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Why has the investment-cash flow sensitivity declined so sharply? Rising R&D and equity market developments

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Why has the investment-cash flow sensitivity declined so sharply? Rising R&D and equity market developments [#]

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Abstract

The study of the investment-cash flow (ICF) sensitivity constitutes one of the largest literatures in corporate finance, yet little is known about changes in the ICF relationship over time, and the literature has largely ignored how rising R&D investment and developments in equity markets have impacted ICF sensitivity estimates. We show that for the time period 1970-2006, the ICF sensitivity: i) largely disappears for physical investment, ii) remains comparatively strong for R&D, and iii) declines, but does not disappear, for total investment. We argue that these findings can largely be explained by the changing composition of investment and the rising importance of public equity as a source of funds, particularly for firms with persistent negative cash flows.

JEL classification: G31; G32

Keywords: Financing constraints; Cash flow; Stock issues; R&D; Physical investment

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I. Introduction

The study of the investment-cash flow (ICF) sensitivity constitutes one of the largest empirical literatures in corporate finance. Many studies find that firms which are *a priori* more likely to confront binding financing constraints display a greater sensitivity of investment to cash flow. Although there is disagreement on how to interpret the findings in ICF studies, ICF regressions continue to be used extensively as a tool to study a variety of issues in corporate finance. But despite the literature's prominence, little is known about the stability of the ICF relationship over time and the R&D-cash flow relationship has been largely ignored. In particular, the literature has not explored how the rising importance of R&D or continued improvements in equity markets may have affected measures of the ICF sensitivity.

There are several reasons to suspect that the ICF sensitivity has declined significantly. Perhaps the most important reason is developments in U.S. equity markets over the last three decades. One major improvement was the creation of the Nasdaq – launched in 1971 and repeatedly improved thereafter – which likely gave young firms access to a much more efficient stock exchange than was available to them for most of the 20th century. Another potentially important development was the explosive growth of equity mutual funds in the 1980s and 1990s.[1] In the last few decades, there has been a sharp increase in the use of public equity finance, suggesting that stock issues may have become a closer substitute for internal finance. A second, closely related reason for a declining ICF sensitivity is the sharp increase in the fraction of publicly traded firms that report persistent negative cash flows. Since these firms often make very heavy use of public equity to expand investment when cash flow is particularly low, failure to account for external finance in ICF regressions can result in a downward omitted-variable bias in the estimated cash flow coefficient. Third, there has been a sharp change in the composition of total investment: the absolute and relative importance of physical investment has declined substantially and R&D intensity has risen dramatically for the typical publicly traded manufacturing firm. Because almost

[1] Between 1979 and 1998, the U.S. mutual fund industry grew from around $15 billion to over $5 trillion, with far more assets invested in stock than bonds. See Engen and Lehnert (2000) and Klapper, Sulla and Vittas (2004) for facts on the growth of the mutual fund industry, and Allayannis and Mozumdar (2004) for comments on its importance for the supply of equity finance.

all ICF studies focus on physical investment, the declining relative importance of physical investment can, by itself, lead to a decline in the conventionally measured ICF sensitivity.

This paper makes three main contributions. First, we provide a systematic documentation of what has happened to the ICF sensitivity over time. The only other studies to examine the ICF sensitivity over relatively long periods of time are Allayannis and Mozumdar (2004) and Agca and Mozumdar (2008), both of which show a substantial decline in the ICF sensitivity for *physical* investment over time.[2] We expand on these studies by considering R&D and total investment in addition to physical investment. Compared to the vast literature on the physical ICF sensitivity, few studies have examined the ICF sensitivity for R&D, and we are aware of no other studies that have explored changes in the R&D-cash flow sensitivity over time. Second, we examine the role of external finance in ICF regressions by estimating dynamic investment models that include measures of stock and debt issues. We argue that these are potentially important omitted variables in most ICF studies, and their inclusion helps address some concerns that have been raised about interpreting ICF sensitivities. Finally, we explore *why* the estimated ICF sensitivity has changed over time, focusing on the impact of both capital market developments and the changing composition of investment.

We explore changes in the ICF sensitivity between 1970 and 2006 using Compustat data for manufacturing firms, divided into three subperiods: 1970-1981, 1982-1993 and 1994-2006. We also split firms into two categories, young and mature, where young firms have stock prices for fewer than ten years before the start of a given subperiod. We expect improvements in equity markets to have the greatest impact on young firms, since they are the most likely to be "equity-dependent." (We considered other sample splits, such as zero versus positive payout ratios, and obtained similar results.) Our summary statistics show that, over time, there has been: i) a very large decline in the physical investment share of total investment, ii) a dramatic rise in the R&D-to-assets ratio, particularly for young firms, iii) a very sharp rise in the proportion of negative cash flow observations, iv) a substantial decline in the median cash flow ratio, particularly for young firms, and v) a pronounced rise in the share of young-firm finance accounted for by new stock issues.

[2] Ascioglu, Hegde, and McDermott (2008) report a decline in the ICF sensitivity for firms with high information asymmetry between 2000 and 2003. Chen (2003), in an unpublished thesis, also reports evidence of declining ICF sensitivities for physical investment.

We estimate the sensitivity of physical investment, R&D, and total investment (physical investment plus R&D) to cash flow with the standard OLS fixed-effects model used in the ICF literature. Our main results, however, are based on dynamic investment regressions using GMM where cash flow and other financial variables are treated as endogenous. The other financial variables include both new stock issues and debt finance, variables that potentially matter a great deal for investment but are rarely included in ICF studies. A consistent pattern of results emerges from the OLS and GMM regressions. For *physical investment*, our OLS estimates show that, even after controlling for negative cash flows, there is a dramatic decline in the ICF sensitivity over time. Similarly, GMM regressions that control for negative cash flow and include measures of external finance show a decline in the ICF sensitivity of at least 70% between 1970-81 and 1994-2006. We argue that much of this decline is due to the sharp fall in the physical investment share of total investment. To our knowledge, no other studies have linked the declining physical ICF sensitivity to the changing composition of investment. For *R&D* investment, on the other hand, there is no decline in the ICF relationship over time in OLS regressions (that control for negative cash flow) or GMM regressions (that control for external finance). We will emphasize, however, that the cash flow coefficients for R&D, absent improvements in equity markets, should have *risen* a great deal because of the sharp rise in the R&D share of total investment that occurred during the period we study. Finally, the ICF pattern for *total investment* reflects a blend of the ICF pattern for physical and R&D investment and shows that the overall ICF sensitivity declined substantially over the time period of our study, but it did not disappear.

Our regression findings also shed light on the different roles of debt and stock issues as well as the rise in importance of the U.S. stock market. First, in the physical investment regressions (where investment has collateral value), debt coefficients are substantial but there is little or no evidence of stock effects. Second, for R&D (arguably the equity-dependent type of investment), stock issues play a more important role than debt, especially in the final period. Third, stock issues appear especially important for young firms, particularly young firms with negative cash flows (arguably the most equity-dependent type of firm). Fourth, in the R&D regressions, estimated coefficients on stock issues rise from near zero to large values by the final period for young firms, which we argue is consistent with improvements in equity markets. Finally, our findings show that young firms with persistent negative cash flows rely heavily on stock issues to finance R&D and failure to account for this appears to cause a downward bias (e.g., negative cash flow coefficients) in the estimated R&D-cash flow sensitivity.

To summarize, the conventional (i.e., physical investment) ICF sensitivity has fallen dramatically, the ICF sensitivity for R&D remains comparatively strong, and the ICF sensitivity for total investment has fallen substantially. Absent improvements in equity markets, however, the ICF sensitivity of R&D should have increased a great deal, given the sharp change in the composition of investment. The bottom line is that the overall ICF sensitivity has declined noticeably over the last four decades and improvements in equity markets were likely a significant contributing factor.

ICF regressions continue to be used extensively as a tool in corporate finance, and our findings suggest that failure to consider R&D can severely bias inference in ICF studies. Our findings also suggest that while the stock market may have been unimportant as a source of finance prior to the 1980s, in recent years the equity-finance channel has become very important for intangible investment. One implication of this finding is that improvements in equity markets may contribute to economic growth by funding innovation, particularly for young companies.

The next section of the paper reviews some of the related literature on financing constraints and further discusses why the ICF sensitivity may have declined over time. The third section describes the econometric models. The fourth section provides summary statistics, the fifth section contains our main regression results and the sixth section discusses the robustness of our findings. The final two sections interpret the results, present the implications, and summarize the paper.

II. Overview of the Investment-Cash Flow Sensitivity

A. Background

Beginning with Fazzari, Hubbard and Petersen (FHP 1988), the standard approach to measuring the ICF sensitivity has been to estimate a fixed-effects regression of *physical* investment on cash flow and Tobin's Q (as a control for investment demand). The typical study separates firms into multiple groups based on the *a priori* likelihood that they face substantial financing constraints. A variety of approaches have been used to sort firms, including firm age, payout ratio, presence of a corporate bond rating, access to commercial paper, and membership in a keiretsu. Most studies find that firms which are *a priori* more likely to face binding financing constraints tend to exhibit the greater sensitivity of investment to cash flow. Excellent surveys of the large empirical literature can be found in Schiantarelli (1996), Hubbard (1998), and Bond and Van Reenen (2007).

ICF regressions continue to be used extensively as a tool for studying various issues in corporate finance. For example, they have been used to draw inferences about the efficiency of internal capital markets (Shin and Stulz, 1998), the impact of managerial characteristics on corporate policies (Bertrand and Schoar, 2003 and Malmendier and Tate, 2005), the effect of agency problems on firm investment (Hadlock, 1998), the role of corporate hedging (Deshmukh and Vogt, 2005), the behavior of financially distressed firms (Allayannis and Mozumdar, 2004 and Bhagat, Moyen and Suh, 2005) and the impact of stock prices on equity-dependent firms (Baker, Stein and Wurgler, 2003).

A number of recent papers criticize conventional ICF regressions, particularly in studies that do not control for the potential endogeneity of cash flow or neglect the possibility of external finance. For example, Alti (2003) and Moyen (2004) calibrate models of firms that use debt as a substitute for internal finance. They run OLS regressions on simulated data from the models to show that ICF sensitivities can be generated even if firms do not face financing frictions. Alti (p. 721) writes that one problem in ICF regressions highlighted by his study is "relatively easy to handle; one can remove the effects of the surprise component of cash flow by using lagged instruments," something that we do in this paper. In Moyen (2004), unconstrained firms have substantial cash flow sensitivities because current period debt finance is correlated with contemporaneous cash flow and debt finance is not included in the regression. In this study, we control for external finance and instrument cash flow to eliminate the contemporaneous correlation between external finance and the cash flow regression variable. In addition, studies critical of ICF regressions have considered only physical investment (consistent with most of the ICF literature) and thus do not offer any explanation for differences in ICF sensitivities across different types of investment. Furthermore, we are aware of no critiques that can explain why ICF sensitivities have fallen sharply over time.

B. R&D Investment

Compared to the large literature exploring the physical ICF sensitivity, relatively few studies examine the sensitivity of R&D to cash flow. Hall (1992) finds a positive relation between R&D and cash flow for U.S. manufacturing firms over 1973-1987. Himmelberg and Petersen (1994) report a strong positive link between R&D and cash flow for a sample of 179 small high-tech firms over 1983-1987. More recently, Mulkay, Hall and Mairesse (2001) show the R&D-cash flow link is stronger for large manufacturing firms in the U.S. than in France, and Brown, Fazzari and Petersen (BFP, 2008) find a positive R&D-cash flow sensitivity for young U.S. high-tech firms over 1990-2004.[3] We are aware of no previous studies that examine how the R&D-cash flow sensitivity has changed over time.

Given the importance of R&D in this study, we briefly mention two relevant features of R&D. The first is that debt finance may be poorly suited for funding R&D, particularly for young high-tech firms. Several studies conclude that R&D-intensive firms use comparatively little debt and there are a number of explanations for this finding.[4] First, the structure of a debt contract (e.g., bounded upside returns) is not well suited for firms with returns having extremely high variance (Stiglitz, 1985). Second, debt financing can lead to *ex post* changes in behavior (moral hazard) that may be especially pronounced for firms already engaged in inherently risky activity. Third, debt finance can lead to problems of financial distress that may be particularly severe for R&D-intensive firms (Cornell and Shapiro, 1988). Finally, the limited collateral value of R&D should greatly restrict the use of debt since risky firms typically must pledge collateral to obtain debt finance (Berger and Udell, 1990). All of these reasons imply that R&D is likely to be an "equity-dependent" investment, and thus public equity availability should be especially important for R&D. This view is supported by BFP (2008), who find that fluctuations in the availability of public equity in the 1990s had a substantial impact on R&D spending by young high-tech firms in the U.S.

A second important feature of R&D is high adjustment costs (see the discussion in Hall (2002) and Himmelberg and Petersen (1994)), likely substantially larger than the adjustment costs for physical investment (e.g., Bernstein and Nadiri, 1989). Most R&D investment consists of wage payments to highly skilled technology workers who often require a great deal of firm-specific training. In addition, these workers know critical proprietary information that firms do not wish to share with competitors. As a consequence, firms will not readily take on new workers (or fire existing workers) in response to

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[3] Studies exploring the sensitivity of R&D to internal funds in countries besides the U.S. include Harhoff (1998), Bond, Harhoff, and Van Reenen (2003) and Bougheas, Gorg and Strobl (2003). Hall (2002) provides an excellent review of the R&D-cash flow literature.

[4] For example, see Bradley, Jarrell and Kim (1984), Titman and Wessels (1988), Fama and French (2002), Hall (2002), and Kayhan and Titman (2007).

transitory shifts in the availability of finance. This implies that when a firm is unsure about the permanence of a positive supply shift in finance (e.g., internal or external equity) it will likely conserve some of its new finance for future R&D expenditures. Symmetrically, a firm facing a transitory decline in cash flow should seek to smooth R&D.

C. Related Literature

In the paper most closely related to our study, Allayannis and Mozumdar (2004) consider what happened to ICF sensitivities for a large sample of Compustat firms over the twenty-year period 1977-1996. After excluding negative cash flow observations, they find that constrained firms had significantly higher ICF sensitivities than less constrained firms (0.585 versus 0.213) in the period 1977-1986. For the time period 1987-1996, however, the cash flow coefficients drop a great deal for the constrained group (0.196) and are nearly equal to the unconstrained group (0.175). They do not report findings for R&D and do not explore why ICF sensitivities may have declined, but they do speculate (p. 929) that "two possible explanations for this development lie in improved informational efficiency of capital markets, and the increased supply of funds to capital markets resulting in easier access to external capital, especially for small, high-growth firms." Agca and Mozumdar (2008) also report a substantial decline in the physical ICF sensitivity for manufacturing firms over rolling ten year periods between 1970 and 2001. They also show that the physical ICF sensitivity decreases with five factors that arguably reduce capital market imperfections and conclude (p. 208) that "the sensitivity of investments to the availability of internal funds cannot be explained solely as an artifact of measurement error." We are not aware of other published studies that directly examine changes in the ICF sensitivity over time.

There are, however, a number of studies that consider other issues – such as negative cash flow observations and the use of external finance – important for our study. In an influential paper, Kaplan and Zingales (KZ, 1997) sort the 49 low-dividend firms from FHP (1988) into one of five categories and find that the firms that KZ classify as the least financially constrained display the highest cash flow sensitivity. Cleary (1999) follows up on KZ and uses a multiple discriminate approach to classify a large sample of firms into three different categories: financially constrained (FC), partially financially constrained (PFC) and not financially constrained (NFC). Cleary finds that cash flow coefficients are largest for the NFC firms, supporting the findings in KZ.

Allayannis and Mozumdar (2004) utilize a similar sample and the same discriminate analysis to reexamine the findings in Cleary (1999). They replicate Cleary's (1999) main finding that FC firms have the lowest cash flow sensitivity. They note, however, that FC firms have considerably more *negative* cash flow observations than the groups of firms classified as less constrained. After removing these observations, they report a substantial rise in the cash flow coefficient for the FC group, resulting in no difference in cash flow coefficients across the different groups.[5] Bhagat, Moyen and Suh (2005) also find that financially distressed firms display a negative ICF sensitivity. When they divide their sample of distressed firms into those with positive and negative operating incomes, it is the firms with negative operating incomes that are responsible for the overall negative ICF sensitivity.[6] Finally, Hovakimian (2006) also finds that firms displaying negative ICF sensitivity tend to be those with negative cash flows.

The results from other recent studies implicitly suggest that *external* finance may be an important *omitted* variable in ICF studies. Moyen (2004) considers a model where some firms can issue debt, estimates the ICF sensitivity with simulated data (but does not include debt in the regression), and finds that "unconstrained" firms have the larger ICF sensitivities because debt finance "magnifies the cash flow sensitivity of unconstrained firms." Almeida and Campello (2007) provide a model and empirical evidence showing that the ICF sensitivity for constrained firms is an increasing function of the tangibility of firms' assets. This occurs because greater tangibility allows for more borrowing, which, like Moyen (2004), implies that omitting debt from ICF regressions may lead to upward biased cash flow coefficients. Cleary, Povel and Raith (2007) also model investment and debt financing of financially constrained firms.[7] They show that if internal funds are sufficiently negative, a further decrease in internal funds might make it optimal (for the firm and lender) to increase borrowing to such a degree that there can be a negative correlation between investment and cash flow; they in fact report regressions showing that negative cash flow firms exhibit a negative ICF relationship.

[5]Allayannis and Mozumdar (2004, p. 902) provide the following intuition for low ICF sensitivities among firms with negative cash flows: "when the cash shortfall is severe, the firm is pushed into financial distress and is able to make only the absolute essential investment," and thus "any further cutback in investment in response to further declines in cash flow is impossible."

[6] Furthermore, among the firms with operating losses, fully 40 percent manage to increase their investment. Their explanation for how these firms can raise investment (leading to a negative ICF correlation) is the heavy use of stock issues (see the summary statistics in Table 13), consistent with "a gamble for resurrection."

[7] Cleary, Povel and Raith (2007) note that their model generalizes to any kind of financial contract, including equity.

Collectively, these studies show that negative cash flows are common and they can have a large impact on the ICF relationship. In addition, while none of the above studies include external finance in an ICF regression, they strongly imply that external finance may be an important omitted variable that can bias the estimated ICF sensitivity in either direction.[8] Thus, some important concerns about interpreting ICF sensitivities can be addressed by controlling for the use of external finance in ICF regressions.

D. Potential Causes of a Declining Investment-Cash Flow Sensitivity

It is useful to begin with a simple financing hierarchy commonly used in the literature (e.g., Hubbard, 1998). In Figure 1, the quantity of finance is measured on the horizontal axis and the marginal cost of funds is measured on the vertical axis. The quantity of internal finance is depicted by CF (standing for cash flow, the usual measure of internal finance), with constant marginal cost MC_{CF}. The cost of external finance is depicted by the schedules S_1 or S_2 or S_3 (depending on the stage of financial market development). For certain types of firms, the marginal cost of external finance is likely increasing for several reasons. If the marginal source of finance is debt, costs may be rising due to limited collateral, moral hazard, or rising marginal costs of financial distress. If the marginal source is equity, financial theories predict that the marginal cost of issuing stock may increase because of adverse selection (e.g., Myers and Majluf, 1984; Krasker, 1986), which is supported by evidence in Asquith and Mullins (1986) and Cornett and Tehranian (1994). In addition, Altinkihc and Hansen (2000) report that the marginal cost of underwriting fees (beyond some minimum scale) increases with issue size, particularly for small firms.

Kaplan and Zingales (KZ, 1997) provide a useful theoretical framework for understanding potential causes of a declining ICF sensitivity. In Figure 1, let D represent the demand for *total* investment, and note that D intersects the upward sloping portion of the financing hierarchy. For firms operating at this margin, KZ (1997) show that the ICF sensitivity can be expressed as:

$$dI/dCF = E_{11}/(E_{11} - F_{11}) \qquad (1)$$

[8] The Bhagat, Moyen and Suh (2005) and Clearly, Povel and Raith (2007) studies imply a downward bias in the ICF sensitivity from omitting external finance, while the theoretical models in Almeida and Campello (2007) and Moyen (2004) suggest the possibility of an upward bias.

where I is investment, CF is cash flow, E_{11} is the slope of the supply curve for external finance and F_{11} is the slope of the investment demand curve. Holding constant F_{11}, the greater the slope of the external finance schedule, the greater the ICF sensitivity.[9]

D.1 Changing Composition of Investment

KZ assumed, as is common in the literature, that there is one type of investment undertaken by the firm. In practice, firms must allocate cash flow and external funds across multiple investments. Suppose the two types of investment are R&D and physical investment. Let the optimal mix of investment be given by β_{RD} and β_{CAP} where $\beta_{RD} + \beta_{CAP} = 1$. Then, within the confines of the KZ model (which ignores adjustment costs), the ICF sensitivity of R&D and physical investment can be expressed as: $\beta_{RD}\{E_{11}/(E_{11} - F_{11})\}$ and $\beta_{CAP}\{E_{11}/(E_{11} - F_{11})\}$, respectively.

This suggests an obvious reason for changes in ICF sensitivities over time: β_{RD} and β_{CAP} may have changed. As we show in our summary statistics, there was a pronounced rise in β_{RD} (and thus a fall in β_{CAP}) for the typical publicly traded firm in manufacturing over the period 1970-2006. A main reason for the sharp rise in β_{RD} is the changing industry composition of firms in the manufacturing sector. A high proportion (relative to public firms in existence) of IPOs in the 1980s and 1990s occurred in high-tech industries such as computers, electronic components, communication equipment and instruments. β_{RD} is much higher in these industries than the typical manufacturing industry of the 1970s. Because of this compositional change, the typical publicly traded manufacturing firm in the 1990s was considerably more R&D intensive than the typical firm in the 1970s. The obvious implication is that, compared to the 1970s, the typical firm in the 1990s likely allocated less of every dollar of cash flow to physical investment and more of every dollar to R&D. This discussion leads to:

Prediction 1: For firms facing financing constraints, if there are no improvements in capital markets (e.g., E_{11} is unchanged), then the pronounced rise in β_{RD} should lead to a sharp rise in the ICF sensitivity for R&D and a sharp fall in the ICF sensitivity for physical investment.

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[9] We note that adjustment costs do not appear in the KZ framework. This does not, however, detract from the usefulness of the framework for understanding the possible causes of a decline in the ICF sensitivity, particularly if adjustment costs of different types of investment do not change over time. In addition, the KZ prediction can be viewed as the "long-run" response of investment to changes in cash flow, which can be potentially captured empirically with an IV approach as discussed in Section III.

The ICF literature rarely examines the ICF sensitivity of "broad" investment measures such as physical capital plus R&D, which we refer to as total investment. The discussion above suggests that total investment may be a more revealing measure of what has happened to the ICF sensitivity over time, as it is less subject to the problem of changing composition.

D.2 Improvements in Capital Markets

Improvements in capital markets should lead to a decline in the ICF sensitivity. During the time period of our study, one major improvement was the creation of the Nasdaq in 1971. In our sample, almost all new publicly traded firms were initially listed on the Nasdaq, typically their only choice given the listing requirements (e.g., profitability) of the major exchanges. Prior to the Nasdaq, it was difficult to obtain accurate and timely information on OTC stock prices and trading of shares was cumbersome.[10] The Nasdaq was created to increase liquidity and to centralize and expedite the trading of stock. Major improvements occurred in the early 1980s with the creation of the National Marketing System. There is a large body of evidence indicating that the Nasdaq has improved efficiency and liquidity in equity markets.[11] In addition, several studies, summarized by Baker (1987), find that firms listed on the Nasdaq do not appear to face a higher cost of equity finance than firms listed on the NYSE.

Another major development in equity markets was the explosive rise of mutual funds, which became a key intermediary between households and firms. Investments in mutual funds rose from around $15 billion in 1979 to over $5 trillion in 1998. Importantly, the preponderance of mutual fund assets are invested in stock funds.[12] One reason for the dramatic growth of mutual funds was regulatory change in the 1980s (e.g., major changes in eligibility and contribution limits for IRAs in 1981). Allayannis and Mozumdar (2004, p. 928) comment on the rise of mutual funds and other intermediaries and note: "Moreover, as the supply of funds into primary markets has experienced rapid growth over the last two

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[10] Ingebretsen (2002) discusses many other shortcomings in the OTC market prior to the Nasdaq, including large broker markups and lack of regulations, information and liquidity. He states (p.19) that because of these problems "relatively few firms went public via the OTC market."

[11] Santomero (1974) and Hamilton (1978) find substantial reductions in the bid-ask spread following the introduction of Nasdaq. A number of studies (e.g., Cooper, Groth and Avera, 1985 and Dubofsky and Groth, 1984) find that the liquidity of firms traded on the Nasdaq compares favorably to firms traded on the NYSE.

[12] At the end of 2000, equity funds had assets of more than 4.5 billion compared to about $1 billion in bond and hybrid funds. U.S. households owning mutual funds rose from 6 percent in 1980 to 44 percent in 1998. See Engen and Lehnert (2000) and Klapper, Sulla and Vittas (2004) for facts on the growth of the mutual fund industry.

decades, largely through mutual funds, pension funds and hedge funds, fund managers have been forced to look beyond large, stable, well-capitalized firms that dominated their portfolios in the past."

Several other studies present evidence consistent with improved U.S. equity markets in recent decades. Fama and French (2001), for example, show that the number of IPOs (mostly listed on the Nasdaq) explodes after 1979. Fama and French (2004) examine the characteristics of new lists and show that, compared to the 1970s, there were pervasive changes in the characteristics (e.g., profitability) of the firms that went public in the 1980s and 1990s. They conclude that the best explanation for the changing characteristics of new lists was a reduction in the cost of public equity funding, leading to a rightward shift in the supply of equity finance in the 1980s and 1990s.

Improvements in capital markets are depicted in Figure 1 by the downward shift and rightward rotation in the external portion of the finance schedule from S_1 to S_2 to S_3. For firms using external finance at the margin (or firms who begin to use external finance), improvements in capital markets should lead to increased use of external finance and greater rates of investment. For example, a shift from S_1 to S_3 causes the use of external finance to increase from I_1 – CF to I_3 – CF and total investment to rise from I_1 to I_3. Shifts in the supply of external finance (as depicted in Figure 1) lead to:

Prediction 2: Other things equal, for firms using external finance at the margin, improvements in capital markets should lead to an increase in both the rate of total investment and the use of external finance.

More importantly for our analysis, based on equation (1), improvements in capital markets should reduce the marginal cost of external finance (E_{11}), leading to a reduction in the ICF sensitivity. This leads to the following prediction:

Prediction 3: Other things equal (e.g., composition of investment), improvements in capital markets should lower the ICF sensitivity for all types of investment.

For physical investment, the changing composition of investment and improvements in capital markets reinforce each other. For R&D, however, rising β_{RD} and improvements in capital markets have *opposite* implications for the ICF sensitivity, which leads to:

Prediction 4: If capital markets are improving and β_{RD} is increasing: i) the ICF sensitivity for physical investment should fall sharply, ii) the ICF sensitivity for R&D need not decline, given the opposing effects *of compositional change and capital market development, and iii) the ICF sensitivity for total investment should fall over time, though not as sharply as the decline for physical investment.*

D.3 Negative Cash Flows and the Use of External Finance

A third reason for a declining ICF sensitivity is the dramatic rise in the proportion of negative cash flow observations (see Table 1). Allayannis and Mozumdar (2004, p. 902) argue that "negative cash flow is a useful proxy for characterizing firms that are in… financially distressed situations," which attenuates their investment response to changes in cash flow. While no doubt many firms with negative cash flows are experiencing financial distress, our evidence suggests that a large fraction of these firms might be better described as startup companies.[13] Our summary statistics show that young firms with persistent negative cash flows made the heaviest use of equity finance (consistent with Bhagat, Moyen and Suh, 2005). This can lead to a bias in conventional estimates of the ICF sensitivity for reasons somewhat different than financial distress: failure to control for external finance can lead to a downward omitted-variable bias because cash flow and stock issues are strongly negatively correlated for the firms that make the heaviest use of stock issues. That is, while we expect improvements in equity markets to drive down cash flow coefficients, failure to include stock in the regression may overstate the "true" decline in the ICF sensitivity.

D.4 Measurement Error in Cash Flow and Q

A final consideration is measurement error for key variables in the ICF regression, including cash flow. A main reason for measurement error in the conventional cash flow measure is the fact that R&D is expensed and thus measures of cash flow are net of R&D expenditures. A more comprehensive measure of cash flow is cash flow before total investment, including R&D. As noted above, R&D has increased dramatically in the last two decades, leading to potentially growing measurement error problems in conventional measures of cash flow. We address this problem by using a gross measure of cash flow, similar to Hall (1992), Himmelberg and Petersen (1994), and Bond, Haroff and Van Reenen (2003). We also note the potential problem of measurement error in Tobin's Q, though as we discuss in section VI

[13] For example, of the firms with persistent negative cash flows in the final period of our sample, only 13% are "mature" (i.e., first stock price in Compustat more than ten years before the start of the sample period).

problems with Q do not appear capable of explaining either the differences in ICF sensitivities across R&D and physical investment or the changes in ICF sensitivities over time that we document.

E. Debt and Stock Issues in ICF Regressions

Our main GMM regressions include measures of debt and stock issues, something that is rarely done in ICF studies.[14] One reason to include measures of external finance is to control for an omitted variable bias, as discussed above. Another reason is to explore the potentially different roles of debt and equity for investment. In their exploration of the "equity finance channel," Baker, Stein and Wurgler (2003) argue that there are certain financial features (e.g., negative cash flows, low incremental debt capacity) that make firms "equity-dependent." Following their line of analysis, we expect that stock effects in ICF regressions should be strongest in samples of firms with equity-dependent features. In addition, for reasons discussed above, R&D is likely an equity-dependent type of investment and thus stock issues are likely the key marginal source of external finance for R&D. New debt issues, on the other hand, are likely more important for investments in physical capital with collateral value. This discussion leads to the following predictions concerning stock and debt in ICF regressions:

Prediction 5: In ICF regressions with measures of external finance: i) stock effects should be strongest for investment in R&D, particularly for equity-dependent firms, while ii) debt effects should be relatively stronger in the physical investment regressions.

What do we mean by stock and debt effects? Part of the answer is the size (and significance) of the estimated stock and debt coefficient in the ICF regressions, together with the importance of stock and debt as sources of finance. In addition, stock and debt effects can also be measured by the impact their inclusion has on the estimated cash flow coefficient in ICF regressions. As discussed above, excluding measures of external finance from ICF regressions can theoretically lead to biased estimates of the true ICF sensitivity. In particular, if negative cash flow firms rely extensively on stock issues to finance investment, then controlling for stock issues should lead to an increase (and perhaps a change in sign) in the estimated cash flow coefficient in the ICF regression.

[14] One exception is Bond and Mehir (1994), who examine U.K. data. They do not, however, consider R&D, the investment for which we find large stock effects. Kim and Weisbach (2008) study the link between stock and debt issues and subsequent increases in physical investment and R&D, but they do not examine role of external finance in ICF regressions.

Finally, the pattern of stock (and debt) effects *over time* in ICF regressions should also convey useful information about improvements in financial markets. In particular, *rising* stock coefficients in ICF regressions provide some suggestive evidence of the increasing importance of equity finance. In the early stages of rapid improvements in equity markets (e.g., 1970s, following the creation of Nasdaq), newly listed firms may have viewed stock issues as a novelty that was unlikely to be repeated on a regular basis. In addition, the wedge between internal finance and external finance may have been large (e.g., S_1 in Figure 1), making stock issues very costly unless equity prices were abnormally high.[15] For both of these reasons, in the early years of rapid improvements in U.S. equity markets, firms raising stock to finance investment might rationally invest only a small fraction of the stock issue, devoting most of the stock issue to precautionary cash holdings to avoid sharp swings in R&D and other investments with high adjustment costs. As time passed and stock markets improved, however, the cost of stock issues should have declined (e.g., shift in the supply schedule from S_1 to S_3), allowing firms to devote more of each dollar of stock issues to investment and less to precautionary cash holdings. A larger fraction of each dollar of stock finance devoted to expanding current levels of R&D should show up as larger stock coefficients in the R&D regressions.[16]

III. Empirical Specification

To empirically evaluate the ICF sensitivity we begin with the standard OLS regression used in the ICF literature :

$$\left(\frac{INV}{TA}\right)_{i,t} = \beta_1 (Q)_{i,t-1} + \beta_2 \left(\frac{GCF}{TA}\right)_{i,t} + d_t + \alpha_i + \nu_{i,t} \qquad (2)$$

where *INV* is investment spending (capital spending, R&D, or total investment) for firm *i* in period *t* and *TA* is the beginning-of-period stock of firm assets. We scale by total assets because we wish to maintain a common scale factor for all regressions, including the R&D and total investment regressions.[17] As

[15] Several studies present evidence suggesting that firms take advantage of high stock prices (e.g., higher than justified by fundamentals) by issuing new shares. See, for example, Loughran and Ritter (1995), Baker and Wurgler (2000), Baker, Stein and Wurgler (2003), and Kim and Weisbach (2008).

[16] This discussion assumes a constant R&D intensity. Rising β_{RD} should also cause firms to allocate a higher fraction of stock issues to R&D (and less to physical investment). We note, however, that our empirical results show stock effects of near zero in the 1970s, something that can not be readily explained by compositional issues alone.

[17] Baker, Stein and Wurgler (2003) also scale by total assets in regressions using total investment (physical investment plus R&D). ICF studies, focusing as they do on physical investment, normally scale all variables by the

discussed above, our measure of cash flow, GCF, adds R&D to the standard measure of net cash flow (after-tax income before extraordinary items plus depreciation and amortization). The remainder of the specification is standard in the literature. In particular, Tobin's Q is included as a control for demand, d_t controls for year fixed effects, α_i is a firm specific effect that controls for all time-invariant determinates of R&D at the firm level, and $v_{i,t}$ is a random error term. (Detailed variable definitions with Compustat data codes are provided in the Appendix.) The firm fixed effects are removed by first-differencing.

We also estimate a dynamic model of investment that includes measures of the use of external finance:

$$\left(INV/TA\right)_{i,t} = \beta_1\left(INV/TA\right)_{i,t-1} + \beta_2\left(Q\right)_{i,t-1} + \beta_3\left(GCF/TA\right)_{i,t} + \beta_4\left(STK/TA\right)_{i,t} + \beta_5\left(DBT/TA\right)_{i,t} + d_t + \alpha_i + v_{i,t} \quad (3)$$

where *STK* measures net new funds from stock issues and *DBT* measures net new long-term debt. This specification (without external finance) is similar to a number of other dynamic investment models (e.g., Blundell et al. 1992). The usual rationale for including the lagged investment term, based on formal models of investment behavior, is the presence of adjustment costs of investment. Our approach is also similar to Bond and Meghir (1994), who include stock and debt terms, instrumented with lagged values, in a dynamic model of physical investment. We include stock and debt issues to control for possible omitted variable biases and to evaluate the changing role of external finance for investment.

To obtain consistent estimates of equation (3) we use the first-difference GMM estimator developed by Arellano and Bond (1991) where lagged values of endogenous regressors are used as instruments. Similar approaches have been used in a number of recent applied studies, such as Beck et al. (2000), Bond et al. (2003), and Beck and Levine (2004). This estimation procedure allows us to deal with three important issues. First, in dynamic models with firm fixed-effects (like equation 3) both OLS levels and within-firm group estimates will be biased in panels with relatively few time periods (e.g., Nickell, 1981). Second, all of the financial variables in equation (3) are potentially endogenous – new stock and debt issues in particular – and thus require the use of instrumental variables. Finally, when adjustment

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stock of physical capital. Studies that examine R&D do not scale by the stock of R&D capital because the stock of R&D is not reported by the firm and is difficult to approximate, particularly for young firms without a long time series of R&D expenditures. Furthermore, R&D intensive firms often have few fixed assets, so using fixed capital as the scale variable in R&D regressions would not be appropriate.

costs are high (e.g., R&D), firms may smooth investment in response to transitory shocks to cash flow, potentially obscuring the long-run relationship between investment and cash flow.[18]

Though lagged levels dated as early as t-2 are potentially valid instruments if the error term in the original (undifferenced) specification is i.i.d. (Arellano and Bond (1991)), tests of instrument validity (e.g., Sargan/Hansen *J* test) reject the validity of the t-2 instruments in a substantial fraction of the regressions. Other studies, including Bond and Meghir (1994), also report rejecting the validity of the t-2 instrument in physical investment studies. Thus, we follow Bond and Meghir (1994) and take the instruments back one period to t-3. Excluding the t-2 instruments has little impact on the overall findings, and we do not reject the validity of t-3 to t-5 instruments in the vast majority of the regressions. We therefore use instruments dated t-3 to t-5 for the GMM regressions that follow.

IV. Data and Sample Description

A. Data

As is typical in the ICF literature, we examine publicly traded manufacturing firms (two-digit SIC codes 20-39) with coverage in the Compustat database over 1970-2006. Firms must have a stock price and total assets of at least $1 million before they enter our dataset (if assets subsequently fall below $1 million the firm remains in the sample). We also require that firms have at least five non-missing capital spending observations during the sample period for the physical investment regressions, five non-missing R&D observations for the R&D regressions and five non-missing total investment observations for the total investment regressions.[19] We drop observations for years in which the firm was involved in a significant merger or acquisition. Outliers in all regression variables are trimmed at the 1% level.

We report separate regression results for three different subperiods: 1970-1981, 1982-1993 and 1994-2006. These time periods divide the overall sample into three periods of approximately equal

[18] If investment responds to the permanent component, but not the transitory component (because of adjustment costs), the estimated cash flow coefficient in a regression with fixed effects will be biased downward. One approach for recovering the long-run relationship is to instrument cash flow with lagged values (Griliches and Hausman, 1986). Himmelberg and Petersen (1994) report a substantial increase in the estimated effect of cash flow on R&D when cash flow is instrumented with lagged values.

[19] Our findings are robust to alternative minimum observation rules. Because we use lagged observations as instruments in the dynamic GMM regressions, considerably more data are needed per firm than for the simple OLS regressions. Thus, with no rule regarding minimum observations the sample would decline considerably (in both firms and observations) moving from the OLS to the GMM regressions. In all samples, R&D must be reported, as R&D is required to compute gross cash flow.

length. We did, however, examine other time splits (including dividing the sample into four shorter periods or two longer periods) and found similar results.

We also split firms based on the number of years since their first stock price appears in Compustat, typically the year of their IPO. Firm age is likely to be strongly correlated with asymmetric information problems and has been used as a proxy for the presence of financing frictions in a number of studies (e.g., Devereux and Schiantarelli, 1990; Oliner and Rudebusch, 1992; Rauh, 2006; BFP, 2008; Fee, Hadlock, and Pierce, 2008; Hadlock and Pierce, 2008).[20] In addition, the impact of developments in equity markets should be most important for firms in the early phase of their life-cycle. Firms are classified as mature if their first stock price is reported by Compustat ten or more years before the start of a given subperiod. For example, for the 1982-1993 period, all firms with a first stock price appearing in Compustat after 1972 are considered young, and all firms with a first stock price appearing on or before 1972 are considered mature. Firms are not permitted to switch between young and mature within a given subperiod, though our results are robust to rules that do allow such switching. In section VI we discuss the results for other classification approaches, including the payout ratio.

We also report separate results for positive and negative cash flow firms. For each firm we compute the *sum* of the gross cash flow ratio during the subperiod. If the sum of the firm's cash flow ratios during the period is less than or equal to zero the firm is considered a negative cash flow firm. This approach for classifying negative cash flow firms follows BFP (2008).

B. Summary Statistics

The sample summary statistics are based on annual firm observations.[21] We focus our discussion on differences between young and mature firms and changes over time. We report summary statistics for all firms in Table 1 and then briefly summarize the key patterns for positive- and negative-cash flow firms. As discussed previously, all finance and investment values are scaled by beginning-of-period total assets.

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[20] Hadlock and Pierce (2008) use qualitative information disclosed by firms (similar to Kaplan and Zingales (1997)) to create an index of financing constraints for a large random sample of firms. They then examine a large number of proxies used in the literature (e.g., leverage, size, etc.) and conclude that firm age and size are the two variables most related to the qualitative information reported by firms concerning the presence of financing constraints.

[21] The summary statistics reported in Table 1 is for the physical investment regression sample (i.e., the sample that requires at least five non-missing capital spending observations). The summary statistics for the R&D sample are virtually identical.

Table 1 shows that the median and average total assets of mature firms are many times larger than the assets of young firms. Median assets (in 2000 dollars) are smaller in the later periods because of the large number of small IPOs in the 1980s and 1990s. Of greater interest, capital investment ratios (CAP/TA) declined substantially for both young and mature firms: median ratios were 0.055 and 0.061 in the early period but only 0.031 and 0.040 by the late period. In sharp contrast, R&D ratios rose substantially over the sample period. For mature firms, the median R&D ratio rose from 0.016 in the first period to 0.030 in the final period. For young firms, the median R&D ratio rose from 0.013 to 0.095, a more than seven-fold increase. (The means exhibit a similar pattern.) Mature firm total investment ratios ((RD+CAP)/TA) are relatively constant across the three periods. In contrast, the total investment ratios for young firms increase sharply over time, due entirely to the rise in R&D intensity. The rise in R&D intensity is also apparent in the increasing share of R&D in total investment (RD/(RD+CAP)). For young firms, the median RD/(RD+CAP) ratio rose from 0.181 in the first period to 0.747 in the final period – a four-fold rise in the R&D share of total investment – while the corresponding ratios for mature firms rose from 0.207 to 0.428.

Overall, these statistics illustrate a dramatic change in the *composition* of investment for publicly traded manufacturing firms. In particular, investment in R&D was a minor use of funds in the 1970s but became the principal type of investment for most young firms and a large fraction of investment for mature firms by 1994-2006. Thus, the statistics show a dramatic increase in β_{RD} (and a decline in β_{CAP}) over the 1970-2006 period, which is of particular importance for understanding the changing pattern of ICF sensitivities as developed in *Predictions 1* and *4* discussed in section II.D.

Cash flow ratios also exhibit substantial variation over time. Net cash flow ratios (CF) – the variable commonly used in ICF studies – are very similar for both young and mature firms in the early period (approximately 0.100 at both the mean and the median). Over time, for mature firms, there is no change in the median net cash flow ratio and a modest decline in the average cash flow ratio. For young firms, however, the median net cash flow ratio declined over eighty percent by the final period, and the average net cash flow ratio is negative (-0.136). Gross cash flow (GCF) is also similar for young and mature firms in the early period. For mature firms, gross cash flow is stable over time. For young firms, median and mean gross cash flow falls over time, though much less than the decline in net cash flow.

Because R&D rose dramatically over time, using cash flow net of R&D greatly exacerbates the decline in measured cash flow (particularly for young firms). Even for gross cash flow, however, there is a noticeable decline in cash flows (especially when measured at the mean) for young firms over time. Much of the explanation for this decline can be found at the bottom of Table 1: there has been a pronounced rise in the fraction of negative cash flow observations, particularly for young firms.[22]

The remainder of Table 1 reports information on sources of finance. For mature firms, mean and median stock issues (STK) are near zero in all periods. For young firms, the medians are also zero in all periods, but stock issues tend to be lumpy, so the medians give a misleading impression of their importance. In contrast, for young firms, *average* values for new stock issues rose rapidly over time, reaching 0.182 in the late period, well above either mean or median gross cash flows. For young and mature firms, median debt issues (DBT) are near zero in all periods. For mature firms, average debt ratios show little change over time and tend to be slightly larger than stock issues. For young firms, average debt issues rise to 0.029 in the final period, a figure dwarfed by stock issues. The substantial average stock issues for young firms in the 1980s and 1990s is consistent with information on stock proceeds reported in Fama and French (2005).

To save space, we briefly summarize the most interesting summary statistics positive- and negative-cash flow firms (tables are available on request). For positive cash flow firms, recall that the *sum* of the gross cash flow ratios in a given subperiod is positive. Across the three periods, the fractions of young firms in the *positive* cash flow group are 96.8, 79.2 and 68.1 percent, reflecting the pronounced rise in the fraction of negative cash flow observations. The corresponding fractions of mature firms classified as *positive* cash flow are 99.0, 95.0 and 92.8 percent. For positive cash flow firms, the capital spending and R&D ratios are broadly similar to those in Table 1, although the rise in the R&D ratio is not as quite as dramatic. In the final period, for positive cash flow firms, the median RD/(RD+CAP) ratio for young and mature firms is 0.672 and 0.421, once again indicating a major change in the composition of investment. As expected, the gross cash flow ratios (GCF) for both young and mature firms in the

[22] While historically IPOs were typically profitable firms (a listing requirement), a large fraction of IPOs in recent decades – typically listed on the Nasdaq – have persistent negative cash flows. This "weaker" quality of IPOs has been explored by Fama and French (2004). They conclude that there was a rightward shift in the supply of public equity finance in the 1980s and 1990s. This shift in finance appears to have allowed firms to survive protracted periods of time with negative cash flows. Also see Ritter and Welch (2002).

positive cash flow sub-sample do not decline at all over time. Thus, once negative cash flow firms are excluded, and cash flow is measured gross of R&D expenditures, there is stability in the cash flow ratios for both young and mature firms over time. Stock issues rise sharply for young, positive cash flow firms, reaching of an average value of 0.092 in the final period.

As noted above, in the final two periods a substantial fraction of young firms (20.8 and 31.9 percent, respectively), and a comparatively small fraction of mature firms (5.0 and 7.8 percent), fall into the *negative* cash flow category. The negative cash flow firms are extremely R&D intensive, especially in the last period, where the median RD/(RD+CAP) ratio is 0.899 for young firms and 0.726 for mature firms. Median and mean net and gross cash flow ratios are negative for both types of firms in all periods except mature firms in 1970-1981. The negative cash flows are large (in absolute value) in the final period, where median net cash flow (CF) for young and mature firms is -0.407 and -0.168, and median gross cash flow (GCF) is -0.172 and -0.098. The mean values are even larger in absolute value. How do firms with persistent negative cash flows finance themselves? These firms typically issue little new debt: the means are small in the first two periods and modest (0.052) for young firms in the final period. In contrast, average stock issues for young firms jump from near zero to very large values in the final period (0.424), more than offsetting negative gross cash flows.

Taken together, the descriptive statistics show that much has changed for publicly traded manufacturing firms. First, median and mean net cash flows (CF) have fallen a great deal. This decline appears to be largely due to the sharp increase in the number of young firms with *persistent* negative cash flows and the increase in R&D investment, which is expensed for accounting purposes. Second, there has been a marked rise in the use of public equity issues. Third, capital investment as a fraction of total investment has fallen sharply. Fourth, the R&D ratio for young firms has risen to the point that it is considerably larger than the capital investment ratio. Fifth, the total investment ratio for young firms rose sharply over the 1970-2006 period. As discussed in *Prediction 1*, the sharp decline in the physical investment share of total investment (β_{CAP}), and the sharp rise in the R&D share of total investment (β_{RD}), implies that the ICF sensitivity for physical investment should have fallen and the ICF sensitivity of R&D should have risen, other things held constant. As discussed in *Prediction 2*, the sharp rise in total investment and the increased use of external finance (especially equity) for young firms (but not mature firms) is consistent with improvements in capital markets over the past three decades.

V. Regression Results

Tables 2-3 contain standard OLS regressions for physical investment and R&D. Tables 4-6 report dynamic investment regressions with external finance (estimated with GMM). Each table reports regressions for the three subperiods discussed above and three different samples: all firms (Panel A), positive cash flow firms (Panel B) and negative cash flow firms (Panel C). Finally, in each panel and time period, we report separate results for young and mature firms. The number of firms and observations appear at the bottom of each cell. In all of the tables, no results are provided for the first subperiod of Panel C because of the small number of observations.

A. OLS Regressions

Table 2 reports OLS regressions for physical investment (CAP).[23] In all panels, the estimated coefficients for Q are positive, statistically significant, and of a similar magnitude to what is typically reported in the ICF literature. For *all firms* (Panel A), cash flow coefficients fall sharply over time. In the 1970-1981 period, the cash flow coefficients for young (0.205) and mature firms (0.232) are broadly consistent with what is found in the literature examining comparable time periods. By the final period, however, cash flow coefficients are near zero for young firms (0.007) and small for mature firms (0.045). For both firm types, differences in the estimated ICF sensitivities across sample periods are statistically significant (p-values for tests that the ICF sensitivities are equal between each period are 0.000 for both firm types). For *positive cash flow firms* (Panel B), the first-period results are similar to those in Panel A (consistent with the lack of negative cash flow firms in this period). In the next two time periods – despite the removal of negative cash flow firms – the cash flow coefficients decline nearly as sharply as those in Panel A. By the final period, the cash flow coefficients for young and mature are only 0.035 and 0.055, respectively. Again, these changes are both quantitatively large and statistically significant (with

[23] Typically, ICF studies use *net* rather than *gross* cash flow and scale by beginning of period *net fixed assets* instead of total assets. We re-estimated all of the physical investment regressions (available on request) and found virtually identical results to those reported in Table 2 if cash flow is measured net of R&D expenditures or if net fixed assets is used as the scale factor.

p-values in all cases equal to 0.000) The *negative cash flow firms* in Panel C have cash flow coefficients typically near zero or negative, consistent with the literature that has examined the impact of negative cash flow observations on the ICF sensitivity (e.g., Allayannis and Mozumdar, 2004). Overall, the findings in Table 2 suggest that the ICF sensitivity for physical investment has all but disappeared.

Table 3 reports OLS regressions for R&D. Among *all firms* (Panel A), the cash flow coefficient for young firms declines from 0.084 in the first period to -0.026 in 1994-2006 (these coefficient estimates are statistically different). For the *positive cash flow firms* (Panel B), the ICF sensitivity for R&D is largely unchanged over time for mature firms but rises slightly for young firms. In the final period, cash flow coefficients for young and mature firms are 0.111 and 0.065; both the change over time for young firms and the difference between young and mature firms is statistically significant at conventional levels. For the *negative cash flow firms* (Panel C) the cash flow coefficients are negative or near zero in all cells. In particular, for young firms in the final period, the estimated cash flow coefficient is -0.101 (and significant). Clearly, negative cash flow firms have a very large impact on the *all* young firm ICF sensitivity in the final period (driving it to zero). The main difference between the physical investment and R&D regressions is the lack of a declining R&D-ICF sensitivity when negative cash flow firms are excluded from the regression sample.

We do not report a table (available on request) of OLS regressions for total investment to save space. As expected, the estimated cash flow coefficients for total investment are approximately the *sum* of the respective cash flow coefficients in Table 2 and 3, consistent with the fact that total investment represents a greater use of finance than either R&D or physical investment. For *all* young firms, cash flow coefficients decline from 0.304 to -0.010, reflecting precisely the same pattern in Tables 2 and 3. For young, *positive* cash flow firms, the cash flow coefficient declines sharply between the first and last period (0.312 to 0.149) but remains statistically significant.. The reason for this attenuated decline (compared to all firms) is almost entirely due to the lack of a decline in cash flow coefficients for R&D (Table 3, Panel B). Cash flow coefficients for *negative* cash flow firms are generally negative or near zero. In particular, the cash flow coefficient for young, negative cash flow firms -0.118 (and significant) in the final period, consistent with the results Tables 2 and 3. Once again, it is clear that negative cash flow firms have a very large (negative) impact on estimated ICF sensitivity for *all* young firms in the final period. This arises both because of the large number of negative cash flow firms and because these firms account for a disproportionate amount of the total variation in the data. Thus, the ICF relationship for total investment vanishes when *all* firms are pooled together, but the decline is much attenuated if firms with persistent negative cash flows are excluded from the sample.

B. Dynamic GMM Regressions with External Finance

GMM estimates of equation (3), which includes stock and debt issues, are reported in Tables 4-6.[24] As discussed above, all financial variables are instrumented with lags dated t-3 to t-5. The Hansen (1982) *J* test rejects instrument validity (at the 5% level) in only two regressions (and is close to rejecting in two others). Furthermore, we found almost no evidence of third-order autocorrelation in the first differenced residuals, further supporting the validity of the instrument set.[25]

In Table 4, for *all firms* (Panel A), the cash flow effects on physical investment are large for both young and mature firms in the first period (0.320 and 0.303). The cash flow coefficients exhibit a sharp and statistically significant decline over time and, by the final period, are near zero (0.013) for young firms and modest (0.076) for mature firms. Thus, the pattern of cash flow coefficients is very similar to the OLS results in Table 2. The coefficients for stock issues are small and insignificant for young firms in all periods, and significant for mature firms only in the middle period. In contrast, the coefficient on new debt finance is large in magnitude (approximately 0.210) and highly significant for both young and mature firms in the first period. Debt coefficients remain significant in the second period, but there is a noticeable drop in the magnitude. By the final period, the debt coefficient is near zero for young firms and is small (0.054) for mature firms.

For *positive cash flow firms* (Panel B), the pattern of cash flow and external finance coefficients are very similar to the results in Panel A. In particular, the cash flow coefficients in Panel B fall nearly as sharply as the coefficients in Panel A. The young-firm cash flow coefficient is statistically significant but

[24] To provide a bridge between the GMM and OLS regressions, we first estimated the dynamic investment equation (3) with external finance *excluded*. Thus, the specification is similar to the OLS regressions except for the addition of the lagged investment term. Because the results are so similar to the corresponding OLS tables, we do not report the three tables (which are available on request). In particular, the main patterns in Tables 2-4 are unaffected when the regressions are estimated with GMM.

[25] Evidence of third-order autocorrelation in the first differenced residuals would imply second-order serial correlation in levels, which would render the t-3 instruments invalid. Only for young, negative cash flow firms in Table 7 (total investment) do we reject the null of no third-order autocorrelation in the first-differenced residuals.

small (0.061) in the final period. Debt coefficients are large in the first period but also decline sharply over time. The declines in both the cash flow and debt coefficients are statistically significant. Except for the modest (and significant) stock coefficients in the middle period, stock coefficients are small and insignificant. For *negative cash flow firms* (Panel C), cash flow coefficients are generally near zero and are statistically insignificant. Stock coefficients are also small and insignificant, and debt coefficients, for both young and mature firms, are significant in the second period but insignificant in the final period.

Overall, the cash flow coefficients in Table 4 are similar to the OLS results in Table 2. Most notably, even after controlling for negative cash flow firms and external finance, the physical ICF sensitivity plummets over time. Comparing the results in Table 4 with those in Table 2 (or with GMM regressions that exclude external finance) shows that including the external financial variables has only a small impact on the estimated cash flow coefficients. Overall, debt appears to be more important in the physical investment regressions than stock issues, consistent with *Prediction 5*. We note, however, that debt coefficients decline sharply over time, similar to the pattern of cash flow coefficients.

Table 5 reports the GMM results for R&D. For *all firms* (Panel A), the cash flow coefficients for young firms are reasonably large and statistically significant in all three periods, with a relatively small and statistically insignificant decline over time. This finding differs sharply from the R&D results in Table 3 which show a steep decline in the cash flow coefficient for all young firms. In particular, the cash flow coefficient in Table 5 for young firms in the final period is 0.080 (0.041) compared to a coefficient of -0.026 in Table 3. Stock coefficients for young firms are near zero in the first period and rise to a large and statistically significant 0.175 by the final period, while stock coefficients for mature firms are small and insignificant. For young firms, debt coefficients are smaller than stock coefficients and are generally insignificant.

For *positive cash flow firms* (Panel B), the estimated R&D-cash flow sensitivity also shows no evidence of a decline over time. In particular, the estimated cash flow coefficients for young firms are similar in magnitude and statistically indistinguishable across the three sample periods. In the final period, the cash flow coefficient for young firms (0.151) is substantially larger than the coefficient for mature firms (0.069) and the difference is statistically significant at the 10% level. Stock effects in Panel B are similar to those in Panel A: in particular, stock coefficients for young firms show an economically and statistically significant rise from near zero in the first period to 0.151 in the final period. Debt coefficients are generally small and insignificant for both young and mature firms.

For *negative cash flow firms* (Panel C), the cash flow coefficient for young firms in the final period is 0.075 (and significant) which is a substantial change compared to the corresponding coefficient in Table 3 (-0.101).[26] As discussed above, this change is not surprising because *negative cash flow firms* are the most dependent on external finance, and thus the omitted variable bias should be substantial. Importantly, stock issues is the key omitted variable: including only stock issues results in a cash flow coefficient of 0.090 (0.046), while including only debt leaves the cash flow coefficient essentially unchanged compared to the GMM regressions that exclude external finance. For young firms (but not mature firms), stock coefficients are large and statistically significant, particularly in the final period. We also find substantial debt coefficients for young firms in the final period. As noted above, however, removing debt from the young firm regressions has no impact on the cash flow coefficients, consistent with the fact that debt finance is relatively small compared to stock finance (see Table 1).

There are three key results in Table 5. The first is that there is no evidence of a falling R&D-cash flow sensitivity once external finance is included in the regression. The second is that stock issues appear to matter a great deal for R&D, arguably the equity-dependent investment, consistent with *Prediction 5*. Finally, stock coefficients rise sharply over time, consistent with improvements in equity markets.

Table 6 reports regressions for *total investment* (physical investment plus R&D). For *all firms* (Panel A), the cash flow coefficient for young firms is 0.162 (0.044) in the final period, which is about 60 percent lower (and statistically different) than the coefficient in the first period (0.406). This decline is, however, considerably smaller than in the OLS total investment regressions or GMM regressions that omit external finance. Debt coefficients are positive and significant in all periods for both young and mature firms, though recall that debt is relatively unimportant as a source of funds. For young firms, the debt coefficients are approximately 0.210 in all periods. For young firms, stock coefficients exhibit a large, statistically significant increase from zero in the first period to 0.198 in the final period, similar to

[26] We note that the rise in the cash flow coefficient for all firms (Panel A) from including external finance in the regression is primarily due to the rise in the cash flow coefficient among negative cash flow firms (Panel C).

the magnitude of the debt coefficients. Stock coefficients for mature firms are insignificant except for the final period.

For *positive cash flow firms* (Panel B), the cash flow coefficient for young firms in the final period is 0.240, approximately 45 percent lower than the first-period coefficient (0.433). This final-period cash flow coefficient for young firms is substantially higher than the coefficient for mature firms (0.145). With the exception of mature firms in the middle period, debt coefficients are generally substantial and significant. Stock coefficients for young firms rise from zero to a substantial number (0.145) in the final period, but are statistically insignificant for mature firms except in the final period.

For *negative cash flow firms* (Panel C), the cash flow coefficient for young firms in the final period is 0.094 (0.041), substantially larger than the OLS coefficient (-0.118) and the GMM coefficient in regressions that omit external finance. Both stock and debt coefficients are large for young firms. Once again, however, stock has the most important impact on the estimated ICF sensitivity: including only debt in the regression results in a cash flow coefficient slightly smaller than the GMM estimate without external finance, while including only stock issues results in a cash flow coefficient similar to what appears in Panel C of Table 6.

VI. Robustness

The basic pattern of results that we discuss in section V is robust to a number of alternative sample selection criteria, specifications and estimation procedures. In this section we summarize a few of the most important of these results. In all cases, the results are available on request.

A. Alternative Sample Splits

We have argued firm age is a useful criteria for splitting the sample, particularly if one is interested in the impact of capital market development. It is also important to consider other common sample splitting rules used in the ICF literature.[27] Perhaps the most common sample split is based on some variation of the firm's payout ratio (FHP, 1988).[28] We considered two different payout splits. First,

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[27] One problem with using splitting criteria such as the payout ratio or firm size is that for firms listed in Compustat, both the median size and the median payout ratio have changed a great deal over the time period of our study. For example, firms paying zero dividends were not very common in the 1970s but became extremely common in the 1990s (see Table 1).

[28] We also split the sample based on firm size during each sample period and found a steep decline in the ICF sensitivity over time, particularly for physical investment.

we sorted firms based on whether they had a positive net payout during the sample period. Second, we sorted firms into high- (upper 25%) and low-payout groups based on their average payout ratio (dividends plus stock buybacks over beginning of period total assets) during the sample period. Because firm age and the propensity to pay dividends are highly correlated, it is not surprising that the results for the sample of firms with zero (or low) payout ratios are similar to the "young" firm results, while the sample with positive (or high) payout rates are similar to the "mature" firm results. Most importantly, the ICF sensitivity for both high and low payout firms declines sharply over time and largely disappears for physical investment, but remains comparatively strong for total investment and R&D, particularly in regressions that control for negative cash flow firms and external finance.[29] In addition, stock issues become increasingly important in the R&D and total investment regressions over time, particularly for low payout firms.

B. Alternative Instruments, Estimating Equations and Scale Factors

For reasons discussed in Section III, we use lagged values dated t-3 to t-5 for the GMM estimates reported in Tables 4-6 because t-2 instruments are more likely to be invalid. Nonetheless, t-2 is a potentially stronger instrument, so as a test of robustness we estimated all regressions with the t-2 instruments included. When we include t-2 in the instrument set, the results are quantitatively very similar to those reported in Tables 4-6. In particular, all of the major patterns are unaffected by the inclusion of instruments dated t-2.

In addition, the results do not change in any significant way if we use slightly different estimating equations. For example, we added sales growth to the regressions as an additional control for investment demand and found no major change in the estimated financial effects in either the capital spending or the R&D regressions. We also included lags of the financial variables in the dynamic regressions reported in Tables 4-6 and the overall results changed little. The GMM results are also unaffected if the dynamic investment term is excluded from the regression. Finally, we followed standard practice in ICF studies that focus on physical investment (e.g., FHP, 1988) and used the stock of physical capital as the scale factor in the physical investment regressions. Again, the findings are broadly similar with those we

[29] For example, in total investment regressions that correspond to Panel B in Table 6, the ICF sensitivity declines from 0.393 to 0.229 for low payout firms and 0.335 to 0.174 for high payout firms.

report, in particular the estimated physical investment ICF sensitivity largely disappears during the period we study, even when controlling for negative cash flow firms and external finance.

C. Measurement Problems in Q and the Declining ICF Sensitivity

Because of measurement problems, Q may not be a sufficient control for investment demand, and thus financial variables may proxy for investment opportunities (e.g., Erickson and Whited, 2000). While important for the ICF literature in general, we believe these concerns are not a major problem for the inferences we draw in this study. In particular, if Q is a poor control for investment demand, it should be equally poor for both R&D and physical investment, and thus problems with Q cannot fully explain why the ICF sensitivity declines sharply for physical investment but remains relatively stable for R&D. Similarly, measurement problems in Q cannot explain the *differences* in the role of financial variables across physical investment and R&D. Finally, we considered the possibility that Q became a better control for investment demand during the period of our study, which could in theory be the reason for a decline in the ICF sensitivity. When we removed Q from all the regressions, however, we continued to find the same pattern of decline in the ICF sensitivity, suggesting that our findings are not being driven by a reduction in measurement error associated with Q.[30]

VII. Interpretation of the Results and Implications

A. The Declining ICF Sensitivity

Suppose we considered only physical investment. We would conclude that the ICF sensitivity has essentially disappeared (e.g., a nearly 100 percent decline for *all* young firms). Even after controlling for negative cash flow firms and the use of external finance (Table 4, Panel B), cash flow coefficients for physical investment have fallen by over 70 percent since the 1970-1981 period for both young and mature firms. A likely explanation for much of this decline is the sharp fall in the physical investment share of total investment, which we denoted earlier in the paper as $\beta_{CAP.}$ The summary statistics show that for *positive* cash flow young firms, median β_{CAP} declined from 0.82 in 1970-1981 to 0.33 in 1994-2006, a

[30] Carpenter and Guariglia (2008) add contractual obligations for new investment projects as an additional proxy for information about investment opportunities. They find that introducing this variable in a standard ICF regression (along side Q) reduces the cash flow coefficients for large firms but has no impact on the cash flow coefficients for small firms, supporting an interpretation that the significance of cash flow (for small firms) arises due to financing frictions.

decline of around 60 percent. Thus, based on *Prediction 1*, we would expect a very large fall in the physical investment sensitivity simply because physical investment has become a much smaller use of funds.

Superficially, the R&D-cash flow sensitivity (Table 5) displays a different pattern: cash flow coefficients do not decline over time. But recall that the R&D share of total investment (β_{RD}) rose dramatically over time. For example, for *all* young firms (Table 1), the median value of β_{RD} rose from 0.18 in 1970-1981 to 0.75, a four-fold increase. Based on *Prediction 1*, without improvements in capital markets, there should have been a very sharp *rise* in the R&D ICF sensitivity. As summarized below, a likely reason for the absence of a rise in the R&D ICF sensitivity is improvements in capital markets.

Because of compositional issues, the clearest evidence of a decline in the ICF sensitivity can be found in the GMM regressions for total investment (Table 6). For *all* firms (Panel A), over the period of our study, cash flow coefficients fell 60 percent for young firms and 41 percent for mature firms. This decline is considerably smaller than for physical investment (Table 4), consistent with *Prediction 4*. For positive cash flow firms (Table 6, Panel B), cash flow coefficients declined by approximately 45 percent for young firms and 51 percent for mature firms. Among these positive cash flow firms, the cash flow coefficient for young firms is still substantial in the final period (0.240).

B. Improvements in Equity Markets?

Previous studies have argued that there was a substantial shift in the supply of public equity finance in the 1980s and 1990s (e.g., Fama and French, 2004). Several findings in our study also suggest that public equity markets improved substantially in recent decades. Most obviously, stock issues by young firms rose from near zero to very high levels in the final period. For *all* young firms (Table 1), the mean of stock issues in the final period is considerably larger than gross cash flow; and for young *negative* cash flow firms stock issues are large enough to more than offset the negative gross cash flow figures. In contrast, debt finance for both young and mature firms, and stock issues for mature firms, rises only modestly.

Other important pieces of evidence are where and in what time periods stock issues matter in the regressions. As we have argued (*Prediction 5*), R&D is likely the equity-dependent investment and young firms are the equity-dependent type of firm. We in fact find strong stock effects primarily for

R&D, and only for young firms. In addition, stock coefficients for young-firm R&D rise from near zero in the early period to large and significant values in the final period, which we argue (Section II.E) is consistent with improvements in equity markets. Furthermore, for young, negative cash flow firms, including stock in the R&D regression substantially raises the cash flow coefficient. This suggests that while improvements in equity markets lower ICF sensitivities, ICF regressions that omit stock issues may actually overstate the true decline in cash flow coefficient for some types of firms.

Finally, we point to the dramatic increase in R&D's share of total investment (β_{RD}) over our sample period. Absent improvements in equity markets, this change in the composition of investment should have led to a sharp rise in the R&D-cash flow sensitivity. Our results indicate that this did not happen. Given the large size of stock issues (Table 1) and the large stock coefficients in the R&D regression, a likely explanation for the static R&D-cash flow sensitivity is that public equity finance became a much closer substitute for internal equity over this time period. The sharply declining total investment-cash flow sensitivity, together with the rising stock effects in total investment regressions, is also consistent with public equity becoming a better substitute for internal funds over the period we study.

VIII. Conclusion

Studies of the ICF sensitivity constitute one of the largest empirical literatures in corporate finance and ICF regressions continue to be used extensively as a tool in corporate finance. Over the time period 1970-2006, we show that the ICF sensitivity for physical investment declined dramatically, the R&D ICF sensitivity remained comparatively strong, and the ICF sensitivity for total investment declined by a considerable amount but remains quantitatively important. These changes over time are consistent with the predictions developed in Section II. In particular, we argue that much of the sharp fall in the physical ICF sensitivity is due to the fall in physical investment's share of total investment. We emphasize that the R&D ICF sensitivity has not increased, as would be expected, given the dramatic change in the composition of investment over the time period of our study. By the final period (1994-2006), controlling for external finance and negative cash flows, young firms have substantially higher cash flow coefficients in both the R&D and the total investment regressions than mature firms.

Our evidence indicates that a likely explanation for the overall decline in the ICF sensitivity is improvements in equity markets over the last three decades. We show that stock issues rose from a trivial source to a major source of finance over the time period of our study. In addition, there are little or no stock effects for physical investment but strong stock effects for R&D (and total investment), arguably the equity-dependent type of investment. Furthermore, the stock effects appear primarily for young firms, arguably the equity-dependent type of firm. Finally, we find a rising pattern of stock coefficients over time, no rise in the R&D-cash flow sensitivity, and a falling pattern of cash flow coefficients for total investment, consistent with public equity becoming a better substitute for internal equity finance. Collectively, the ICF and stock market findings are consistent with an attenuation of financing frictions brought about by improvements in equity markets in recent decades.

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Data Appendix

Variable Definitions with Compustat Data Codes

$(RD/TA)_t$: Research and development expense (data46) in period t divided by the book value of total assets (data6) at the beginning of period t.

$(CAP/TA)_t$: Capital expenditures (data128) in period *t* divided by the book value of total assets (data6) at the beginning of period *t*.

$(SALES/TA)_t$: Net sales (data12) in period *t* divided by the book value of total assets (data6) at the beginning of period *t*.

$(CF/TA)_t$: Cash flow in period *t* divided by the book value of total assets (data6) at the beginning of period *t*, where cash flow is defined as (after-tax) income before extraordinary items (data18) plus depreciation and amortization (data14).

$(GCF/TA)_t$: Gross cash flow in period *t* divided by the book value of total assets (data6) at the beginning of period *t*, where gross cash flow is defined as (after-tax) income before extraordinary items (data18) plus depreciation and amortization (data14) plus research and development expense (data46).

$(DBT/TA)_t$: Net new long-term debt issued in period *t* divided by the book value of total assets (data6) at the beginning of period *t*, where net new long-term debt is equal to long-term debt issued (data 111) minus long-term debt reduction (data114).

$(STK/TA)_t$: Net cash raised from stock issues in period *t* divided by the book value of total assets (data6) at the beginning of period *t*, where net cash from stock issues is equal to the sale of common and preferred stock (data108) minus the purchase of common and preferred stock (data115).

$(Q)_{t-1}$: Market value of assets in period *t-1* divided by the book value of total assets (data6) in period *t-1*, where market value of assets is equal to the market value of equity (data25*data199) plus the book value of assets (data6) minus the book value of equity (data60 – data74).

Figure 1:
Financing Hierarchy with Improving Capital Markets

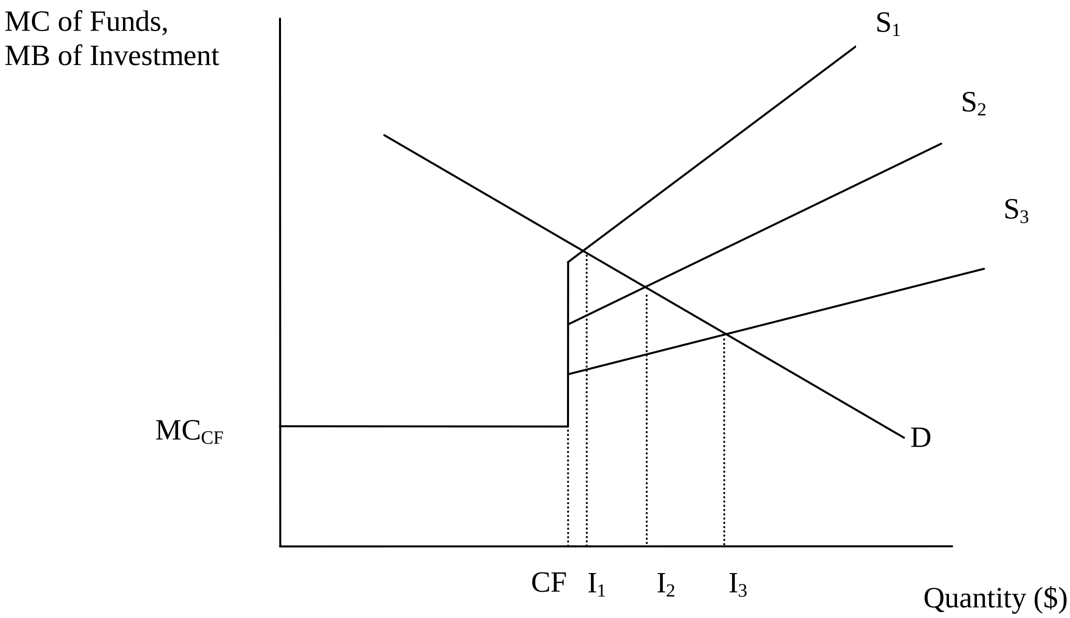

Table 1
Sample Descriptive Statistics: All Firms

The sample is constructed from manufacturing firms (SIC codes 20-39) with coverage in the Compustat database during 1970-2006. We exclude firms incorporated outside of the U.S. and firms without at least five non-missing capital spending observations in a given sample period. Firms must have a non-missing stock price and total assets of at least $1 million before they enter the sample. Firm-years involving a significant merger or acquisition are excluded. All variables are scaled by beginning-of-period total assets. Firms are classified as young if their first stock price in Compustat is within ten years of the start of the sample period. The dollar value of total assets is reported in millions of 2000 dollars.

Sample Period		***1970-1981***		***1982-1993***		***1994-2006***	
Firm Type:		Young	Mature	Young	Mature	Young	Mature
Assets$_t$	Mean	379.80	2726.31	106.27	2510.15	375.41	2976.96
	Median	106.30	681.20	29.29	350.90	61.95	302.00
(CAP / TA)$_t$	Mean	0.070	0.070	0.064	0.063	0.047	0.049
	Median	0.055	0.061	0.045	0.055	0.031	0.040
(RD / TA)$_t$	Mean	0.026	0.022	0.081	0.034	0.165	0.053
	Median	0.013	0.016	0.055	0.022	0.095	0.030
(RD+CAP / TA)$_t$	Mean	0.108	0.096	0.155	0.105	0.218	0.110
	Median	0.089	0.089	0.127	0.094	0.149	0.088
(RD / RD+CAP)$_t$	Mean	0.236	0.235	0.499	0.304	0.649	0.435
	Median	0.181	0.207	0.533	0.285	0.747	0.428
(CF / TA)$_t$	Mean	0.102	0.103	0.026	0.091	-0.136	0.078
	Median	0.102	0.101	0.071	0.097	0.018	0.096
(GCF / TA)$_t$	Mean	0.128	0.125	0.108	0.124	0.034	0.132
	Median	0.123	0.122	0.120	0.126	0.097	0.133
(STK / TA)$_t$	Mean	0.006	0.002	0.060	0.001	0.182	0.005
	Median	0.000	0.000	0.001	0.000	0.008	0.000
(DBT / TA)$_t$	Mean	0.016	0.012	0.011	0.007	0.029	0.009
	Median	0.000	0.000	-0.002	-0.002	0.000	-0.001
Q$_{t-1}$	Mean	1.133	1.092	1.945	1.298	2.975	1.762
	Median	0.944	0.927	1.393	1.151	2.033	1.439
Share obs negative net cash flow		0.058	0.020	0.299	0.092	0.472	0.148
Share obs negative gross cash flow		0.046	0.015	0.196	0.067	0.322	0.097
Share obs positive dividends		0.660	0.880	0.185	0.743	0.110	0.502
Observations		9156	4226	7999	6895	11367	8121
Firms		1349	502	1195	774	1506	877

Table 2
Physical Investment-Cash Flow Sensitivity

Estimation is by OLS. Fixed firm and time effects are included in all regressions. Firm effects are removed by first-differencing. The samples are described in Tables 1A-1C. Outliers in first-differences are trimmed at the 1% level. Standard errors robust to firm-level clustering are reported in parenthesis.

Dependent Variable: $(CAP / TA)_t$

Sample Period	***1970-1981***		***1982-1993***		***1994-2006***	
Panel A: All Firms						
	Young	**Mature**	**Young**	**Mature**	**Young**	**Mature**
$\mathbf{Q_{t-1}}$	0.011	0.018	0.008	0.016	0.004	0.007
	(0.002)	(0.002)	(0.001)	(0.002)	(0.000)	(0.001)
$\mathbf{(GCF / TA)_t}$	0.205	0.232	0.054	0.104	0.007	0.045
	(0.013)	(0.022)	(0.006)	(0.009)	(0.002)	(0.005)
Observations	9156	4226	7999	6895	11367	8121
Firms	1349	502	1195	774	1506	877
Adj. R^2	0.082	0.107	0.047	0.083	0.055	0.070
Panel B: Positive Cash Flow Firms						
	Young	**Mature**	**Young**	**Mature**	**Young**	**Mature**
$\mathbf{Q_{t-1}}$	0.011	0.018	0.008	0.016	0.004	0.007
	(0.002)	(0.002)	(0.001)	(0.002)	(0.001)	(0.001)
$\mathbf{(GCF / TA)_t}$	0.215	0.230	0.079	0.109	0.035	0.055
	(0.013)	(0.022)	(0.007)	(0.010)	(0.004)	(0.005)
Observations	8987	4193	6826	6633	8296	7739
Firms	1306	497	947	735	1026	808
Adj. R^2	0.084	0.107	0.056	0.084	0.072	0.079
Panel C: Negative Cash Flow Firms						
	Young	**Mature**	**Young**	**Mature**	**Young**	**Mature**
$\mathbf{Q_{t-1}}$			0.008	0.013	0.004	0.004
			(0.002)	(0.014)	(0.000)	(0.001)
$\mathbf{(GCF / TA)_t}$			-0.001	0.054	-0.013	-0.006
			(0.009)	(0.015)	(0.003)	(0.008)
Observations			1173	262	3071	382
Firms			248	39	480	69
Adj. R^2			0.069	0.111	0.089	0.061

Table 3
R&D-Cash Flow Sensitivity

Estimation is by OLS. Fixed firm and time effects are included in all regressions. Firm effects are removed by first-differencing. Firms must have five non-missing R&D observations in a given period, additional sample restrictions are described in Tables 1A-1C. Outliers in first-differences are trimmed at the 1% level. Standard errors robust to firm-level clustering are reported in parenthesis.

Dependent Variable: $(RD / TA)_t$

Sample Period	***1970-1981***		***1982-1993***		***1994-2006***	
Panel A: All Firms						
	Young	**Mature**	**Young**	**Mature**	**Young**	**Mature**
$\mathbf{Q_{t-1}}$	0.001	0.002	0.005	0.002	0.014	0.003
	(0.000)	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)
$\mathbf{(GCF / TA)_t}$	0.084	0.062	0.045	0.042	-0.026	0.058
	(0.005)	(0.005)	(0.006)	(0.003)	(0.011)	(0.006)
Observations	6653	3517	7450	5948	11175	7448
Firms	862	385	1036	617	1412	755
Adj. R^2	0.159	0.182	0.046	0.102	0.065	0.066
Panel B: Positive Cash Flow Firms						
	Young	**Mature**	**Young**	**Mature**	**Young**	**Mature**
$\mathbf{Q_{t-1}}$	0.001	0.002	0.004	0.002	0.009	0.003
	(0.000)	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)
$\mathbf{(GCF / TA)_t}$	0.087	0.063	0.081	0.044	0.111	0.065
	(0.005)	(0.005)	(0.006)	(0.003)	(0.012)	(0.006)
Observations	6569	3501	6333	5801	8106	7144
Firms	844	383	825	598	955	702
Adj. R^2	0.166	0.185	0.114	0.105	0.093	0.083
Panel C: Negative Cash Flow Firms						
	Young	**Mature**	**Young**	**Mature**	**Young**	**Mature**
$\mathbf{Q_{t-1}}$			0.006	0.007	0.014	0.003
			(0.002)	(0.005)	(0.002)	(0.004)
$\mathbf{(GCF / TA)_t}$			-0.031	0.018	-0.101	0.018
			(0.014)	(0.011)	(0.014)	(0.016)
Observations			1117	147	3069	304
Firms			211	19	457	53
Adj. R^2			0.038	0.191	0.118	0.041

Table 4
Physical Investment-Cash Flow and External Finance Sensitivity

Estimation is by first-differenced GMM. Fixed firm and time effects are included in all regressions. The samples are described in Tables 1A-1C. Lagged levels dated t-3 through t-5 are used as instruments for the investment and financing variables. Outliers in first-differences are trimmed at the 1% level. Standard errors robust to heteroskedasticity and with-in firm serial correlation are reported in parenthesis.

Sample Period	***1970-1981***		***1982-1993***		***1994-2006***	
	Young	**Mature**	**Young**	**Mature**	**Young**	**Mature**
Panel A: All Firms						
$(CAP / TA)_{t-1}$	0.091 (0.057)	0.185 (0.055)	0.054 (0.043)	0.264 (0.050)	0.286 (0.062)	0.275 (0.048)
Q_{t-1}	0.008 (0.002)	0.011 (0.003)	0.005 (0.001)	0.013 (0.003)	0.003 (0.001)	0.005 (0.001)
$(GCF / TA)_t$	0.320 (0.066)	0.303 (0.074)	0.079 (0.027)	0.082 (0.043)	0.013 (0.013)	0.076 (0.018)
$(STK / TA)_t$	-0.027 (0.088)	0.088 (0.142)	0.037 (0.020)	0.080 (0.038)	0.014 (0.008)	0.007 (0.018)
$(DBT / TA)_t$	0.214 (0.053)	0.215 (0.052)	0.161 (0.042)	0.078 (0.026)	-0.001 (0.021)	0.054 (0.020)
Observations	8154	4016	6589	6578	9616	7802
Firms	1318	500	1159	772	1489	872
***J*-test (p-value)**	0.170	0.292	0.801	0.054	0.113	0.052
Panel B: Positive Cash Flow Firms						
$(CAP / TA)_{t-1}$	0.081 (0.054)	0.173 (0.055)	0.086 (0.045)	0.262 (0.049)	0.318 (0.056)	0.282 (0.048)
Q_{t-1}	0.008 (0.002)	0.011 (0.003)	0.003 (0.002)	0.013 (0.003)	0.003 (0.001)	0.004 (0.001)
$(GCF / TA)_t$	0.324 (0.065)	0.284 (0.073)	0.122 (0.031)	0.096 (0.045)	0.061 (0.022)	0.081 (0.021)
$(STK / TA)_t$	0.021 (0.083)	0.013 (0.148)	0.086 (0.028)	0.086 (0.040)	0.003 (0.009)	0.014 (0.024)
$(DBT / TA)_t$	0.234 (0.054)	0.228 (0.053)	0.155 (0.042)	0.068 (0.025)	0.043 (0.024)	0.076 (0.022)
Observations	8024	3987	5702	6328	7160	7471
Firms	1279	495	922	733	1018	805
***J*-test (p-value)**	0.156	0.263	0.910	0.113	0.356	0.085
Panel C: Negative Cash Flow Firms						
$(CAP / TA)_{t-1}$			0.065 (0.086)	0.170 (0.079)	0.078 (0.069)	0.201 (0.113)
Q_{t-1}			0.006 (0.002)	0.014 (0.010)	0.003 (0.001)	0.004 (0.002)
$(GCF / TA)_t$			0.030 (0.019)	0.071 (0.027)	-0.010 (0.010)	0.032 (0.013)
$(STK / TA)_t$			0.026 (0.013)	0.030 (0.032)	0.004 (0.009)	-0.022 (0.020)
$(DBT / TA)_t$			0.076 (0.029)	0.063 (0.036)	-0.021 (0.019)	0.035 (0.018)
Observations			887	250	2456	331
Firms			237	39	471	67
***J*-test (p-value)**			0.998	1.000	0.663	1.000

Table 5
R&D-Cash Flow and External Finance Sensitivity

Estimation is by first-differenced GMM. Fixed firm and time effects are included in all regressions. Lagged levels dated t-3 through t-5 are used as instruments for the investment and financing variables. Outliers in first-differences are trimmed at the 1% level. Standard errors robust to heteroskedasticity and with-in firm serial correlation are reported in parenthesis.

Sample Period	***1970-1981***		***1982-1993***		***1994-2006***	
	Young	**Mature**	**Young**	**Mature**	**Young**	**Mature**
Panel A: All Firms						
$(RD / TA)_{t-1}$	0.199 (0.072)	0.473 (0.071)	0.103 (0.080)	0.118 (0.087)	-0.042 (0.065)	0.174 (0.082)
Q_{t-1}	0.000 (0.001)	0.000 (0.001)	0.000 (0.001)	0.001 (0.001)	0.001 (0.002)	0.001 (0.001)
$(GCF / TA)_t$	0.126 (0.021)	0.083 (0.013)	0.084 (0.027)	0.044 (0.014)	0.080 (0.041)	0.092 (0.018)
$(STK / TA)_t$	-0.030 (0.026)	0.006 (0.033)	0.091 (0.018)	0.016 (0.015)	0.175 (0.026)	0.037 (0.027)
$(DBT / TA)_t$	0.009 (0.012)	0.018 (0.010)	0.064 (0.034)	0.025 (0.009)	0.111 (0.052)	0.059 (0.025)
Observations	5596	3044	6144	5604	9443	7149
Firms	848	384	1015	617	1399	752
***J*-test (p-value)**	0.125	0.169	0.485	0.152	0.187	0.087
Panel B: Positive Cash Flow Firms						
$(RD / TA)_{t-1}$	0.186 (0.072)	0.467 (0.071)	0.210 (0.085)	0.110 (0.088)	0.026 (0.098)	0.143 (0.072)
Q_{t-1}	0.000 (0.001)	0.000 (0.001)	0.002 (0.001)	0.001 (0.001)	-0.002 (0.003)	0.001 (0.001)
$(GCF / TA)_t$	0.134 (0.022)	0.081 (0.013)	0.082 (0.030)	0.042 (0.014)	0.151 (0.045)	0.069 (0.022)
$(STK / TA)_t$	-0.032 (0.026)	0.008 (0.033)	0.041 (0.019)	0.018 (0.015)	0.151 (0.036)	0.057 (0.019)
$(DBT / TA)_t$	0.004 (0.013)	0.016 (0.011)	0.027 (0.030)	0.023 (0.009)	0.116 (0.061)	0.038 (0.021)
Observations	5539	3030	5307	5477	7000	6890
Firms	832	382	818	598	954	701
***J*-test (p-value)**	0.120	0.129	0.874	0.087	0.151	0.036
Panel C: Negative Cash Flow Firms						
$(RD / TA)_{t-1}$			-0.004 (0.076)	0.452 (0.053)	-0.061 (0.066)	0.201 (0.094)
Q_{t-1}			0.000 (0.002)	-0.003 (0.003)	0.005 (0.002)	0.002 (0.004)
$(GCF / TA)_t$			0.063 (0.031)	0.014 (0.006)	0.075 (0.036)	0.011 (0.025)
$(STK / TA)_t$			0.095 (0.018)	-0.027 (0.023)	0.139 (0.032)	0.068 (0.033)
$(DBT / TA)_t$			0.099 (0.028)	0.006 (0.008)	0.143 (0.058)	0.055 (0.025)
Observations			837	127	2443	259
Firms			197	19	445	51
***J*-test (p-value)**			0.973	1.000	0.796	1.000

Table 6
Total Investment-Cash Flow and External Finance Sensitivity

Estimation is by first-differenced GMM. Fixed firm and time effects are included in all regressions. Lagged levels dated t-3 through t-5 are used as instruments for the investment and financing variables. Outliers in first-differences are trimmed at the 1% level. Standard errors robust to heteroskedasticity and with-in firm serial correlation are reported in parenthesis.

Sample Period	***1970-1981***		***1982-1993***		***1994-2006***	
	Young	**Mature**	**Young**	**Mature**	**Young**	**Mature**
Panel A: All Firms						
$(RD+CAP / TA)_{t-1}$	0.138 (0.067)	0.231 (0.053)	0.028 (0.066)	0.184 (0.064)	-0.022 (0.051)	0.203 (0.065)
Q_{t-1}	0.008 (0.002)	0.013 (0.003)	0.007 (0.002)	0.013 (0.003)	0.002 (0.002)	0.007 (0.002)
$(GCF / TA)_t$	0.406 (0.081)	0.309 (0.077)	0.159 (0.047)	0.221 (0.045)	0.162 (0.044)	0.182 (0.029)
$(STK / TA)_t$	-0.006 (0.090)	0.121 (0.129)	0.142 (0.024)	0.049 (0.043)	0.198 (0.027)	0.094 (0.036)
$(DBT / TA)_t$	0.208 (0.053)	0.218 (0.049)	0.215 (0.051)	0.070 (0.031)	0.218 (0.067)	0.131 (0.031)
Observations	5344	2948	5715	5415	8884	6861
Firms	844	384	985	616	1347	740
***J*-test (p-value)**	0.636	0.104	0.767	0.075	0.035	0.262
Panel B: Positive Cash Flow Firms						
$(RD+CAP / TA)_{t-1}$	0.126 (0.067)	0.224 (0.053)	0.075 (0.057)	0.185 (0.063)	0.063 (0.065)	0.155 (0.057)
Q_{t-1}	0.008 (0.002)	0.013 (0.003)	0.006 (0.002)	0.014 (0.003)	0.000 (0.002)	0.007 (0.001)
$(GCF / TA)_t$	0.433 (0.081)	0.294 (0.076)	0.187 (0.046)	0.222 (0.045)	0.240 (0.056)	0.145 (0.030)
$(STK / TA)_t$	0.024 (0.083)	0.123 (0.129)	0.111 (0.031)	0.064 (0.045)	0.145 (0.034)	0.090 (0.033)
$(DBT / TA)_t$	0.232 (0.053)	0.220 (0.049)	0.208 (0.048)	0.058 (0.030)	0.130 (0.059)	0.124 (0.027)
Observations	5300	2934	4982	5289	6761	6631
Firms	830	382	798	595	942	692
***J*-test (p-value)**	0.639	0.084	0.835	0.115	0.118	0.063
Panel C: Negative Cash Flow Firms						
$(RD+CAP / TA)_{t-1}$			0.016 (0.105)	0.237 (0.074)	-0.096 (0.055)	0.089 (0.095)
Q_{t-1}			0.007 (0.004)	-0.007 (0.011)	0.006 (0.003)	0.011 (0.005)
$(GCF / TA)_t$			0.150 (0.047)	0.082 (0.028)	0.094 (0.041)	0.064 (0.026)
$(STK / TA)_t$			0.157 (0.040)	0.068 (0.067)	0.174 (0.031)	0.075 (0.043)
$(DBT / TA)_t$			0.334 (0.067)	0.033 (0.044)	0.184 (0.066)	0.160 (0.053)
Observations			733	126	2123	230
Firms			187	21	405	48
***J*-test (p-value)**			0.987	1.000	0.979	1.000