (Tong and Wei, 2008) and incorporate inequality constraints with respect to dividend payouts and the stock of debt in every period. Parameterizing the model and estimating it with

Generalized Methods of Moments (GMM), they identify the best fit for predicting financial constraints. We use the Whited and Wu index in our baseline regression and we use an alternative measure for financial constraints as a robustness check. We compare the results of our baseline regression with the results using the work of Hadlock and Pierce (2009) as an alternative measure. Hadlock and Pierce (2009) carefully read financial filings of a sample of U.S. firms to pre-classify firms in five categories of constraints. Essentially replicating the analysis of Lamont, Polk, and Saa-Requejo (2001), they find age, size, cash flow, and leverage to be the only significant predictors of financial distress. To avoid endogeneity issues, they propose an index, labelled the SA index, which focuses solely on age and size. The WW index highly correlates with the SA index, and Hadlock and Pierce (2009) report a simple correlation coefficient of 0.8 in their underlying sample.

To test whether the WW and Hadlock and Pierce (2009) indices have the same predictions for financial constraints in our sample, we divide the whole high-tech sample into small young firms and large mature firms. Small firms are firms with total assets below the median value and young firms are firms with an age of 15 years or younger. Large and mature firms are respectively all other firms. The definition of “young” and “mature” firms is based on the number of years the firm is listed in Compustat. We compute descriptive statistics for the WW index and its components and present them in the first two columns of table 2. According to Hadlock and Pierce (2009), large and mature firms should be less constrained in receiving external financing than small and young firms. And indeed, the average value of the WW index for the sample of large mature firms is smaller (-0.851) than the value for the sample of small and young firms (-0.637). Hence large mature firms are less financially constrained than small and young firms. If we also compare each component of the index between the two groups, we can see the ratio of cash flow to total assets is more than 10 times smaller for the sample of small young firms than for large and mature firms (-2.004 and -0.168, respectively). Moreover, as we would expect, small young firms pays less dividends, but have higher sales growth and greater research and development expenses than large and mature firms.

In columns three and four of table 2, we compare the mean values of the WW index and its components for the sample of high-tech firms and all other firms excluding seven high-tech industries and utilities and financial firms (SIC 490-494 and 600-699). Expectedly, high-tech firms have on average a higher percentage of R&D expenditures (20.4%) in relation to their total assets comparing to the sample without R&D intense industries (5.4%). High-tech firms also pay fewer dividends, they are smaller, but remarkably they are less financially constrained as compared to the sample of all other firms.

[INSERT TABLE 2 HERE]

Figure 4 plots R&D expenditures according to four quartiles of their level of financial constraints as measured by the Whited and Wu (2006) index. The solid line represents the fourth quartile which includes the firms with the highest level of financial constraints and the dot-dashed line represents the firms with the lowest level of financial constraints. At first glance, the figure suggests conter-intuitive results, that is, firms with the highest level of financial constraints have the highest level of R&D. However, these findings are consistent with the discussion above, where we argue that R&D investment might not be directly affected by the shock in the financial sector, but the slowdown in the growth of R&D investment is due to the recession in the whole economy. Hence, financially constrained firms might not necessarily reduce their R&D expenditures due to financial constraints, but because of other broader economic fundamentals. Also, according to the Whited and Wu (2006) index, a firm is considered more financially constrained if it is small and has a high level of sales growth. This means that small and growing firms are generally more financially constrained, but at the same time these firms tend to invest most in the development of new goods and services.

[INSERT FIGURE 4 HERE]

2.2 Financial Distress

Parts of the literature draw a distinction between purely financial and economic distress (cf. Andrade and Kaplan, 1998). It is not straight-forward to distinguish these two types of distress. For the purpose of this paper will not draw this distinction. Altman (1968) assesses a firm's probability of defaulting on its liabilities by using ratio analysis of accounting-based balance sheet data. Ohlson (1980) proposes a similar indicator derived from a conditional logit model also employing accounting-based measures. In his seminal contribution, Merton (1974) proposes an alternative approach by describing a firm's equity as a call option on the value of its assets. Current equity prices help to determine the probability of default incorporating market evaluations in the financial distress assessment. Subsequent research attempts to improve on the accuracy of both accounting and market-based measures or partly combines them (cf. Campbell, Hilscher, and Szilagyi, 2008).

To measure financial distress of firms in this study we employ Altman's Z-score. Altman Z-scores are a linear combination of five financial ratios computed from firms' financial statements and are often used in academic literature because they are intuitive and easy to compute. The exact specification of the Z-score is noted in the appendix. By measuring financial distress we investigate whether the financial crisis 2007-2009 contributes to creative destruction, that is it drives weak businesses out of the market and firms performing badly before the crisis are negatively affected by the crisis. These firms cannot find projects with a positive net present values during the crisis and they reduce their investment. In figure 5 we plot R&D expenditures according to the four quartiles of their level of financial distress measured by Altman’s Z-score. The graphs show that the firms which are least financially distressed (fourth quartile of Altman’s Z-score index), tend to have the highest level of R&D expenditures. However, the pattern for the three lower quartiles does not allow for preliminiary conclusions and we will explore the effect of the financial distress of firms on their investment further on.

[INSERT FIGURE 5 HERE]

In figure 6 we plot our indicators for financial distress and financial constraints over time. Both indicators develop according to intuition in 2008 and 2009 and firms are on average more financially distressed and constrained during the crisis. The simple correlation of the winsorized measures for financial constraints and financial distress is -0.53.

[INSERT FIGURE 6 HERE]

3 Related Literature

Huge scale governmental interventions in the financial sector during the crisis 2007-2009 raise the question whether it is worth spending tax-payers’ money to save big banks and whether the fluctuations in the financial sector are strongly connected to the performance of the non-financial sector. The theories of impaired access to capital build the foundation for a wide range of policy interventions during the crisis, including the Troubled Asset Relief Program implemented in 2008. Some studies have indeed shown theoretically and empirically that fluctuations on financial markets effect the growth of non-financial companies. For example, Duchin et al. (2010), Almeida et al. (2012) and Campello et al. (2010) show that firms reduce capital expenditures due to the negative shocks to credit supply (bank lending supply shocks or credit supply shocks in general). Contradicting these results, other researchers (e.g. Kahle and Stulz (2012); Hetland and Mjos (2012)) find evidence that the lending supply shock is not necessarily the dominant causal factor for financial and investment policies during the crisis and that investment levels of financially constrained firms are not more affected than investment levels of financially unconstrained firms. Below, we describe the aforementioned research in greater detail. First we present evidence supporting the notion that a credit supply shock directly harms investment of firms and subsequently we describe contrary findings.

A branch of research finds evidence that corporate investment, especially of small, bank-related firms or financially constrained firms, declines significantly following the onset of a crisis. This type of studies uses the model of credit rationing of Stiglitz and Weiss (1981) as the theoretical background for its empirical hypothesis. According to the model of credit rationing, the prices at the loan markets are not cleared through the simple price mechanism, but equilibrium at loan markets is characterized by credit rationing. The term credit rationing occurs when among identical loan applicants, some of the applicants receive a loan and others do not. Moreover, the rejected applicants would not receive a loan even if they were ready to pay a higher interest rate. Alternatively, in identical groups of individuals with a given credit supply, some are unable to obtain a loan even though they would be able to do so in case of larger credit supply. Stiglitz and Weiss (1981) emphasize in their conclusions that "in a rationing equilibrium, to the extent that monetary policy succeeds in shifting the supply of funds, it will affect the level of investment, not through the interest rate mechanism, but rather through the availability of credit." These findings are quite plausible since the decrease in credit supply cannot increase the price (the interest rate) of the loan until the supply is equal to demand because increasing interest rates or collateral requirements would increase the riskiness of banks' loan portfolios by inducing the borrowers to invest in the riskier and potentially more profitable projects.

Several empirical studies base their hypothesis on the model of credit rationing and are able to confirm this hypothesis. For example, Duchin et al. (2010) assess the impact of the crisis on investment by regressing firm-level quarterly investment (both capital expenditures and R&D) on a crisis indicator variable, on the interaction of this indicator variable with the firm's cash reserves and on controls for firm fixed effects, Q, and cash flow. They find that the corporate investment declines significantly after the onset of the crisis, especially for firms that have low cash reserves or high net short-term debt, face financially constraints and operate in industries dependent on external finance. Almeida et al. (2012) use a matching approach to compare the evolution of capital expenditures of treated firms relative to their control group during the crisis. They test whether firms with a large fraction of long-term debt maturing during the crisis decrease corporate investment more compared to firms that did not need to refinance a lot of their debt during the crisis. Almeida et al. (2012) find that firms whose long-term debt was maturing right after the third quarter of 2007, cut their quarterly investments rates by 2.5 percentage points more than firms whose debt was due after the crisis. An earlier empirical paper which confirms the theory of impaired access to capital is the paper of Hoshi et al. (1991). They study a sample of Japanese industrial firms and show that the investment of the set of firms that are closely tied to large banks are less sensitive to liquidity constraints than the investment of firms with weak relationships with banks.

However, recent studies question the empirical findings listed above and question the idea that a credit supply shock is the dominant factor for investment policies during the crisis. For instance, Kahle and Stulz (2012) use cross-sectional variation in changes in firm investment and financing policies and investigate whether the credit supply shock is a first-order determinant of changes in investment policies of the firms during the crisis. They consider four channels through which investment levels of firms change during the crisis: 1) bank lending supply shock, which predicts that net debt issuance should fall more for bank-dependent firms; 2) supply of credit in general, which predicts that not just bank-dependent, but credit-dependent firms are affected more during the crisis; 3) the demand shock, which suggests that losses of housing wealth, decrease in consumer credit and panic after the failure of Lehman Brothers in September 2008 led to firms' demand for funding investment; 4) collateral channel or balance sheet multiplier effect, which suggests that capital expenditures of firms are decreased due to the fact that during the crisis, the value of the assets fall and hence the firms have less collateral against which to borrow. To assess these four channels empirically, Kahle and Stulz (2012) use the matching approach of Almeida et al. (2012) and the methodology employed by Duchin et al. (2010). They compare highly levered, bank-dependent firms to firms with similar leverage, but no bank loan or revolver two years prior the crisis. Likewise, they compare a sample of firms with zero leverage two years prior to the crisis (firms not dependent on credit) to a sample of firms with consistently high cash holdings. They do not find support for the view that bank-lending or credit-supply shocks play a major role in decreasing capital expenditures of firms in the last two quarters of 2007 and first two quarters of 2008. Moreover, they do not support the collateral channel or balance sheet multiplier effect on capital expenditures. But they emphasize that during the crisis effects pervasive across firms irrespective of their leverage exist, meaning that a common shock to the demand for firms' products and uncertainty about future demand could lead to a general decrease in capital expenditures that would not depend on financial characteristics of firms.

Hetland and Mjos (2012) empirically show that investment levels of financially constrained firms are not more affected during the crisis. They assess the impact of the crisis 2008-2009 in Norway on non-listed small and medium-sized firms. And in contrast to Duchin et al. (2010) they find that changes in credit availability affect investments most for the least financially constrained firms. They explain their finding stating that financially constrained firms tend to use more cash holdings and other types of crisis hedging instruments than financially unconstrained firms. Hence in the times of the crisis the unconstrained firms experience the largest shock to their investment policies and the effect of financial constraints on real investment is more complex that it has been generally assumed in the literature.

Given the current status of research in the area, it is ambiguous if the non-financial firms decrease investment due to the decrease of the credit supply or due to the fact the economy is in recession and there are not enough investment opportunities. We contribute to the literature and examine the effect of the financial crisis on the real economy.

4 Data and empirical approaches

In their famous capital structure irrelevance principle Modigliani and Miller (1958) state that in the absence of taxes, bankruptcy costs, agency costs, and asymmetric information and in an efficient market, the firm's capital structure is irrelevant to its value. Meaning that the firm's investment decision is independent from its financing decision and external and internal funds are perfect substitutes. Empirical literature that determines the effect of financial constraints on investment departs from the idea that external and internal funds are perfect substitutes.

4.1 Empirical model

Subsequent research demonstrates that external and internal finance are not perfect substitutes in the presence of informational asymmetry, costly monitoring and contract enforcement problems (Majluf and Myers, 1984; Stiglitz and Weiss, 1981; Jensen and Meckling, 1976). External finance is shown to be costlier than internal finance. The wedge between the cost of external and internal finance widens with increasing interest rates, leading to adverse effects on investment. During bank lending supply shocks some borrowers may be constrained from receiving external funds owing to their dependence on banks. Empirical tests of the importance of financial constraints for investment most commonly use two approaches: 1) testing for financial constraints using Q-models or 2) directly estimating the Euler equation for capital stock.

Fazzari et al. (1988) introduce the approach using Q-models. They add proxies for the availability of internal funds to the investment equation and thus assume that the investment rate should not depend on any other variables than average Q (the market value of the firm relative to the replacement value of the capital stock). Cash flow usually proxies for the availability of internal funds in this approach. However, this approach was subject to criticism as cash flow may contain information about future profitability and hence can be correlated with investment demand (opportunities).

The main alternative to using Q models of investment for testing for financial constraints is direct estimation of the Euler equation for the capital stock. The main advantage of this approach is that it does not rely on unobservable measures such as the market value of the firm. The Euler equation is derived from the same maximization problem used to derive Q equations. It replaces the expected values of observable variables with actual values plus an error orthogonal to the predetermined instruments. The structural model by Bond and Meghir (1994) and Bond et al. (2003) is commonly used in this framework. In this model current investment is positively related to expected future investment and a current-average-profit term and negatively related to the user cost of capital. In the empirical work the unobserved expected future investment is replaced by the realized level of investment rate plus a forecast error. The cost of capital term is replaced by the time effects and firm-specific effects. The output/capital ratio can also be introduced in the model to account for the cost of other factors of production; the debt term can be used to control for non-separability between investment and borrowing decisions.

Following Bond et al. (2003) and Brown et al. (2009)) the empirically operational investment equation takes the following form:

$$RD_{i,t} = \alpha_i + \alpha_1 RD_{i,t-1} + \alpha_2 RD_{i,t-1}^2 + \alpha_3 CF_{i,t-1} + \alpha_4 Sales_{i,t-1} + d_t + \epsilon_{it} \qquad (1)$$

Where $RD_{i,t}$ is lagged R&D expenditures for firm *i* in period *t*, $RD_{i,t-1}^2$ quadratic adjustment costs, $CF_{i,t-1}$ is lagged gross cash flow which accounts for the cost of other factors of production under the assumption of constant returns to scale. $Sales_{i,t-1}$ stands for the firm's lagged sales which proxies for the output of the firm. All variables are scaled by the beginning-of-period of firms' assets. The structural model of Bond and Meghir (1994) implies that firm investments should be scaled by the physical capital stock. But it is hard to determine this value in the case of R&D due to the absence of a long time series of R&D expenditures and their rate of depreciation. Thus, we follow Brown et al. (2009) and use a firm's stock of total asset as a scale factor in the regression.

Following Brown et al. (2009) and their basic approach, we include measures of financial constraints (Whited and Wu (2006)) and financial distress (Altman (1968)) and their interaction with the crisis dummy in investment equation (1). The exact specification of the measures is noted in the appendix.

$$\begin{aligned} RD_{i,t} = {} & \\ & \alpha_i + \alpha_1 RD_{i,t-1} + \alpha_2 RD_{i,t-1}^2 + \alpha_3 CF_{i,t-1} + \alpha_4 Sales_{i,t-1} + \alpha_5 Sales_t + \alpha_6 Dum_{Crisis} + \\ & \gamma FD_{it-1} + \gamma_1 Dum_{Crisis} FD_{it-1} + \beta FC_{it-1} + \beta_1 Dum_{Crisis} FC_{it-1} + ind_j + \epsilon_{it} \qquad (2) \end{aligned}$$

where Dum_{Crisis} is an indicator variable that is one during the crisis period and zero otherwise. FC_{it-1} stands for the lagged measure of financial constraints and FD_{it-1} is the lagged measure of financial distress. We also include contemporaneous sales, $Sales_t$, in the model as an additional control for demand. To control for movements in the aggregate cost of capital and tax rates, Bond and Meghir (1994) include time dummies and Brown et al. (2009) use industry level time dummies to control for industry-specific changes in technological opportunities. Since we are only interested in the effect of the crisis period (2008-2009) on investment, we use only the crisis time dummy. To control for the industry-specific changes, we include industry (ind_j) dummies in our model.

Moreover, the structural theoretical model implies that under the null hypothesis of no financial constraints α_1 is positive and slightly larger than one and α_2 is slightly less than minus one. The coefficient of lagged cash flow (α_3) is expected to have a negative sign since it is a proxy of other factors of production. The coefficient of lagged sales (α_4) is expected to be positive since lagged sales proxy for output and should positively affect investment opportunities of firms. We also expect α_5 (the coefficient for contemporaneous sales) to be positive because it proxies for the demand for the firms' goods or services.

4.2 Data

All data is taken from the Compustat U.S. database. We use annual data starting from 1998 and our last observation is from 2012. Brown et al. (2009) distinguish seven high-tech industries, where R&D investment is concentrated: drugs, office equipment and computers, electronic components, communication equipment, scientific instruments, medical instruments, and software. We follow Brown et al. (2009) and use these seven industries (SIC 283, 357, 366, 367, 382, 384 and 737) and drop all firms from other industries. Our sample of firms comprises 1,569 firms and to use all available information we apply an unbalanced panel approach, that is, we use also information if there are no observations in all the years.

The descriptive overview of all our variables is displayed in table 3. Following common practice in the literature, we winsorize all variables at the 1% level. We also exclude observations with negative sales and negative total assets.

[INSERT TABLE 3 HERE]

In figure 7 we plot average R&D for each industry used in this study. In line with our previous discussion, it shows that average scaled R&D expenditures do not decline during 2008-2009 which constitutes the financial crisis period. Figure 7 also highlights that average R&D expenditures are highest in the pharmaceutical industry (SIC 283). We will later on take this into account and check if the results also hold excluding this industry.

[INSERT FIGURE 7 HERE]

5 Empirical Results

5.2 Dynamic panel estimation

According to the structural model of investment of Bond and Meghir (1994) current investment is positively related to expected future investment. This implies that our empirical specification includes the lagged value of the dependent variable. This leads to endogeneity issues in the panel data regression. Additionally, due to the inclusion of a contemporaneous term ($Sales_t$), simultaneity can cause OLS estimates to be biased and inconsistent. Since our panel is characterized by large N and small T, autocorrelation still remains a problem in our regressions. The most commonly used estimators designed to overcome the described problems are the Arellano and Bond (1991) and Arellano and Bover (1995) estimators. We use the Arellano and Bover (1995) system GMM estimator as our primary approach. We treat RD_{t-1}, RD_{t-1}^2 and $Sales_t$ as potentially endogenous.

In the following we estimate the model as described in equation (2). We report both OLS fixed effects and random effects results and the Arellano and Bover (1995) estimation results with two different choices of instruments. The estimates are on display in table 4. The Hausman test confirms that random effects are inconsistent and the results are reported for completeness. The two specifications following Arellano and Bover (1995) differ in the choice of instruments. In the first specification we choose to use instruments only for the dynamic part of the equation and contemporaneous sales whereas the second specification instruments for all included variables. We use the third lag in both specifications. While we encounter problems with overidentification in particular when using instruments for all explanatory variables, the main variables of interest are consistently significant across the different estimations. The problem of overidentification is less severe when we use only lags of three variables ($RD_{i,t-1}, RD_{i,t-1}^2$ and $Sales_t$) as instruments. The p-value of Hansen test (0.167) in this regression indicates not to reject the null hypothesis that the instruments are valid, i.e. uncorrelated with the error term. Thus, we use the results from this regression as a baseline in our analysis.

The estimation results show that the index of financial constraints FC_{t-1} is insignificant in all specifications, meaning that the financial constraints measured by Whited and Wu (2006) index do not have the effect on the R&D expenditures during normal times. However, the coefficient for interaction term between the financial constraints and crisis dummy is positive and significant, suggesting that firms with higher financial constraints invest more during the financial crisis. This result is significant throughout the four specifications presented in table 4. Moreover, the result is in line with our initial predictions based on descriptive statistics as figure

4 shows that firms with the highest financial constraints have the highest level of investment. One of the potential explanations for this result is that R&D expenditures of firms are not affected directly through the frictions in the financial sector, but rather that R&D expenditures are sensitive to the dynamics of demand during economic cycles. Below, we will present some arguments to support this explanation.

First, we further discuss the results presented in table 4. The estimated coefficients conform reasonably well to the Euler equation predictions under the null hypothesis of no financial constraints. In particular, the dynamic effect of lagged R&D is in line with the theoretical predictions discussed in the section 4.1 and the coefficient α_1 from the equation (2) is highly significant and greater than one. The structural model also suggests that the coefficient of quadratic adjustment costs should be greater than minus one. In all our regressions, the coefficients for the adjustment costs are negative and highly significant, although they are never smaller than minus one. The sign of the coefficient for the lagged cash flow is also in line with theoretical predictions, but is not significant. The only result which contradicts the theoretical predictions is the negative sign for the coefficient of the lagged sales. According to theory, this coefficient should be positive since the output of the firm should be positively related to expected future investment. The investment equation of Bond and Meghir (1994) is derived under the null hypothesis of no financial constraints and the estimated coefficients mainly conform with the theoretical predictions. This may suggest that the firms in our sample are not severely financially constrained and that is why Whited and Wu (2006) is even positive in the times of the crisis.

Second, the results are similar to Kahle and Stulz (2012). They investigate access to capital and capital expenditures during the financial crisis 2008-2009 for bank-dependent firms and firms highly levered before the crisis. These firms should be more financially constrained during financial crises due to the negative supply shock, but Kahle and Stulz (2012) find that highly levered firms decrease their capital expenditures during the crisis as much as unlevered firms. Bank-dependent firms do not decrease capital expenditures more than firms that are not dependent on banks in the first years of the crisis and in the two quarters after the Lehman collapse. Thus, they argue that a bank lending shock or a credit supply shock are not first determinates of firm investment and financial policies during the crisis and rather support the demand shock theory. Kahle and Stulz contradict the finding of Brown et al. (2009), who find that access to internal and external finance have a significant effect on R&D investment of young firms, but has no impact on mature firms. Together with the fact that there was no boom in R&D for mature firms, Brown et al. (2009) explain their findings with a shift in supply of finance and argue that it is difficult to explain them with a demand-side story. They do not investigate firms' investment during a financial crisis, but these periods are in particular characterized by the considerable changes in demand and supply. Thus, our results support the findings of Kahle and Stulz (2012) and we argue that demand shock during the recession has greater impact on R&D expenditures. As we saw in figure 1, R&D expenditures are not considerably affected in 2008 when a possible negative supply shock occurred, but are more affected in 2009 when the economy had already been in recession (real GDP growth in the USA dropped to -2.78% in 2009, while it was -0,29% in 2008 according to the data from the Bureau of Economic Analysis). Moreover, the coefficient of contemporaneous sales (proxy for the firms demand) is positive and significant throughout all four specifications. This result suggests that the demand has significant impact on R&D investment of high-tech firms for the period of our study.

In addition, our findings are in line with the findings of Hetland and Mjos (2012) who show that for their sample of non-listed Norwegian firms, credit availability affects investments most for the least financially constrained firms. The suggested explanation is that financially constrained firms use their cash holdings and other means to hedge against future credit market distractions to a greater extent compared to generally less constrained firms that rely more on external financing.

Financially distressed firms are neither economically nor statistically substantially different from non-distressed firms, neither during normal times nor during the financial crisis. This result indicates that the financial distress measured by Altman's Z-scores does not have significant impact on R&D expenditures. While we initially expected to see some effect, we may explain these results with the fact that Altman Z-scores cannot measure purely financial distress, but are a mixed measure of economic and financial distress. As we already control for demand effects our measure for financial distress might not capture enough of the purely financial distress to play a significant role.

[INSERT TABLE 4 HERE]

5.3 Robustness

As a lot of the literature uses capital expenditures to measure corporate investment, we also apply capital expenditures as the dependent variable and apply the model described in equation (2). The results reported in table 5 confirm our previous analysis. The analysis also shows that the dynamic part of the model is not statistically significant in the dynamic panel estimation according to Arellano and Bover (1995). It's not surprising that capital investment is less persistent as adjustment costs are usually much less important. The results illustrate that the result of relatively higher investment of more constrained firms also holds for capital investment during the financial crisis.

[INSERT TABLE 5 HERE]

We additionally extend the crisis period until 2010 as the descriptive statistics show that average R&D were further declining in 2010. Although the financial crisis was arguably over in 2010, it could be argued that the effects might only transmit with a larger delay than we take into account when limiting the crisis period to 2008-2009. The analysis shows that the results are not substantially different.

[INSERT TABLE 6 HERE]

As the descriptive part shows, pharmaceuticals (SIC 283) have a substantially higher level of average R&D expenditures and might drive the results. We thus perform the same analysis excluding all firms with SIC 283. Table 5 shows that the main results are unaffected.

[INSERT TABLE 7 HERE]

As described in section 2.2, an active body of literature discusses how to best measure financial constraints. Hadlock and Pierece (2010) argue that a very simple measure of firm age and size (the so called SA index) best captures financial constraints. They report a correlation of 0.8 with the Whited and Wu index that we use as our primary indicator. In our sample the correlation is much lower (0.4). However, as we show in first two columns of table 2, firms are less financially constrained according to WW index in the sample of large and mature firms. This suggests that WW and SA indices give the same prediction about the level of financial constraints in our sample. The exact specification of the SA index is presented in the appendix.
Replacing the Whited and Wu index by the SA index and estimating our regression as before is depicted in table 8. The main results remain unchanged.

[INSERT TABLE 8 HERE]

We also perform two other robustness tests. First, to test that our results are not affected by the changes in the value of total assets, we use the natural logarithm of all the balance-sheet variables instead of the ratios in the regressions. The results are consistent with our baseline regression, even though we lose some observations as the natural logarithm of a negative value is not defined and many of our variables have negative values (cash flow for example). Second, we test the sensitivity of our results to the magnitude of the coefficients in the index of Whited and Wu (2006). We replace WW index in our regressions with the equally-weighted index. Namely, we replace the coefficients, estimated by Whited and Wu (2006) by equal weights of 0.17. The signs of the coefficients are kept from the original index. Even though, the choice of the weights is quite arbitrary, the results of the estimations are in line with the ones presented previously. However, the magnitude of the main variable of interest is slightly smaller. We present the results of these two robustness check in the Internet appendix.

5.4 Delayed effect of the crisis

R&D expenditures are often planned well in advance. Figure 1 illustrates that the drop in average R&D expenditures only started in 2009 and continued in 2010. This period does not match the financial crisis as few would argue that the financial was still on-going in 2010. This delay can be explained by the following reasons: 1) changes in R&D expenditures are independent from the turbulences in the financial sector; 2) R&D expenditures are affected by the financial crisis, but with a time lag, due to certain peculiarities of planning and accounting. To test this issue we use time dummy for 2009-2010 instead of 2008-2009 in our regressions. If the first explanation holds, we expect our main variable of interest, namely $FC_{t-1}*Dum_{Crisis}$, to be insignificant. In this case, the argumentation for a demand side scenario would be further strengthened. If the second reason is true, we expect $FC_{t-1}*Dum_{Crisis}$ to be negative and significant. And we have more arguments to advocate the supply of funds as a determinant of investment decisions of the firms.

Table 9 shows that the effect of financial constraints is not statistically significant anymore when using 2009 and 2010. This suggests that in 2009-2010 financial constraints were not a determinant of R&D investments.

[INSERT TABLE 9 HERE]

6 Conclusions and discussion

This paper explores the effect of the financial crisis on R&D expenditures of 1,569 publicly traded high-tech firms from 1998 to 2012. We in particular explore the effect of financial constraints and distress on firms' R&D investments. We measure financial constraints by the Whited and Wu (2006) index and distress by Altman's Z-scores. Using a GMM procedure to estimate a dynamic R&D model, we find that financial distress plays a minor role, if any, as a determinant of R&D expenditures during the financial crisis. Financial constraints have a substantial impact on R&D expenditures during the crisis. Everything else equal, more constrained firms invest more during the financial crisis. The result is robust to extending the crisis period, excluding the dominant industry and using an alternative measure for financial constraints. Also the investment patterns for capital expenditures are similar. The significance of the results only disappears if we shift the crisis period to 2009 and 2010 when the financial crisis itself was arguably already over.

While at first sight surprising, our result is consistent with the observation that average R&D expenditures were increasing during the financial crisis. Moreover, the outcome is consistent with the findings of Kahle and Stulz (2012) and Hetland and Mjos (2012) that question whether firms' investment behavior is affected via a supply side shock during the financial crisis. Also, our analysis only takes into account listed firms that tend to have better overall access to financing. A plausible argument for the at first surprising result that financially constraint firms invest more during the crisis is that they are more experienced overcoming such constraints compared to non-constrained firms.

Interpreting the results from a macroeconomic perspective, it becomes evident that the financial crisis has not affected listed technology firms' R&D investment negatively. This finding is evidence that there is not much long-term damage of the financial crisis for innovation and future growth proxied by R&D expenditures. It also supports the argumentation that the financial crisis transmits rather through a demand-side shock than through a supply-side shock.

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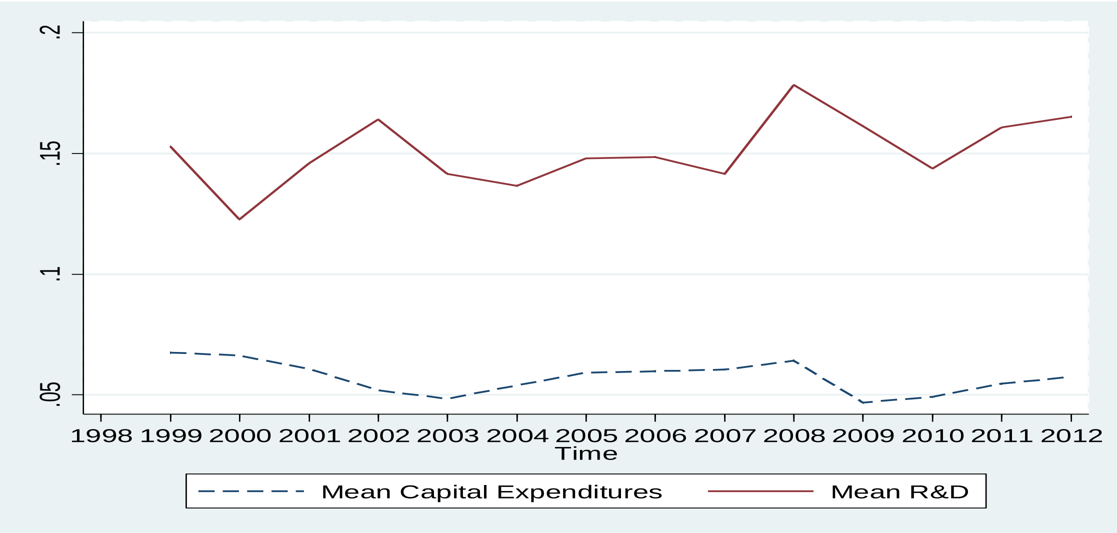
Figure 1

Average Expenditures for Research and Development vs. Capital Expenditures

Panel A: Whole sample

The figure contains all non-financial firms available in the Compustat U.S. database. The dashed line plots yearly averaged capital expenditures and the solid line plots R&D yearly averaged capital expenditures. Both variables are scaled by total assets and winsorized at the 1% level.



Panel B: Technology firms

The dashed line plots yearly averaged capital expenditures and solid line plots yearly averaged R&D expenditures. The figure contains all firms available in the Compustat U.S. database with SIC 283, 357, 366, 367, 382, 384 and 737 as the primary industry classification. Both variables are scaled by total assets and winsorized at the 1% level.

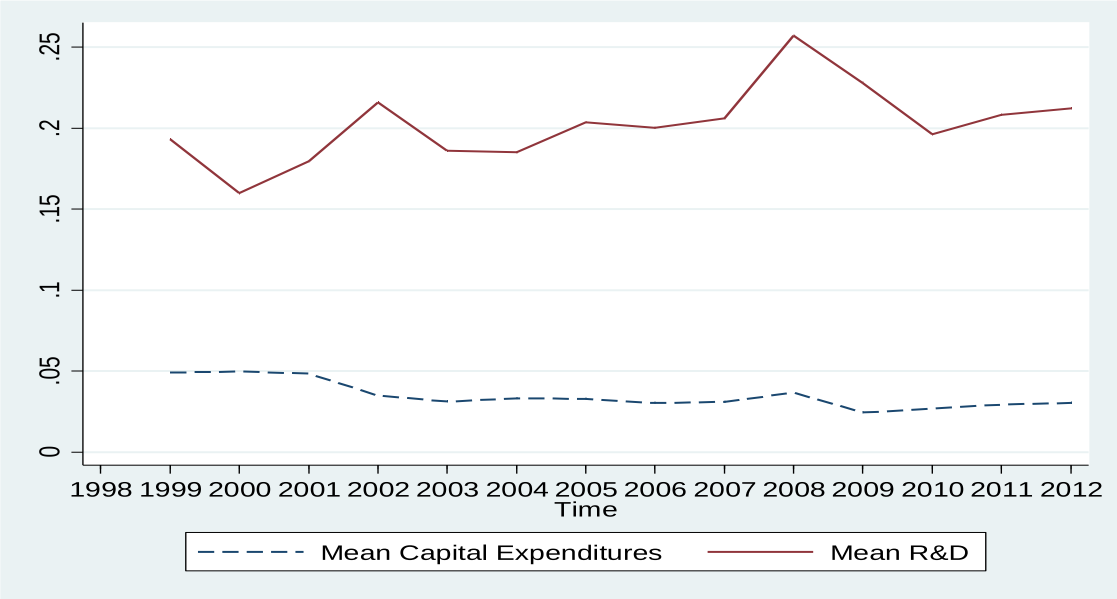


Figure 2

Total Research and Development Expenditures and EBIT over time

The dashed line plots the yearly sum of earnings before interest and taxes (EBIT) and solid line plots the yearly sum of R&D expenditures. The sample contains all firms available in the Compustat U.S. database with SIC 283, 357, 366, 367, 382, 384 and 737 as the primary industry classification.

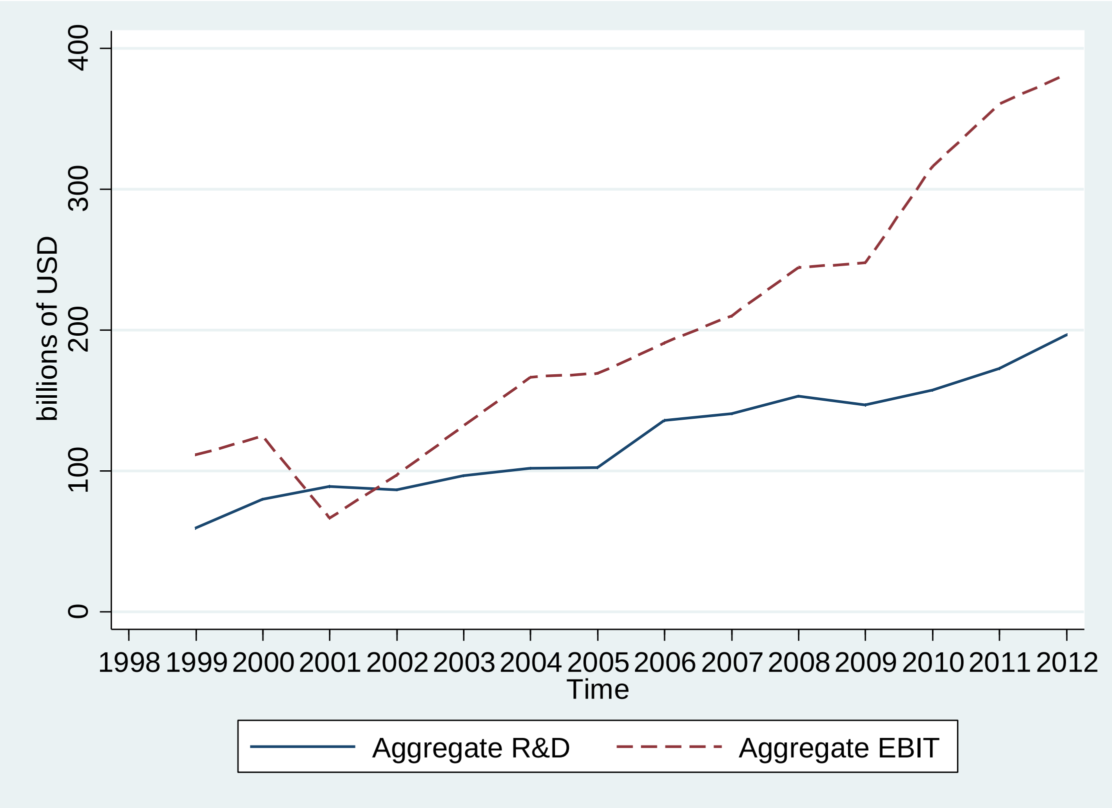


Figure 3

Average Leverage for the sample of high-tech industries and industries excluding high-tech

The solid line pots yearly averaged leverage (Total Debt/Total Assets) for the sample of high-tech firms (with SIC 283, 357, 366, 367, 382, 384 and 737 as the primary industry classification) and the dashed line plot yearly averaged leverage for all other firms, excluding high-tech. The figure contains all firms available in the Compustat U.S. for the period 1998-2012 excluding financial firms and utilities. Variables are winsorized at the 1% level.

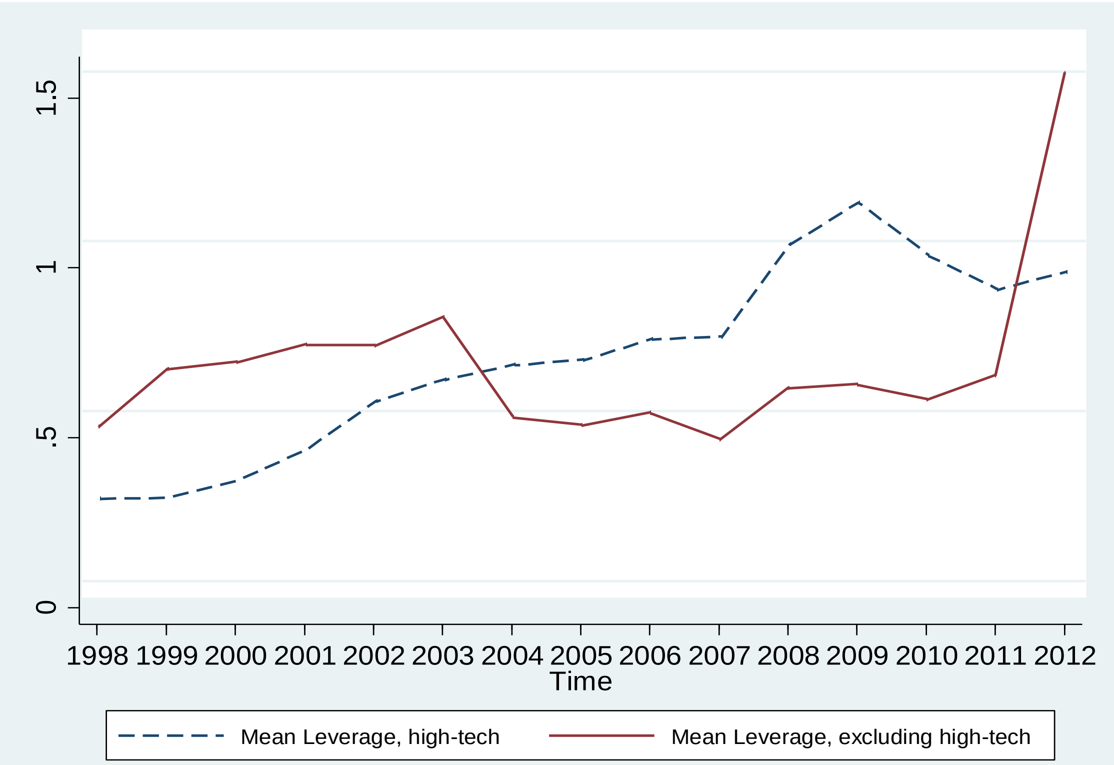


Figure 4

Research and Development Expenditures by four quartiles of financial constraints

The figure plots yearly averaged R&D expenditures grouped by four quartiles of financial constraints. Financial constraints are measured according to Whited and Wu (2006) and firms in the first quartile are least constrained. R&D is scaled by total assets and winsorized at the 1% level. The sample contains all firms available in the Compustat U.S. database with SIC 283, 357, 366, 367, 382, 384 and 737 as the primary industry classification.

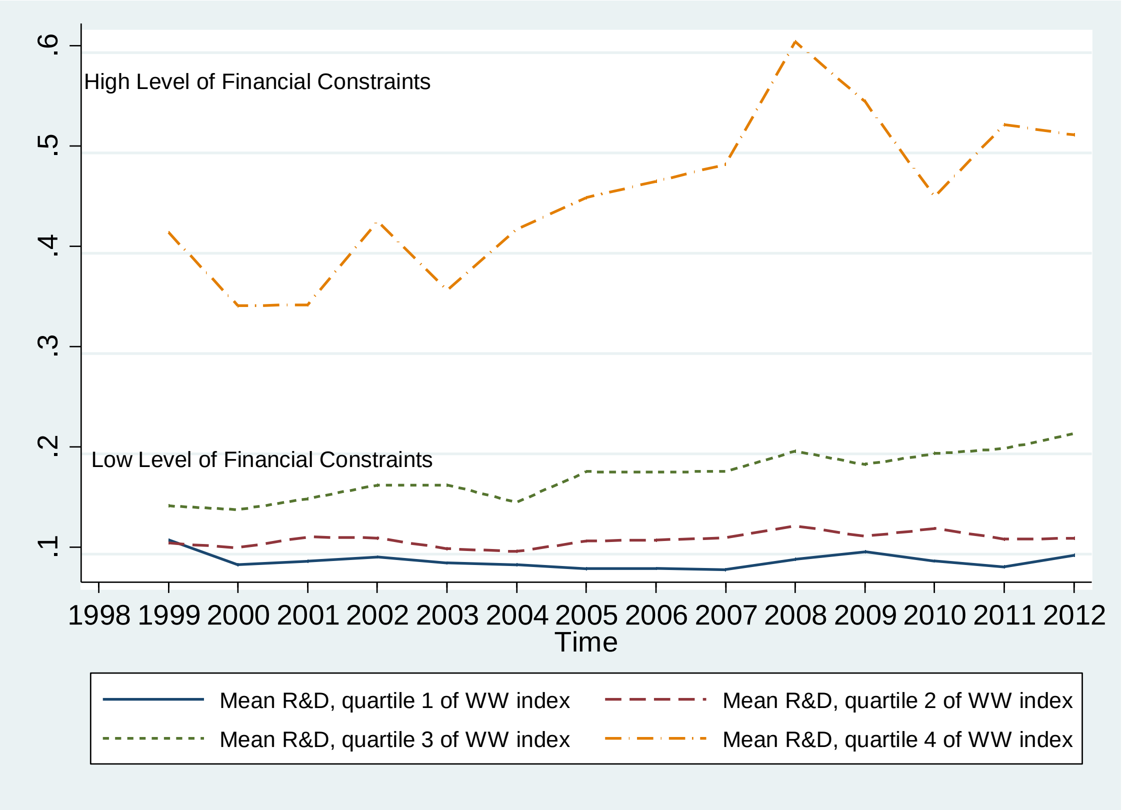


Figure 5

Research and Development Expenditures by four quartiles of financial distress

The figure plots yearly averaged R&D expenditures grouped by four quartiles of financial distress. Financial distress is measured according to Altman (1968) and firms in the first quartile are most distressed. R&D is scaled by total assets and winsorized at 1% level. Altman's Z-scores are also winsorized at the 1% level. The sample contains all firms available in the Compustat U.S. database with SIC 283, 357, 366, 367, 382, 384 and 737 as the primary industry classification.

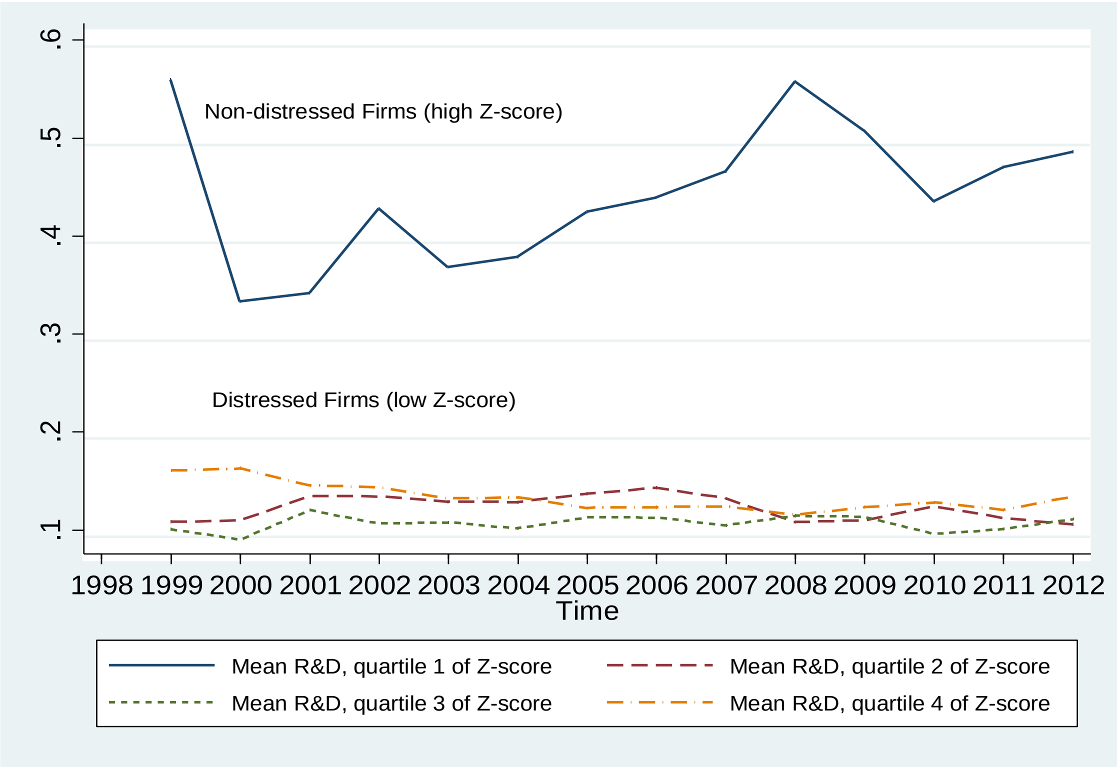


Figure 6

Financial distress and financial constraint indicators over time

The figure plots yearly averaged Altman's Z-score and the Whited and Wu (2006) index. The solid line plots Altman's Z-score and dashed line plots the WW index. Both indicators are normalized and winsorized at the 1% level. The sample contains all firms available in the Compustat U.S. database with SIC 283, 357, 366, 367, 382, 384 and 737 as the primary industry classification.

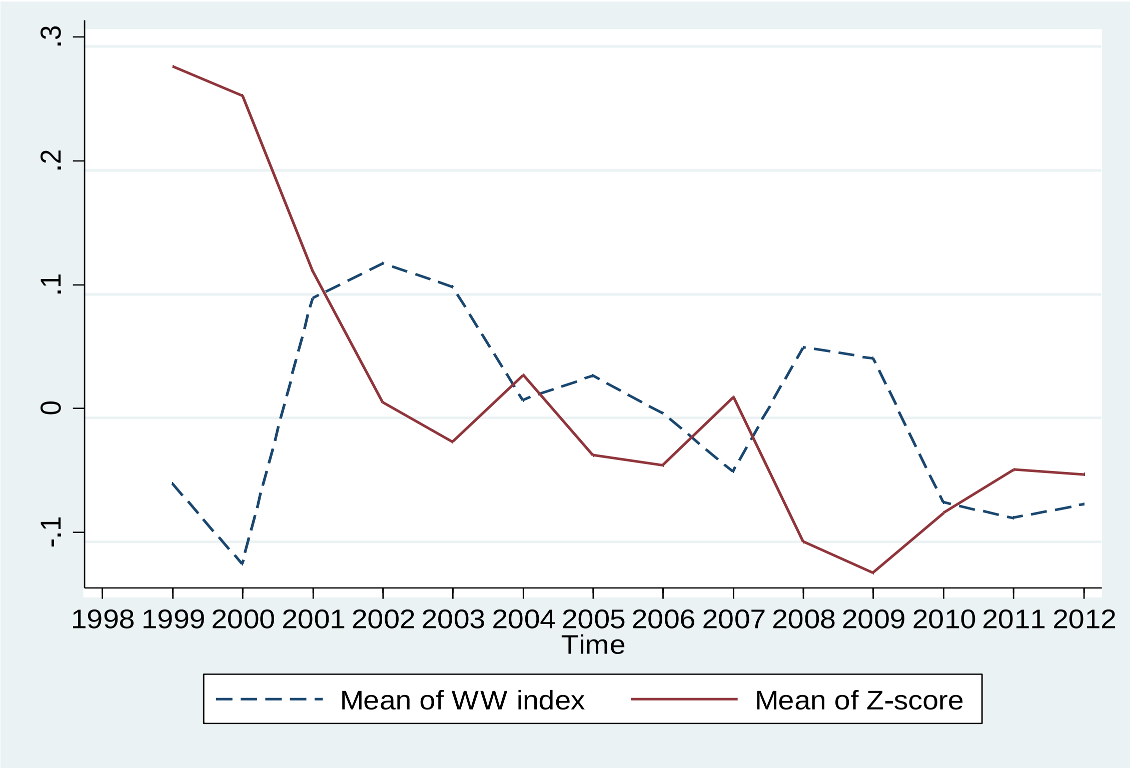


Figure 7

Research and Development Expenditures over time

Each line plots yearly averaged R&D expenditures for the respective industry. R&D is scaled by total assets and winsorized at the 1% level. The sample contains all firms available in the Compustat U.S. database with SIC 283, 357, 366, 367, 382, 384 and 737 as the primary industry classification.

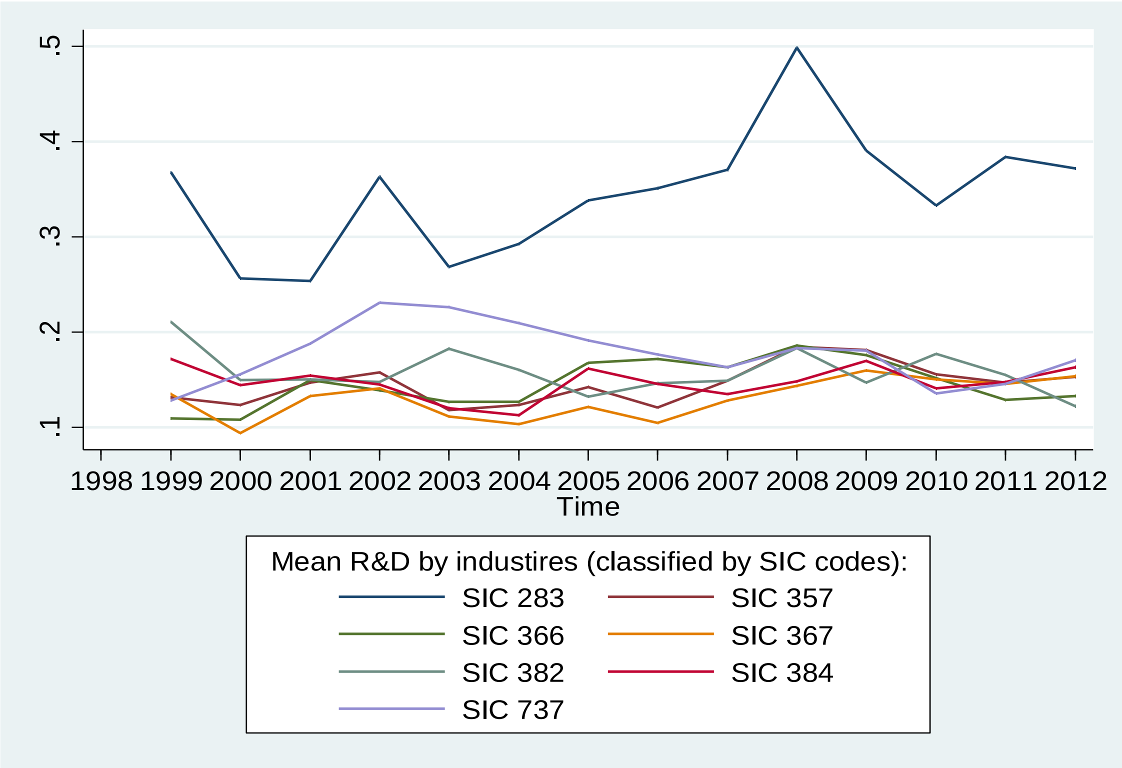


Table 1

Descriptive statistics of Leverage for high-tech and non-high-tech firms

The table reports the following: Panel A reports the percentiles and descriptive statistics for the aggregate value of the leverage for the entire sample of Compustat U.S. database for the period 1998-2012; panel B reports descriptive statistics for the aggregate value of leverage for seven high-tech industries (SIC 283, 357, 366, 367, 382, 384 and 737) and average value of leverage for each high-tech industry for 1998-2012. The variables are winsorized at the 1% level.

Panel A. Leverage: Entire sample

Descriptive Statistics		Percentiles	Leverage (average)
Observations	41,499	25%	0.012
Mean	0.596	50%	0.168
Std. Dev.	16.34	75%	0.346
Variance	266.96	90%	0.585
Min	0	95%	0.892
Max	3,172.48	99%	5.819

Panel B. Leverage: High-tech firms

Descriptive Statistics		SIC	Leverage (average)
Observations	14,589	283	0.558
Mean	0.599	357	0.131
Std. Dev.	4.74	366	1.070
Variance	22.49	367	0.241
Min	0	382	0.345
Max	204.03	384	0.391
		737	0.958

Table 2

Investment, the WW index and its components grouped by small young and large old firms

The table reports descriptive statistics for different groups of firms. The first two columns present mean, standard deviation and number of observations for R&D expenditures, capital expenditures, the WW index and its components for the sample of high-tech firms (SIC 283, 357, 366, 367, 382, 384 and 737) grouped by small and young versus large and mature firms. Small firms are firms with total assets below the median value and young firms are firms with age of 15 years or younger. Large and mature firms are respectively all other firms with total assets greater than the man and older than 15 years. Columns three and four present the same statistics for high-tech firms; all firms excluding high-tech and firms with SIC 490-494 and 600-699 (financial firms and utilities).

Variable	Large and Mature	Small and Young	High-tech	Excluding High-Tech
Research and Development				
observations	9,192	3,787	12,979	12,629
mean	0.146	0.344	0.204	0.054
st.dev	0.221	0.475	0.329	0.195
Capital Expenditures				
observations	10,084	4439	14,523	26,780
mean	0.035	0.033	0.034	0.064
st.dev	0.041	0.054	0.045	0.077
Whited and Wu index				
observations	10,126	4463	14,589	26,912
mean	-0.851	-0.637	-0.785	-0.869
st.dev	0.157	0.228	0.207	0.183
Cash Flow/Total Assets				
observations	10,126	4463	14,589	26,912
mean	-0.168	-2.004	-0.730	-0.348
st.dev	1.887	16.727	9.421	8.316
Long term debt to total assets				
observations	10,126	4463	14,589	26,912
mean	0.150	0.269	0.186	0.224
st.dev	0.884	1.773	1.227	0.765
Total Assets (ln)				
observations	10,126	4463	14,589	26,912
mean	12.266	9.075	11.290	12.510
st.dev	2.315	1.624	2.587	2.646
Industry sales growth				
observations	10,126	4463	14,589	26,912
mean	0.001	0.001	0.001	0.001
st.dev	0.001	0.001	0.001	0.008
Sales Growth				
observations	10,126	4463	14,589	26,912
mean	0.509	1.530	0.821	0.596
st.dev	6.406	15.947	10.319	10.452
Dividends (paid=1, not paid =0)				
observations	10,126	4463	14,589	26,912
mean	0.144	0.011	0.104	0.311
st.dev	0.351	0.105	0.305	0.463

Table 3

Descriptive statistics for the sample of high-tech firms

The table reports the descriptive statistics for all variables used in the regressions (SIC 283, 357, 366, 367, 382, 384 and 737). All variables are winsorized at the 1% level. All balance-sheet variables are scaled by Total Assets. Z-Scores and the Whited and Wu index are normalized in the regressions but reported here as initially computed.

Variable	Observations	Mean	Std. Dev.	Min	Max
Research & Development (RD)	12,979	0.204	0.329	0.000	2.375
Capital Expenditures (CE)	14,523	0.034	0.045	0.000	0.439
Cash Flow (CF)	14,589	-0.501	2.119	-19.052	0.463
Sales	14,589	0.889	0.776	0.000	4.936
Z-Scores (FD)	14,589	-5.630	62.373	-561.336	117.477
Whited and Wu index (FC)	14,589	-0.785	0.207	-1.212	0.099
Total Assets (in million USD)	14,589	1,588.88	7,074.12	0.03	78,862.86

Table 4

Panel estimation results – Research and Development

The table reports results estimating the model described in equation (2). The sample contains all firms available in the Compustat U.S. database with SIC 283, 357, 366, 367, 382 384 and 737 as the primary industry classification. For the dynamic estimation according to Arellano and Bover (1995) we use the third lag in both specifications and apply system GMM. In column three we only instrument for the dynamic part and contemporaneous sales ($RD_{i.t-1}$, $RD^2_{i.t-1}$ and $Sales_t$) and use all other variables directly as instruments. All variables are winsorized at the 1% level. All balance-sheet variables are scaled by total assets. Standard errors robust to heteroscedasticity and with-in firm serial correlation are reported in parenthesis.

	OLS – Random Effects	OLS – Fixed Effects	AB-Dynamic Part Instrumented	AB-All Instrumented
RD_{t-1}	1.052***	0.693***	1.224***	1.224***
	(0.037)	(0.054)	(0.341)	(0.154)
RD_{t-1}^2	-0.251***	-0.175***	-0.416**	-0.273***
	(0.026)	(0.030)	(0.173)	(0.073)
Dum_{Crisis}	0.024***	0.027***	0.051***	0.021***
	(0.006)	(0.006)	(0.020)	(0.006)
FD_{t-1}	-0.000	-0.000	-0.001**	-0.000
	(0.000)	(0.000)	(0.001)	(0.000)
FD_{t-1}* Dum_{Crisis}	0.000	0.000	0.001**	0.001**
	(0.000)	(0.000)	(0.000)	(0.000)
FC_{t-1}	0.010	-0.090	0.034	-0.123
	(0.045)	(0.070)	(0.205)	(0.143)
FC_{t-1}*Dum_{Crisis}	0.029***	0.022***	0.041***	0.031***
	(0.005)	(0.005)	(0.009)	(0.006)
$Sales_{t-1}$	-0.117***	-0.074***	-0.102***	-0.128***
	(0.013)	(0.013)	(0.021)	(0.047)
$Sales_t$	0.129***	0.140***	0.140***	0.153***
	(0.013)	(0.014)	(0.020)	(0.052)
CF_{t-1}	-0.008	-0.001	0.008	-0.027
	(0.009)	(0.010)	(0.016)	(0.019)
357.SIC3	-0.049***		-0.114	-0.074
	(0.010)		(0.626)	(0.218)
366.SIC3	-0.046***		1.173	0.112
	(0.012)		(0.881)	(0.161)
367.SIC3	-0.045***		-0.044	0.006
	(0.008)		(0.395)	(0.120)
382.SIC3	-0.046***		-0.784	-0.129
	(0.011)		(0.824)	(0.139)
384.SIC3	-0.051***		-0.550	-0.172
	(0.009)		(0.501)	(0.156)
737.SIC3	-0.049***		-0.914**	-0.075
	(0.008)		(0.360)	(0.113)
_cons	0.059	-0.044	0.282	-0.087
	(0.041)	(0.061)	(0.288)	(0.150)
Observations	11,378	11,378	11,378	11,378
R2	0.600	0.522		
Instruments			48	145
Hansen(p-value)			0.167	0.002

Standard errors in parentheses. *** , ** and * indicate statistical significance at the 0.01, 0.05 and 0.10 levels, respectively.

Table 5

Panel estimation results – Capital Expenditures

The table reports results estimating the model described in equation (2) replacing R&D expenditures with capital expenditures as the dependent variable and the lagged explanatory variables. The sample contains all firms available in the Compustat U.S. database with SIC 283, 357, 366, 367, 382, 384 and 737 as the primary industry classification. For the dynamic estimation according to Arellano and Bover (1995) we use the third lag in both specifications and apply system GMM. In column three we only instrument for the dynamic part and contemporaneous sales ($CE_{i.t-1}$, $CE_{i.t-1}^{2}$ and $Sales_{t}$) and use all other variables directly as instruments. All variables are winsorized at the 1% level. All balance-sheet variables are scaled by total assets. Standard errors robust to heteroscedasticity and with-in firm serial correlation are reported in parenthesis.

	OLS – Random Effects	OLS – Fixed Effects	AB-Dynamic Part Instrumented	AB-All Instrumented
CE_{t-1}	0.604***	0.371***	0.022	0.449***
	(0.039)	(0.049)	(0.360)	(0.171)
CE_{t-1}^{2}	-1.003***	-0.810***	0.746	-0.542
	(0.208)	(0.231)	(1.551)	(0.727)
Dum_{Crisis}	-0.001	-0.001	0.000	-0.000
	(0.001)	(0.001)	(0.002)	(0.001)
FD_{t-1}	-0.000	0.000	0.000	0.000**
	(0.000)	(0.000)	(0.000)	(0.000)
FD_{t-1} * Dum_{Crisis}	0.000	-0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)
FC_{t-1}	-0.013***	-0.020***	-0.030*	-0.005
	(0.005)	(0.007)	(0.017)	(0.016)
FC_{t-1} * Dum_{Crisis}	0.007***	0.009***	0.009***	0.007***
	(0.001)	(0.001)	(0.002)	(0.001)
$Sales_{t-1}$	-0.004***	-0.003**	-0.003	0.005
	(0.001)	(0.001)	(0.003)	(0.005)
$Sales_{t}$	0.006***	0.006***	0.004	-0.008
	(0.001)	(0.001)	(0.003)	(0.005)
CF_{t-1}	-0.001	-0.001	-0.000	-0.004**
	(0.001)	(0.001)	(0.001)	(0.002)
357.SIC3	-0.002		0.059	-0.043
	(0.001)		(0.111)	(0.037)
366.SIC3	-0.004***		-0.149	-0.017
	(0.001)		(0.096)	(0.025)
367.SIC3	0.010***		-0.004	0.009
	(0.002)		(0.040)	(0.017)
382.SIC3	-0.001		-0.112	-0.015
	(0.001)		(0.140)	(0.024)
384.SIC3	0.002		-0.004	0.013
	(0.001)		(0.082)	(0.028)
737.SIC3	0.001		0.047	0.003
	(0.001)		(0.050)	(0.015)
_cons	0.007*	0.010*	0.015	0.028*
	(0.004)	(0.006)	(0.033)	(0.015)
Observations	12,733	12,733	12,733	12,733
R2	0.227	0.269		
Instruments			48	145
Hansen (p-value)			0.025	0.000

Standard errors in parentheses. *** , ** and * indicate statistical significance at the 0.01, 0.05 and 0.10 levels, respectively.

Table 6

Panel estimation results – Extended crisis period

The table reports results estimating the model described in equation (2). The sample contains all firms available in the Compustat U.S. database with SIC 283, 357, 366, 367, 382, 384 and 737 as the primary industry classification. For the dynamic estimation according to Arellano and Bover (1995) we use the third lag in both specifications and apply system GMM. In column three we only instrument for the dynamic part and contemporaneous sales ($RD_{i.t-1}$, $RD^2_{i.t-1}$ and $Sales_t$) and use all other variables directly as instruments. All variables are winsorized at the 1% level. All balance-sheet variables are scaled by total assets. Standard errors robust to heteroscedasticity and with-in firm serial correlation are reported in parenthesis.

	OLS – Random Effects	OLS – Fixed Effects	AB-Dynamic Part Instrumented	AB-All Instrumented
RD_{t-1}	1.062***	0.693***	1.238***	1.232***
	(0.037)	(0.054)	(0.330)	(0.161)
RD_{t-1}^2	-0.252***	-0.175***	-0.392**	-0.272***
	(0.026)	(0.030)	(0.169)	(0.073)
Dum_{Crisis}	0.010**	0.016***	0.013	0.008
	(0.005)	(0.005)	(0.016)	(0.005)
FD_{t-1}	-0.000	-0.000	-0.001**	-0.001
	(0.000)	(0.000)	(0.001)	(0.000)
FD_{t-1}* Dum_{Crisis}	0.000	0.000	0.001	0.001*
	(0.000)	(0.000)	(0.000)	(0.000)
FC_{t-1}	0.010	-0.093	-0.013	-0.130
	(0.044)	(0.071)	(0.199)	(0.148)
FC_{t-1}*Dum_{Crisis}	0.018***	0.019***	0.027***	0.023***
	(0.005)	(0.005)	(0.010)	(0.006)
$Sales_{t-1}$	-0.118***	-0.074***	-0.103***	-0.142***
	(0.013)	(0.013)	(0.021)	(0.046)
$Sales_t$	0.130***	0.140***	0.145***	0.164***
	(0.013)	(0.014)	(0.020)	(0.051)
CF_{t-1}	-0.008	-0.001	0.011	-0.021
	(0.009)	(0.010)	(0.016)	(0.019)
357.SIC3	-0.046***		-0.164	-0.089
	(0.009)		(0.607)	(0.221)
366.SIC3	-0.043***		1.039	0.132
	(0.012)		(0.865)	(0.157)
367.SIC3	-0.042***		-0.071	-0.010
	(0.008)		(0.387)	(0.121)
382.SIC3	-0.044***		-0.793	-0.120
	(0.010)		(0.813)	(0.144)
384.SIC3	-0.049***		-0.417	-0.157
	(0.008)		(0.473)	(0.166)
737.SIC3	-0.047***		-0.884**	-0.079
	(0.008)		(0.354)	(0.115)
_cons	0.057	-0.045	0.101	-0.047
	(0.041)	(0.062)	(0.292)	(0.154)
Observations	11,378	11,378	11,378	11,378
R^2	0.600	0.520		
Instruments			48	145
Hansen (p-value)			0.010	0.001

Standard errors in parentheses. *** , ** and * indicate statistical significance at the 0.01, 0.05 and 0.10 levels, respectively.

Table 7

Panel estimation results – Excluding pharmaceuticals

The table reports results estimating the model described in equation (2). The sample contains all firms available in the Compustat U.S. database with SIC 283, 357, 366, 367, 382, 384 and 737 as the primary industry classification. For the dynamic estimation according to Arellano and Bover (1995) we use the third lag in both specifications and apply system GMM. In column three we only instrument for the dynamic part and contemporaneous sales ($RD_{i.t-1}$, $RD^2_{i.t-1}$ and $Sales_t$) and use all other variables directly as instruments. All variables are winsorized at the 1% level. All balance-sheet variables are scaled by total assets. Standard errors robust to heteroscedasticity and with-in firm serial correlation are reported in parenthesis.

	OLS – Random Effects	OLS – Fixed Effects	AB-Dynamic Part Instrumented	AB-All Instrumented
RD_{t-1}	1.034***	0.729***	1.368***	1.294***
	(0.056)	(0.081)	(0.328)	(0.164)
RD_{t-1}^2	-0.228***	-0.153***	-0.446***	-0.294***
	(0.040)	(0.047)	(0.153)	(0.082)
Dum_{Crisis}	0.015***	0.014**	0.042***	0.016***
	(0.005)	(0.006)	(0.015)	(0.005)
FD_{t-1}	-0.000	0.000	-0.001	0.000
	(0.000)	(0.000)	(0.000)	(0.000)
FD_{t-1}* Dum_{Crisis}	0.000	0.000	0.001	0.000
	(0.000)	(0.000)	(0.000)	(0.000)
FC_{t-1}	-0.029	-0.137	-0.022	-0.206
	(0.064)	(0.118)	(0.178)	(0.128)
FC_{t-1}*Dum_{Crisis}	0.013***	0.009**	0.019***	0.009
	(0.005)	(0.004)	(0.007)	(0.005)
$Sales_{t-1}$	-0.093***	-0.056***	-0.112***	-0.136***
	(0.015)	(0.015)	(0.020)	(0.035)
$Sales_t$	0.114***	0.119***	0.110***	0.145***
	(0.013)	(0.013)	(0.018)	(0.036)
CF_{t-1}	-0.011	-0.001	-0.001	-0.044***
	(0.011)	(0.013)	(0.014)	(0.014)
366.SIC3	0.006		0.466	0.265
	(0.010)		(0.837)	(0.200)
367.SIC3	0.004		-0.257	-0.043
	(0.007)		(0.413)	(0.172)
382.SIC3	0.004		-0.245	-0.065
	(0.010)		(0.385)	(0.158)
384.SIC3	0.001		-0.343	0.008
	(0.008)		(0.452)	(0.153)
737.SIC3	0.004		-0.697*	0.021
	(0.007)		(0.364)	(0.176)
_cons	-0.031	-0.116	0.323	-0.221
	(0.060)	(0.102)	(0.391)	(0.215)
Observations	8655	8655	8655	8655
R^2	0.617	0.551		
Instruments			48	145
Hansen (p-value)			0.030	0.005

Standard errors in parentheses. *** , ** and * indicate statistical significance at the 0.01, 0.05 and 0.10 levels, respectively.

Table 8

Panel estimation results – Alternative measure of financial constraints

The table reports results estimating the model described in equation (2) replacing the Whited and Wu index with the SA-Index. The sample contains all firms available in the Compustat U.S. database with SIC 283, 357, 366, 367, 382, 384 and 737 as the primary industry classification. For the dynamic estimation according to Arellano and Bover (1995) we use the third lag in both specifications and apply system GMM. In column three we only instrument for the dynamic part and contemporaneous sales ($RD_{i.t-1}$, $RD^2_{i.t-1}$ and $Sales_t$) and use all other variables directly as instruments. All variables are winsorized at the 1% level. All balance-sheet variables are scaled by total assets. Standard errors robust to heteroscedasticity and with-in firm serial correlation are reported in parenthesis.

	OLS – Random Effects	OLS – Fixed Effects	AB-Dynamic Part Instrumented	AB-All Instrumented
RD_{t-1}	1.045***	0.675***	1.029***	1.374***
	(0.037)	(0.053)	(0.296)	(0.150)
RD_{t-1}^2	-0.248***	-0.169***	-0.347**	-0.367***
	(0.025)	(0.029)	(0.167)	(0.080)
Dum_{Crisis}	0.027***	0.027***	0.056***	0.021***
	(0.006)	(0.006)	(0.020)	(0.006)
FD_{t-1}	-0.000*	-0.000	-0.001*	-0.000
	(0.000)	(0.000)	(0.001)	(0.000)
FD_{t-1}* Dum_{Crisis}	0.000	0.000	0.001**	0.001*
	(0.000)	(0.000)	(0.000)	(0.000)
FC_{t-1}	0.035***	-0.026	0.147	-0.008
	(0.010)	(0.017)	(0.116)	(0.022)
FC_{t-1}*Dum_{Crisis}	0.006***	0.006***	0.007***	0.007***
	(0.001)	(0.001)	(0.002)	(0.001)
$Sales_{t-1}$	-0.116***	-0.074***	-0.095***	-0.154***
	(0.013)	(0.013)	(0.020)	(0.048)
$Sales_t$	0.130***	0.139***	0.144***	0.152***
	(0.013)	(0.014)	(0.021)	(0.051)
CF_{t-1}	-0.007	0.003	0.007	-0.019
	(0.007)	(0.009)	(0.016)	(0.017)
357.SIC3	-0.049***		0.044	-0.161
	(0.009)		(0.655)	(0.200)
366.SIC3	-0.044***		0.779	0.084
	(0.012)		(0.797)	(0.168)
367.SIC3	-0.043***		-0.046	0.013
	(0.008)		(0.405)	(0.123)
382.SIC3	-0.042***		-0.935	0.035
	(0.011)		(0.785)	(0.142)
384.SIC3	-0.050***		-0.931*	-0.149
	(0.009)		(0.508)	(0.148)
737.SIC3	-0.052***		-0.827***	-0.028
	(0.008)		(0.311)	(0.112)
_cons	0.176***		0.869*	-0.031
	(0.036)		(0.459)	(0.102)
Observations	11,378	11,378	11,378	11,378
R2	0.603	0.512		
Instruments			48	145
Hansen(p-value)			0.115	0.001

Standard errors in parentheses. *** , ** and * indicate statistical significance at the 0.01, 0.05 and 0.10 levels, respectively.

Table 9

Panel estimation results – Delayed effect of the crisis

The table reports results estimating the model described in equation (2). The sample contains all firms available in the Compustat U.S. database with SIC 283, 357, 366, 367, 382, 384 and 737 as the primary industry classification. For the dynamic estimation according to Arellano and Bover (1995) we use the third lag in both specifications and apply system GMM. In column three we only instrument for the dynamic part and contemporaneous sales ($RD_{i.t-1}$, $RD_{i.t-1}^2$ and $Sales_t$) and use all other variables directly as instruments. Standard errors robust to heteroscedasticity and with-in firm serial correlation are reported in parenthesis. The dummy variable for the financial crisis comprises 2009 and 2010.

	OLS – Random Effects	OLS – Fixed Effects	AB-Dynamic Part Instrumented	AB-All Instrumented
RD_{t-1}	1.055***	0.699***	1.527***	1.244***
	(0.037)	(0.055)	(0.310)	(0.162)
RD_{t-1}^2	-0.252***	-0.177***	-0.473***	-0.265***
	(0.026)	(0.030)	(0.154)	(0.074)
Dum_{Crisis}	-0.021***	-0.011**	-0.057***	-0.021***
	(0.005)	(0.005)	(0.016)	(0.006)
FD_{t-1}	-0.000	-0.000	-0.001	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)
FD_{t-1} * Dum_{Crisis}	-0.000	-0.002	-0.001	-0.003
	(0.001)	(0.002)	(0.002)	(0.004)
FC_{t-1}	0.014	-0.087	-0.149	-0.141
	(0.046)	(0.071)	(0.179)	(0.151)
FC_{t-1}*Dum_{Crisis}	-0.006	-0.018	-0.011	-0.023
	(0.012)	(0.019)	(0.017)	(0.033)
$Sales_{t-1}$	-0.118***	-0.075***	-0.109***	-0.130***
	(0.013)	(0.013)	(0.021)	(0.042)
$Sales_t$	0.130***	0.141***	0.146***	0.150***
	(0.013)	(0.014)	(0.018)	(0.047)
CF_{t-1}	-0.008	-0.000	0.008	-0.022
	(0.009)	(0.010)	(0.015)	(0.020)
357.SIC3	-0.049***		-0.079	-0.181
	(0.009)		(0.562)	(0.224)
366.SIC3	-0.046***		0.800	0.146
	(0.012)		(0.831)	(0.155)
367.SIC3	-0.045***		-0.088	0.036
	(0.008)		(0.363)	(0.120)
382.SIC3	-0.047***		-0.471	-0.172
	(0.011)		(0.773)	(0.141)
384.SIC3	-0.051***		-0.060	-0.116
	(0.009)		(0.427)	(0.170)
737.SIC3	-0.049***		-0.705**	-0.076
	(0.008)		(0.322)	(0.120)
_cons	0.064	-0.038	-0.008	-0.098
	(0.042)	(0.062)	(0.269)	(0.166)
Observations	11,377	11,377	11,377	11,377
R2	0.600	0.519		
Instruments			48	145
Hansen(p-value)			0.037	0.002

Standard errors in parentheses. *** , ** and * indicate statistical significance at the 0.01, 0.05 and 0.10 levels, respectively.

Appendix

Altman Z-scores

$$Z = 0.012WC_{it} + 0.014RE_{it} + 0.033EBIT_{it} + 0.006MVTL_{it} + 0.999SA_{it}$$

Here WC_{it} is working capital/total assets. RE_{it} represents retained earnings/total assets. $EBIT_{it}$ stands for earnings before interest and taxes/total assets. $MVTL_{it}$ represents the market value equity/book value of total liabilities and SA_{it} stands for sales/total assets.

Whited and Wu Index

$$-0.091CF_{it} - 0.062DIVPOS_{it} + 0.021TLTD_{it} - 0.044LNTA_{it} + 0.102ISG_{it} - 0.035SG_{it}$$

Here CF_{it} is the ratio of cash flow to total assets. $DIVPOS_{it}$ represents an indicator that is one if a firm pays cash dividends and zero otherwise. $TLTD_{it}$ is the ratio of long term debt to total assets. $LNTA_{it}$ is the natural log of total assets. ISG_{it} is the firm's three digit industry sales growth and SG_{it} is the firm's sales growth.

SA Index

$$SA = -0.737Size_{it} + 0.043Size_{it}^2 - 0.040Age_{it}$$

Size equals the log of inflation-adjusted book assets. Age is the number of years the firm is listed with a non-missing data entry in Compustat. Size is winsorized at (the log of) $4.5 billion. Age is winsorized at thirty-seven years.

The Impact of the Financial Crisis on Innovation and Growth: Evidence from Technology Research and Development

EMANUEL ALFRANSEDER | VALERIIA DZHAMALOVA

An increasing body of literature discusses how and to which extent the financial crisis of 2007-2009 transmits to the real economy. This paper investigates the impact of the financial crisis of 2007-2009 on corporate investment, in particular research and development (R&D) expenditures. We measure financial constraints and financial distress of firms and investigate whether those measures have a significant impact on R&D during the financial crisis. We find evidence that financial distress has little impact for our sample of listed technology firms and we argue that the credit supply shock does not play a decisive role as financially constrained firms invest comparatively more than non-constrained firms during the crisis.

Keywords: Financial Constraints, Financial Distress, Financial Crisis, R&D, Investment

JEL: G31, G32, G33

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LUND UNIVERSITY
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Working paper 2014:8
The Knut Wicksell Centre for Financial Studies
Printed by Media-Tryck, Lund, Sweden 2014