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Young Innovative Firms, Investment-Cash Flow Sensitivities and Technological Misallocation *

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Abstract

Can technological misallocation generate financial frictions? We build a theoretical model with testable implications, in which the misallocation between R&D and production activities generates borrowing constraints. The investor offers the innovator a rent that is contingent to the success of its project in order to make them exert an incentive-compatible effort level. However, this rent distorts the allocation of effort between activities. Specifically, it leads to a suboptimal level of effort impulsing a reallocation of resources from production to R&D. Consequently, the investor cannot appropriate the surplus resulting from innovation. This distortion increases the cost of external financing for firms that have large amount of intangible assets. Using Compustat data for manufacturing firms in the United States between 1982 and 2007, we show that cash-flow sensitivities are positive and increasing in firms with high R&D intensities.

Key Words: Moral Hazard, Endogenous Borrowing Constraints, and Technological Misallocation

JEL Codes: G11, 033, D86 Introduction

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1 Introduction

Recently the study of young innovative companies has gained attention in the literature (Czarnitzki and Delanote (2013); Audretsch et al. (2014); Coad et al. (2016)). The Industrial Organization framework has shown that these firms are responsible for an important share of output growth and job creation (Haltiwanger et al. (2013);Lawless (2014)). This fact has impulsed the development of policy initiatives to increase the number of young leading innovators, especially in European countries in which the number of young innovative firms is far behind the US. Arguably the major difficulty faced by young firms is the existence of barriers to post-entry growth relating with borrowing constraints.

There is an ample literature studying the nexus between financial constraints and economic growth. However, only a small number of papers study how and to what extent technological factors matter for endogenous borrowing constraints (credit rationing). The existence of informational asymmetries between investors and entrepreneurs may play an important role in this relation. This paper presents a theoretical model where an entrepreneur allocates effort between standard production activities and R&D projects. Task substitutability is imperfect and to begin a production process the entrepreneur requires investment which is financed from internal resources (i.e. cash flow) or external funds provided by an investor. Production is stochastic and proportional to the level of investment. The entrepreneur privately observes innovations that increase production. This informational asymmetry creates a distortion in the allocation of effort between production and R&D activities and therefore increase the cost of external financing.

We show that in equilibrium a suboptimal level of effort is devoted to each activity. In this asymmetrical information setup, the investor uses the repayment to align the entrepreneur's incentives. We find that effort levels and repayment are positively correlated with the size of the innovation, while the sensitivity of cash flows to investment is positively associated with changes in the size of innovations. In this model the endogenous borrowing constraint is measured by the difference between investment levels under full and asymmetric information. As a result, the size of innovations relates negatively to the degree of borrowing constraints.

Our paper builds over the seminal papers of Stiglitz and Weiss (1981) and Jensen and Meckling (1976), which show that information asymmetries may lead to credit rationing and misallocation in the loan market. However, in contrast to these papers, in our model the entrepreneur has private information about the effort exerted in the different productive activities and financial frictions arise due to the misallocation of effort between these activities within the firm.

We test the theoretical implications of our model using Compustat data for the period 1982-2007. The substitutability parameter is difficult to capture directly from the data. Hence, we use our theoretical finding indicating that it is positively correlated with R&D intensities. In this sense, we first test the effect of R&D investment on the sensitivity of cash flows to investment in physical capital. As predicted by our model, we find a positive effect of cash flows on investment, indicating that internal and external sources of funding are not perfectly substitutable (as in Fazzari et al. (1988)). Additionally, this effect increases as firms become more R&D intensive, showing that highly innovative firms face higher financial constraints than otherwise similar companies.

Our contributions to the literature are two-folded. On the one hand, we provide a theoretical model predicting that financial constraints are tighter for innovative firms. On the other hand, we provide empirical evidence supporting this prediction. Particularly, we show that cash flows matter for investment and, more importantly, that they matter more for more innovative firms.

The remaining of the paper is organized as follows: In Section 2, we do a brief survey of the related literature. Section 3 presents a model in which there are endogenous borrowing constraints and optimal investment in R&D. In Section 4 our empirical strategy and main estimation results are described. Finally, the last section concludes.

2 Related Literature

Financial markets efficiency cannot be taken for granted, as informational asymmetries may generate important friction, such as credit rationing (Stiglitz and Weiss (1981)) and misallocations in loan markets (Jensen and Meckling (1976)). Several empirical papers study the role of informational asymmetries in investment decisions. Hu and Schiantarelli (1998) develops an investment switching model to differentiate between firms with weak balance sheets and those facing problems of asymmetric information. Specifically, the paper studies the case in which external and internal sources of finance are not perfectly substitutable, as in Fazzari et al. (1988). Generally speaking, informational imperfections in credit markets imply that external finance is more expensive when debt is not fully collateralised, and its premium is inversely related to the borrower's net worth.[1]. Given this issue, firms optimally

[1]See Bernanke and Gertler (1990),Kiyotaki and Moore (1997)

determine their cash holdings by comparing their marginal cost to the cost of obtaining external financing for the development of new projects (see, for instance, Kim et al. (1998)).

Determining how likely a firm is of facing financial constraints is of outmost importance. In this sense, Almeida et al. (2004) propose a taxonomy based upon five classification criteria. They are: the firm's dividend payout policy [2], its asset size, its bond ratings, its commercial paper ratings and its Kaplan and Zingales (KZ) index.[3]They show that, for the first four criteria, the marginal propensity to save cash out of cash inflows is positive and significant for firms that are more likely to face financial constraints, and not significantly different from zero for financially unconstrained firms. They also find empirical evidence that financially constrained firms increase their cash holdings when facing macroeconomic shocks or a downturn in the business cycle, while unconstrained firms do not.

Although the KZ index has been widely used in the empirical literature, interpretation of its results must be cautiously done. Whited and Wu (2006) construct a new index and show its advantages over the KZ. Using their classification, the authors show that firm-level external financing constraints are a source of undiversifiable risk that is recognised by the market and make financially constrained firms subject to higher borrowing costs.

Faulkender and Wang (2006) report some other implications of financing constraints for investment. Their study shows that firms that are subject to financial frictions have a higher marginal cash value than unconstrained companies. Pinkowitz and Williamson (2007) show that R&D-intensive firms have a higher market value per marginal dollar of cash. The study of Almeida and Campello (2007) uncovers evidence of a credit multiplier effect where investment–cash flow sensitivities are affected by asset tangibility. Using a difference-in-differences methodology, they compare the effects of asset tangibility on financially constrained and unconstrained firms and show the a statistically different effect of cash flows on constrained and unconstrained firms.

Acharya et al. (2007) show that, in general, firms with high hedging needs are more likely to implement precautionary cash accumulation than increase debt capacity. A similar study by Guariglia (2008) applies an error-correction specification model to analyse the sensitivity of investment to cash flow where there are internal and external financial constraints. It finds

[2]Payout policy is the cash that the firm return to their shareholders through dividends and the repurchase of shares.

[3]The KZ index is defined as: -1.001909 x Cash Flows /(Property plant and equipment) + 0.2826389 x Q + 3.139193 x Debt / Total Capital -39.3678 x Dividends / (Property plant and equipment) -1.314759 x Cash /(Property plant and equipment). The Tobint́s Q is labed as Q and represents the ration between firmt́s market value and its asset value. For more details see Kaplan and Zingales (1997).

that when the sample is categorised according to internal financial criteria, the relationship between investment and cash flow is U-shaped. On the other hand, when firms are categorised based on external financial constraints there is a monotonically increasing relationship. Other studies, such as Kim and Weisbach (2008) show how high cash holdings and R&D investment may motivate equity offers.

Brown et al. (2009) show how the availability of stock issues, and booms and busts help explain R&D investment. Similarly, Brown and Petersen (2011) argues that the sharp increase in R&D in recent decades has important implications for corporate liquidity management. The authors study whether firms use cash flow reserves to smooth their R&D expenditure during transitory shocks, given the high adjustment costs for highly skilled technology workers. They use panel data for publicly traded firms in the United States manufacturing sector for the years 1970–2006, and estimate dynamic R&D models to study the management of cash flow and cash reserves for R&D smoothing. Taking the firm's age as a proxy for financial constraints, they sort firms according to the likelihood of facing binding constraints. Their principal finding is that there is a negative coefficient between changes in cash holdings in R&D regressions for firms that are likely to face financial frictions. The coefficient is very close to zero for firms that are less likely to face these issues. This shows how corporate liquidity directly affects real investment. Borisova and Brown (2013) find a robust positive link between cash inflows from fixed asset sales and R&D investment in firms subject to financial constraints; this is evidence of the significant impact of financial frictions on R&D investment.

3 The Model

Consider the case where there is an entrepreneur who invests resources in both production and R&D. Endogenous borrowing constraints arise due to moral hazard, given the fact that the entrepreneur chooses a level of effort for each activity and this is unobservable to the investor. When an innovation occurs the entrepreneur has an incentive to allocate more effort to R&D activities and reduce the repayment to the investor, which creates a conflict of interest.

3.1 Environment, Preferences, and Technology

The economy is composed by an entrepreneur and an investor[4]. The entrepreneur simultaneously carries out production and R&D activities and requires initial resources to start the production process. In particular, there is a level of investment I and a level of effort e_1 that is not contractible with $e_1 \in [0,1]$. R&D inputs are immaterial ideas that reflect the agent's human capital and their effort level $e_2 \in [0,1]$.. The entrepreneur holds cash denoted by A, with $A < I$. They can be invest this cash holdings in production or R&D.

Production is a stochastic process and can take two values, I or zero, which reflect, respectively, success or failure. Additionally, the entrepreneur privately observes an innovation opportunity that can increase production to μI, where μ is the size of the innovation in terms of output, and $\mu > 1$. Therefore, the innovation opportunity takes two values: μI or zero. In this context, R&D investments correspond to the allocation of resources devoted to increase production. Note that the two activities are dependent; this means that if production fails, R&D activities serve no purpose.

The probability of zero revenue is $1 - e_1$.[5] The probability that production is successful but R&D is not, is given by $e_1 (1 - e_2)$; in this case revenue is I. The case of success in both activities occurs with probability $e_1 e_2$, generating revenue of μI. Total expected output is equal to the expected production plus the expected outcome in the event of innovation, as follows:

$$\tilde{y} = I e_1 \left(1 + e_2 \left(\mu - 1\right)\right) \tag{1}$$

Exerting effort in both activities is costly. The cost function is proportional to the level of investment (Holmstrom and Tirole (1997)) and is given by:

$$c\left(e_1, e_2\right) = I \left[\frac{1}{2}\left(e_1^2 + e_2^2\right) + \gamma e_1 e_2\right] \tag{2}$$

Where γ measures substitutability between production and R&D activities. In other words, as γ increases, substitutability between activities increases. The aggregate level of

[4]We focus on monopolistic investor since we want to characterise the relationship between an innovative entrepreneur and a joint-venture. Note that in joint ventures the venture capitalist resembles a stock holder rather than a lender. The low value value of collateral held by innovators makes this type of contract better than a debt contract.

[5]Note that the investment will obtain a zero revenue whenever production is unsuccessful, regardless of the occurrence of the innovation.

effort is given by $e = e_1 + e_2$. The entrepreneur is risk-neutral, and their profits are described as follows:

$$\pi^E = Ie_1\left(1 - R\right) + Ie_1e_2\left(\mu - 1\right) - I\left[\frac{1}{2}\left(e_1^2 + e_2^2\right) + \gamma e_1e_2\right] - A \tag{3}$$

In [3], the first term corresponds to the net outcome expected from the repayment to investor, R. I assume that the repayment function is linear on the outcome, such as shares of the expected return. The second term is the expected return on innovation. The third term corresponds to the cost function and A is the cash flow allocated to production. Note that the reimbursement rate is not applied to the R&D return. This is because the latter comes from an immaterial idea that can be used in other innovation projects, but is not directly observed in the production return.

The investor is also risk-neutral and their profits are described by:

$$\pi^I = Ie_1R - (I - A) \tag{4}$$

The investor derives profit from the repayment e_1IR minus the resources $I - A$ lent to the entrepreneur.

Timing

The timing of the production process is as follows:

1. The investor proposes a repayment R to the entrepreneur in exchange for an amount of resources $(I - A)$.

2. The entrepreneur accepts or refuses the contract.

3. The entrepreneur exerts a level of effort in production e_1 and in R&D activity e_2. This effort levels are private information of the investor.

4. The outcome is realized in production and R&D.

5. The contract is executed.

3.2 First-Best : The Full Information Case

In order to have a benchmark with which to compare the equilibrium results in the presence of informational asymmetries, we begin by studying the full information case in which the effort levels exerted by the investor are public information. Throughout we assume that $(\mu - 1) - \gamma > 0$. We call this quantity a, and hence we focus in interior solutions for e_1, e_2. The objective of the investor is to maximise the social value of the project $\pi = \pi^E + \pi^I$. The problem to solve is:

$$\max_{e_1,e_2,I} Ie_1 + Ie_1e_2(\mu - 1) - I\left[\frac{1}{2}\left(e_1^2 + e_2^2\right) + \gamma e_1 e_2\right] - A$$

The first order conditions of this problem are:

$$[e_1] : \qquad 1 + e_2 a = e_1 \tag{5}$$

$$[e_2] : \quad e_1 a = e_2 \tag{6}$$

Both equations require that the marginal benefit of each activity equals the marginal cost in terms of effort. In addition, we see that the effort given to each activity is positively related to its own return and negatively related to the effort given to the other activity. The socially efficient level of output for each activity is given by:

$$e_1^* = \frac{1}{1 - a^2} \tag{7}$$

$$e_2^* = \frac{a}{1 - a^2} \tag{8}$$

The concavity of the program collapses to the the condition $0 < a < 1$. Notice that e_1^* and e_2^* are increasing in a which itself is increasing with μ. The social surplus is given by:

$$\pi^* = \frac{1}{2}\frac{I^*}{1 - a^2} - A \tag{9}$$

The social surplus is also increasing with respect to the size of the innovation and negatively related with the degree of correlation between the projects.

3.3 R&D Investment under Moral Hazard

In this subsection we analyse the case where the effort is non-observable by the investor. A conflict of interest arises as the entrepreneur decides the level of effort in the project, and the investor cannot distinguish between the effort given to different activities. They only observe output levels.

The contract specifies the share of the return repaid to the venture capitalist agreed by the parties. Resources are allocated according to the level of effort exerted in each activity. The optimal contract is a solution to the following maximization problem:

$$\max_{R} Ie_1R - (I - A) \tag{10}$$

Subject to the incentive compatibility and participation constraints

$$e_1, e_2 \in \arg\max\ _{\tilde{e}_1,\tilde{e}_2} I\tilde{e}_1 (1 - R) + I\tilde{e}_1\tilde{e}_2 (\mu - 1) - I \left[\frac{1}{2}\left(\tilde{e}_1^2 + \tilde{e}_2^2\right) + \gamma\tilde{e}_1\tilde{e}_2\right] - A \tag{11}$$

$$\pi^E = Ie_1 (1 - R) + Ie_1e_2 (\mu - 1) - I \left[\frac{1}{2}\left(e_1^2 + e_2^2\right) + \gamma e_1e_2\right] - A \geq 0 \tag{12}$$

Levels of effort in production and R&D that are incentive compatible (denoted by IC) are given by:

$$e_1^{IC} = \frac{(1 - R)}{1 - a^2} \tag{13}$$

$$e_2^{IC} = \frac{a (1 - R)}{1 - a^2} \tag{14}$$

Note from above that the equilibrium levels of effort correspond to the socially optimal levels multiplied by$(1 - R)$,and hence the former are smaller than the latter. In other words, effort levels under asymmetric information are suboptimal. We then solve the investor's problem, equation 10, to get the optimal repayment:

$$R^{sb} = \frac{1}{2} \tag{15}$$

We obtain the second-best effort level for each activity:

$$e_1^{sb} = \frac{1}{2(1-a^2)} \tag{16}$$

$$e_2^{sb} = \frac{a}{2(1-a^2)} \tag{17}$$

The reasoning for this result is the following. To encourage the entrepreneur to exert effort, the investor needs to provide rent in the case of success. This rent distorts the allocation of effort between activities. Specifically, it reduces the effort given to the final production with respect to the first-best result and leads to the reallocation of resources from production to R&D. Consequently, the investor cannot appropriate the surplus resulting from the innovation. On the top of that, the economy is better-off as the size of innovation increases.

Endogenous Borrowing Constraints and Cash Flow Sensitivities to Physical Capital Investment

The main purpose of this paper is to understand how R&D investment can generate endogenous credit constraints for entrepreneurs. The standard corporate finance literature (e.g. Fazzari et al. (1988); Kaplan and Zingales (2000)) suggests that one way to analyze the impact of technological factors on credit frictions is by studying the sensitivity of cash flows to investment. In this subsection we analyze the impact of the size of the innovation on optimal investment under moral hazard.

Let I^{sb} be a threshold at which the investor would be willing to finance production projects. The zero profit condition for the investor entails an investment threshold determined by:

$$I^{sb} = A\frac{4\left(1-a^2\right)}{3-4a^2}$$

The investor is willing to finance investments satisfying the condition $I_1 \leq I_1^{sb}$. The sensitivity of cash flow to investment (sca) is given by $sca = \frac{\partial I}{\partial A} = \frac{4(1-a^2)}{3-4a^2}$. The impact of innovations on sca for $\gamma \in (0, 1]$ is :

$$\frac{\partial sca}{\partial a} = \frac{8a}{\left(3-4a^2\right)^2} > 0 \tag{18}$$

As a is increasing in μ then the sensitivity of cash flows to physical investment increases as the innovation size increases. In addition, we show that as long as there is more correlation between activities the marginal impact on the innovation size on sca decreases.

In this framework, the borrowing constraint is the difference between investments that are financed under first-best conditions and the moral hazard scenario, $BC = I^* - I^{sb}$. Then we can express the borrowing constraint as:

$$BC = I^* - I^{sb}$$

Which corresponds to:

$$BC = 2A\left(1 - a^2\right)\left[\frac{1 - 4a^2}{3 - 4a^2}\right] \tag{19}$$

Notice that the marginal impact of the borrowing constraint to the innovation size through the parameter a is given by $\frac{\partial BC}{\partial a} = \frac{\partial BC}{\partial \mu} = -A\left[4a + \frac{\partial sca}{\partial a}\right] < 0$. Increases in the size of the innovation lead to higher levels of effort in both activities and therefore in the repayment to the investor. This in turn reduces the borrowing constraint. When the production and R&D are highly substitutable, the innovation has less impact on the repayment and, therefore, on the amount available to invest.

4 Empirical Model and Estimation Results

In this section we test empirically the main predictions of our theoretical model described above using firms data. With this purpose in mind we study the marginal and conditional (conditioning on R&D) effects of cash flows on investment. Specifically, we test for the empirical validity of equation (18). In other words, we investigate whether the sensitivity of investment to cash flows in positive and increasing on R&D.

The database used in this study is taken from the CompuStat North America Fundamentals Annual (Compustat Monthly Updates) for the years 1982–2007. We selected all firms trading domestic common shares on the New York Stock Exchange (NYSE), the American Stock Exchange (AMEX), and the National Association of Securities Dealers Automated Quotations (NASDAQ) in the manufacturing sector (Standard Industrial Classification codes 2000–3990) for firm-year combinations with non-missing R&D expenditure. We excluded firm-year combinations with negative or missing sales values, firms with negative real sales growth (to reduce the confounding effect of financial distress, as suggested by Li (2011)), firm-year combinations where the number of employees was not specified, firms in the first and last percentile of the sales variable, and observations for which the year was not specified.

We estimate the following regression equation:

$$INV_{it} = \beta_0 + \beta_1 INV_{it-1} + \gamma_1 cf_{it} + \gamma_2 rd_{it} + \gamma_3 cf_{it} * rd_{it} + \gamma_4 tobinq_{it} + \gamma_5 saindex_{it} + \gamma_6 saindex_{it} * rd_{it} + u_{it}$$

where INV is a measure of firm-level investment, cf corresponds to the firm's cash flow, rd is a measure of R&D investment, and $saindex$ is the size-age index proposed by Hadlock and Pierce (2010). Covariates are standard variables frequently used in empirical models of investment demand. The first is cash flow, which is a proxy of the firm's internal resources used used to finance physical capital investment. The second is Tobin's Q, which is a proxy of business opportunities for the firm that represent its expected discounted present value. The third is R&D investment. This is more complex because while it may have an impact, this impact is not immediate. For example, investment in physical capital is defined as the variation in the physical capital of the firm, while R&D investments are understood as a process innovation or the introduction of a new product. Both cases represent increased investment in the future if they affect capital goods or generate new resources for the firm. The fourth variable is a proxy that captures the firm's financial constraints.

The parameters of interest areγ_1 andγ_3. We expect both of them to be positive. Our specification allows us to test for heterogeneous effects of financial constraints as a function of R&D investment. We capture these effects through the sign and value of γ_6.

The age of the firm was computed as the number of years it had been listed with a non-missing stock price on Compustat. Two measures were used to assess firm size: quartiles of the number of employees and sales. The firm's total debt was computed as the sum of long-term debt and current liabilities. Total capital was the sum of long-term debt, current liabilities and total stockholder equity. Market value was derived from the product of the current value of company stock and the total number of shares. Cash flow was computed as income before extraordinary items, depreciation and amortisation.

We use four measures of R&D intensity. The first is the ratio of R&D expenditure to sales in a specific year. The second is the ratio of R&D expenditure to total assets. The third is the ratio of R&D expenditure to the number of employees. The fourth is the ratio of R&D

capital to total assets. The calculation of R&D capital follows that of Chan et al. (2001); it is expressed as five-year cumulative R&D expenditure, assuming an annual depreciation rate of 20%, as follows:

$$RDC_{i,t} = RD_{i,t} + 0.8 * RD_{i,t-1} + 0.6 * RD_{i,t-2} + 0.4 * RD_{i,t-3} + 0.2 * RD_{i,t-4}$$

Firm investment is computed as the ratio of capital expenditure to the lag of the beginning of the period capital stock.

There are several indicators of reliance on external financing traditionally used in the literature to measure financial constraints. At the firm level, we use the SA index proposed by Hadlock and Pierce (2010), computed as follows:

$$SA = (-0.737 * size) + (0.043 * size)^2) - (0.040 * age)$$

where size is the log of inflation-adjusted book assets and age is the number of years the firm has been listed with a non-missing stock price on Compustat. Other financial constraint proxies are explained in detail in the subsection on robustness checks. Our selection of measures was based on the work of Rajan and Zingales (1998) concerning external dependence at the industry level. The purpose of these measures is to characterise demand for external resources. As a proxy for the short-term debt to sales ratio, we use the cash holdings to assets ratio and the Rajan Zingales external financial dependence indicator, which is the ratio of capital expenditure and cash flow to total capital expenditure.

In order to minimize the impact of outliers we excluded from our sample firms with cash flow values under -1000% or over 1000%. Additionally, *tobinq* exhibited several missing values. We recovered some of those missing values using linear interpolation. Last but not least, in order to face the endogeneity problems generated when estimating the equations presented above by traditional linear methods[6], we implemented a dynamic panel data model using the method proposed by Arellano and Bover. The implementation of this method allows us to obtain consistent and efficient estimators. Due to the intensive use of instruments in the dynamic panel model, we include in our dataset only firms with 5 or more observations. Our final sample includes 15272 observations corresponding to 1256 firms (12 observations per firm on average).

[6] Endogeneity problems arise mainly due to the simultaneity between cash flows and investment.

Table 1: Descriptive Statistics Firms' Characteristics

	All		**1982-1993**		**1994-2007**	
Investment	0.305	0.341	0.295	0.286	0.310	0.373
Cash flow	0.565	0.904	0.523	0.620	0.587	1.089
R&D	0.073	0.266	0.046	0.120	0.097	0.341
Q-tobin	3.148	1.763	2.833	1.325	3.439	2.028
SA Index	-3.151	0.617	-2.970	0.599	-3.309	0.592

Table 1 presents descriptive statistics for the whole sample and for two sub-periods (1983-1993 and 1994-2007). These subperiods are used to study the sensibility and robustness of our empirical results. In general all variables exhibit reasonable average values, and when the two sub-periods are compared a decrease in the average values of all variables is observed specially for R&D investment. We estimate three different dynamic panel data models for each of these samples. In the first model we use GMM instruments of the type proposed by Holtz-Eakin et al. (1988) for cash flows and R&D investment. In the second model we use these type of instruments for the whole set of explanatory variables. Finally, in the third model we do the same that in the second one, but we include only firms with at least 7 years of data. All three models include year fixed effects.

Table 2 presents estimation results when the whole sample is used. We find the expected signs for all the included covariates and high levels of statistical significance. The test for second-order autocorrelation shows also satisfactory results. Particularly, positive inertia is found in the investment indicator as well as a positive and significant effect of cash flows and Tobin's Q on investment in physical capital. This result validates the first prediction of our theoretical model stating that higher cash flows facilitate higher investments to firms. This result goes in line with Fazzari et al. (1988)who estate that internal and external sources of funding are not perfectly substitutable. Additionally, there is a negative relation between investment in R&D and investment in physical capital, coinciding with the fact that these two types of investments compete for the resources that are available to the firm.

Table 2: Dynamic Panel Model for Investment

	(1)	(2)	(3)
Lag investment	0.1568***	0.1720***	0.1870***
	(0.012)	(0.010)	(0.053)
Cash flow	0.0283***	0.0332***	0.0347***
	(0.004)	(0.004)	(0.010)
R&D	-0.3158***	-0.2390**	-0.1980
	(0.118)	(0.116)	(0.277)
Cash flow * R&D	0.0374***	0.0368***	0.0313
	(0.012)	(0.012)	(0.024)
Q-Tobin	0.0303***	0.0273***	0.0255***
	(0.002)	(0.002)	(0.004)
SA Index	0.0984***	0.0843***	0.0734***
	(0.006)	(0.006)	(0.011)
SA Index * R&D	-0.1733***	-0.1541***	-0.1446
	(0.038)	(0.037)	(0.093)
Constant	0.5052***	0.4538***	0.3707***
	(0.042)	(0.040)	(0.045)
Observations	6,975	6,975	6,386
Year FE	YES	YES	YES
Number of firms	1,142	1,142	872
pval AR(1) corr. Test	0.000	0.000	0.000
pval AR(2) corr. Test	0.846	0.959	0.980

Authors' calculations. Standard errors in parentheses.
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Interestingly, we find that the sensitivity of investment to cash flows increases with R&D. Specifically, considering that the average value of R&D is 0.07, the sensitivity of investment to cash flows changes from 0.0283 for a firm that does not invest in R&D to 0.031 for a firm presenting the average value of R&D investment. This result empirically validates the theoretical implication of our model shown in equation (18). These results hold valid in the case in which the models are estimated using instruments for all the set of covariates and when only firms with seven of more observations are included in the sample.

As seen from Table 3 and Table 4, the main theoretical implications of our model remain valid under the two sub-samples considered in this paper. Interestingly, we find that the sensitivity of investment to cash flows is higher for the period 1982-1993. This result probably responds to the fact that financial markets have developed rapidly during the last two decades. This higher pace of development has given firms more access to external funds, easing firms' financial constraints.

Table 3: Dynamic Panel Model for Investment: 1982-1993

	(1)	(2)	(3)
Lag investment	0.1184***	0.1085***	0.1952***
	(0.025)	(0.020)	(0.053)
Cash flow	0.0378***	0.0407***	0.0495***
	(0.010)	(0.010)	(0.019)
R&D	-0.8314***	-0.7521***	-0.5770
	(0.213)	(0.209)	(0.403)
Cash flow * R&D	0.1161***	0.1108***	0.1011***
	(0.027)	(0.026)	(0.034)
Q-Tobin	0.0211***	0.0222***	0.0162***
	(0.005)	(0.004)	(0.005)
SA Index	0.1117***	0.0967***	0.0796***
	(0.011)	(0.010)	(0.017)
SA Index * R&D	-0.4357***	-0.4045***	-0.3414**
	(0.084)	(0.082)	(0.144)
Constant	0.0000	0.5176***	0.4467***
	(0.000)	(0.050)	(0.072)
Observations	2,653	2,653	2,486
Year FE	YES	YES	YES
Number of firms	669	669	576
pval AR(1) corr. Test	0.000	0.000	0.009
pval AR(2) corr. Test	0.483	0.397	0.909

Authors' calculations. Standard errors in parentheses.
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 4: Dynamic Panel Model for Investment: 1994-2007

	(1)	**(2)**	**(3)**
Lag investment	0.1669***	0.1886***	0.1803***
	(0.014)	(0.012)	(0.067)
Cash flow	0.0256***	0.0304***	0.0305***
	(0.005)	(0.005)	(0.011)
R&D	-0.2408	-0.1131	-0.0580
	(0.151)	(0.146)	(0.374)
Cash flow * R&D	0.0342**	0.0367***	0.0326
	(0.013)	(0.013)	(0.027)
Q-Tobin	0.0324***	0.0286***	0.0280***
	(0.002)	(0.002)	(0.004)
SA Index	0.0984***	0.0843***	0.0761***
	(0.008)	(0.007)	(0.013)
SA Index * R&D	-0.1411***	-0.1076**	-0.0943
	(0.047)	(0.045)	(0.116)
Constant	0.4134***	0.3976***	0.0000
	(0.034)	(0.031)	(0.000)
Observations	4,322	4,322	3,900
Year FE	YES	YES	YES
Number of firms	944	944	758
pval AR(1) corr. Test	0.000	0.000	0.000
pval AR(2) corr. Test	0.431	0.281	0.775

Authors' calculations. Standard errors in parentheses.
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

5 Concluding Remarks

This paper studies the impact of R&D intensity on the firm's investment needs. We present a theoretical model showing that financial frictions may arise as a problem of resource misallocation within the firm. Specifically, firms with higher R&D intensity increase the cost of external financing. Moreover, when there is a high correlation between activities the marginal effect of the sensitivity of cash flow to R&D investment is reduced. This conclusion is in line with the findings of the empirical literature about cash-flow sensitivity and R&D investment.

We test the theoretical implications of our model using Compustat data for the period 1982-2007. The substitutability parameter is difficult to capture directly from the data. Hence, we use our theoretical finding indicating that it is positively correlated with R&D

intensities. In this sense, we first test the effect of R&D investment on the sensitivity of cash flows to investment in physical capital. As predicted by our model, we find a positive effect of cash flows on investment, indicating that internal and external sources of funding are not perfectly substitutable (as in Fazzari et al. (1988)). Additionally, this effect increases as firms become more R&D intensive, showing that highly innovative firms face higher financial constraints than otherwise similar companies.

References

Acharya, V. V., Almeida, H., and Campello, M. (2007). Is cash negative debt? a hedging perspective on corporate financial policies. *Journal of Financial Intermediation*, 16(4):515–554.

Almeida, H. and Campello, M. (2007). Financial constraints, asset tangibility, and corporate investment. *Review of Financial Studies*, 20(5):1429–1460.

Almeida, H., Campello, M., and Weisbach, M. S. (2004). The cash flow sensitivity of cash. *The Journal of Finance*, 59(4):1777–1804.

Audretsch, D., Segarra, A., and Teruel, M. (2014). Why don't all young firms invest in R&D? *Small Business Economics*, 43(4):751–766.

Bernanke, B. and Gertler, M. (1990). Financial fragility and economic performance. *The Quarterly Journal of Economics*, 105(1):87–114.

Borisova, G. and Brown, J. R. (2013). R&D sensitivity to asset sale proceeds: New evidence on financing constraints and intangible investment . *Journal of Banking & Finance*, 37(1):159–173.

Brown, J. R., Fazzari, S. M., and Petersen, B. C. (2009). Financing innovation and growth: Cash flow, external equity, and the 1990s R&D boom. *The Journal of Finance*, 64(1):151–185.

Brown, J. R. and Petersen, B. C. (2011). Cash holdings and R&D smoothing. *Journal of Corporate Finance*, 17(3):694–709.

Chan, L. K., Lakonishok, J., and Sougiannis, T. (2001). The stock market valuation of research and development expenditures. *The Journal of Finance*, 56(6):2431–2456.

Coad, A., Segarra, A., and Teruel, M. (2016). Innovation and firm growth: Does firm age play a role? *Research Policy*, 45(2):387–400.

Czarnitzki, D. and Delanote, J. (2013). Young innovative companies: the new high-growth firms? *Industrial and Corporate Change*, 22(5):1315.

Faulkender, M. and Wang, R. (2006). Corporate financial policy and the value of cash. *The Journal of Finance*, 61(4):1957–1990.

Fazzari, S., Hubbard, R. G., and Petersen, B. (1988). Financing constraints and corporate investment. *Brookings Papers on Economic Activity*, 19(1):141–206.

Guariglia, A. (2008). Internal financial constraints, external financial constraints, and investment choice: Evidence from a panel of uk firms. *Journal of Banking & Finance*, 32(9):1795–1809.

Hadlock, C. J. and Pierce, J. R. (2010). New evidence on measuring financial constraints: Moving beyond the kz index. *Review of Financial Studies*, 23(5):1909–1940.

Haltiwanger, J., Jarmin, R. S., and Miranda, J. (2013). Who Creates Jobs? Small versus Large versus Young. *The Review of Economics and Statistics*, 95(2):347–361.

Holmstrom, B. and Tirole, J. (1997). Financial intermediation, loanable funds, and the real sector. *The Quarterly Journal of Economics*, 112(3):663–91.

Holtz-Eakin, D., Newey, W., and Rosen, H. (1988). Estimating vector autoregressions with panel data. *Econometrica*, 56(6):1371–95.

Hu, X. and Schiantarelli, F. (1998). Investment and capital market imperfections: A switching regression approach using us firm panel data. *Review of Economics and Statistics*, 80(3):466–479.

Jensen, M. C. and Meckling, W. H. (1976). Theory of the firm: Managerial behavior, agency costs and ownership structure. *Journal of financial economics*, 3(4):305–360.

Kaplan, S. N. and Zingales, L. (1997). Do investment-cash flow sensitivities provide useful measures of financing constraints? *The Quarterly Journal of Economics*, 112(1):169–215.

Kaplan, S. N. and Zingales, L. (2000). Investment-cash flow sensitivities are not valid measures of financing constraints. *The Quarterly Journal of Economics*, 115(2):707–712.

Kim, C.-S., Mauer, D. C., and Sherman, A. E. (1998). The determinants of corporate liquidity: Theory and evidence. *Journal of Financial and Quantitative Analysis*, 33(03):335–359.

Kim, W. and Weisbach, M. S. (2008). Motivations for public equity offers: An international perspective. *Journal of Financial Economics*, 87(2):281–307.

Kiyotaki, N. and Moore, J. (1997). Credit cycles. *Journal of Political Economy*, 105(2):211–48.

Lawless, M. (2014). Age or size? Contributions to job creation. *Small Business Economics*, 42(4):815–830.

Li, D. (2011). Financial constraints, R&D investment, and stock returns. *Review of Financial Studies*, 24(9):2974–3007.

Pinkowitz, L. and Williamson, R. (2007). What is the market value of a dollar of corporate cash? *Journal of Applied Corporate Finance*, 19(3):74–81.

Rajan, R. G. and Zingales, L. (1998). Financial dependence and growth. *American Economic Review*, 88(3):559–86.

Stiglitz, J. E. and Weiss, A. (1981). Credit rationing in markets with imperfect information. *The American economic review*, 71(3):393–410.

Whited, T. M. and Wu, G. (2006). Financial constraints risk. *Review of Financial Studies*, 19(2):531–559.


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