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Firm Investment and Financial Frictions

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Abstract

In this paper we investigate the analytical and empirical linkages between firms' capital investment behavior and financial frictions arising from asymmetric information, proxied by firms' liquidity and degree of uncertainty. Measures of intrinsic and extrinsic uncertainty are derived from firms' daily stock returns and S&P 500 index returns along with a CAPM-based risk measure. We employ a panel of U.S. manufacturing firm data obtained from COMPUSTAT over the 1984–2003 period. Financial frictions captured by interactions between firms' cash flow and both *intrinsic* and *CAPM*-based measures of uncertainty have a significant negative impact on firms' investment spending, while *extrinsic* uncertainty has a positive impact.

Keywords: capital investment, asymmetric information, financial frictions, uncertainty, CAPM

JEL: E22, D81, C23

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1 Introduction

It is well known that the variability of private investment spending accounts for the bulk of business fluctuations. To that end several theoretical studies have examined the extent to which uncertainty affects aggregate or firm-specific capital investment behavior. These studies concentrate on the impact of uncertainty arising from various sources which affects managers' decision-making process regarding the timing and the quantity of fixed capital investment.[1] In this paper, we extend the standard Tobin's Q model on which we base our empirical investigation to analyze the impact of uncertainty on the firm's investment decision problem while scrutinizing the role of asymmetric information in that relationship.

As many researchers have shown, when uncertainty varies over time, the presence of asymmetric information problems will affect potential lenders' assessment of the firm's creditworthiness and thus the firm's ability to raise external funds. In such circumstances, firms' capital expenditures will be distorted as the risk premium that lenders require to provide funds increases along with the uncertainty in the environment. Hence, one can gauge financial frictions as a function of the firm's cash flows and the degree of uncertainty they face, and capture this effect by investigating the interactions between firms' cash flow and various sources of uncertainty. Incorporating this modification to the standard model, it would not be surprising to find in times of heightened uncertainty that the firm's managers may not be willing to take up investment opportunities with positive expected returns—even in the presence of adequate cash flow—for they become more cautious and perceptive of the turbulence they are experiencing.[2]

We specifically consider the effects of three different forms of uncertainty on firms' cost of external funds, and thus on their investment behavior: *Own* (intrinsic) uncertainty, derived from firms' stock returns; *Market* (extrin-

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[1]See Hartman (1972), Abel (1983), Bernanke (1983), Craine (1989), Dixit and Pindyck (1994), Caballero (1999).

[2]Several researchers, including Bloom, Bond and Van Reenen (2001), Bond and Cummins (2004) have investigated the impact of uncertainty on firms' investment behavior through its effects on other variables. The former study, concentrating on the interaction term between uncertainty and sales growth, shows that higher uncertainty would reduce the response of firms to demand shocks making them more cautious. The latter study investigates the effects of uncertainty on firm capital investment through its interaction with Q or changes in sales, yet fails to find any significant impact arising from these interaction terms.

sic) uncertainty, driven by S&P 500 index returns,[3] and the relations between intrinsic and extrinsic uncertainty. To capture the latter effect, we introduce a *covariance* term (our CAPM-based risk measure) and allow the data to determine the differential impact of each of these components on the financial frictions facing the firm. These uncertainty factors, interacted with firm cash flow, serve to proxy the shadow price of external finance in our analytical framework. We employ annual firm-level U.S. manufacturing sector data obtained from COMPUSTAT and match it to firm-level daily financial data from CRSP over the 1984–2003 period. Furthermore, to carry out our analysis, we must compute reasonable measures of uncertainty. We utilize daily stock returns and market index returns to compute intrinsic and extrinsic uncertainty via a method based on Merton (1980) from the intra-annual variations in stock returns and aggregate financial market series. This approach provides a more representative measure of the perceived volatility while avoiding potential problems, such as the high persistence of shocks when moving average representations are used, or low correlation in volatility when ARCH/GARCH models are applied to quantify volatility in low-frequency series. In that respect, our study improves upon much of the literature in its method of using high-frequency data to quantify volatility evaluated at a lower frequency.[4]

We can summarize the results of the paper as follows. Similar to earlier findings, our basic regression model provides evidence that cash flow is an important determinant of firms' capital investment behavior along with Q and the debt ratio. The impact of financial frictions on capital investment behavior is captured by introducing interactions of uncertainty proxies and firm-specific cash flow. Hence, we estimate the degree to which the effects of uncertainty on investment may be strengthened or weakened by the firm's current financial condition. In contrast to earlier research, we find a significant role for each uncertainty measure while Q, cash flow and the debt ratio maintain their significance. Intrinsic uncertainty always exerts a negative and significant effect on investment. Contrarily, extrinsic uncertainty has a positive effect when it is introduced in conjunction with our CAPM-based proxy and intrinsic uncertainty. As theory suggests, we also find that the CAPM risk measure always has a significant and negative impact on investment. Our findings suggest that uncertainty significantly affects investment

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[3]In this paper we use the terms Own, idiosyncratic and intrinsic uncertainty interchangeably. Likewise, $Market$ is taken as synonymous with extrinsic uncertainty.

[4]Leahy and Whited (1996), Bloom et al. (2001), Bond and Cummins (2004) have also utilized daily stock returns to compute firm-level uncertainty. However, the methodology they used to generate a proxy for uncertainty is different from ours.

behavior while the role of cash flow diminishes in importance as firms' managers behave more cautiously and possibly forego investment opportunities with positive net returns in times of greater uncertainty.

The rest of the paper is constructed as follows. Section 2, though not comprehensive given the vast literature on capital investment, provides a brief survey of the empirical literature discussing the effects of uncertainty on investment. Section 3 presents the modeling framework and discusses the methodology we employ in our investigation. Section 4 documents the data and our empirical findings, while Section 5 concludes and draws implications for future research.

2   The empirical literature on investment and uncertainty

Researchers have expended considerable effort in trying to understand the linkages between uncertainty and firm-level and aggregate investment behavior. Fluctuations in aggregate investment can arise from various sources of uncertainty. For instance, there is substantial effort to understand the impact of exchange rate uncertainty on aggregate or industry level investment behavior. To that end Goldberg (1993) shows that exchange rate uncertainty has a weak negative effect on investment spending. Campa and Goldberg (1995) find no significant impact of exchange rate volatility on investment. Darby, Hallett, Ireland and Piscatelli (1999) provide evidence that exchange rate uncertainty may or may not depress investment, while Serven (2003) unearths a highly significant negative impact of real exchange rate uncertainty on private investment in a sample of developing countries.

Many other researchers have investigated the importance of uncertainty arising from output, prices (inflation), taxes and interest rates. Driver and Moreton (1991) conclude that while a proxy for uncertainty driven from output growth has a negative long–run effect on aggregate investment, the measure of uncertainty obtained from inflation has none. Calcagnini and Saltari (2000) find that while demand uncertainty has a significant negative effect on investment, interest rate uncertainty has none. Huizinga (1993) reports a negative effect on investment for uncertainty proxies obtained from wages and raw materials prices but a positive effect for a proxy obtained from output prices. Ferderer (1993) captures a measure of uncertainty on long term bonds using the term structure of interest rates and finds a negative impact on aggregate investment. Hurn and Wright (1994) find that the linkage between oil price variability and the decision to develop an oil field

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(more specifically the North Sea oil field) is not significant. Pindyck and Solimano (1993) use the variance in the marginal revenue product of capital as a proxy for uncertainty to study an implication of irreversible investment models to find the effects of uncertainty on the investment trigger. Edminston (2004) investigates the role of tax uncertainty on investment and finds a significant negative effect between the two.[5]

Turning now to research which has used firm level data, we also see several studies employing measures of uncertainty that emerge from movements in exchange rates, output, demand, firm-specific liquidity, inflation or a CAPM framework. Brainard, Shoven and Weiss (1980) find that a CAPM-based risk measure yields mixed results on the linkages between investment and their uncertainty measure. Ghosal and Loungani (1996) report a negative role of output uncertainty on investment. Leahy and Whited (1996) using risk measures constructed from stock return data find that uncertainty exerts a strong negative effect on investment and point out that uncertainty affects investment directly rather than through covariances. Guiso and Parigi (1999) investigate the impact of demand uncertainty using firm level data to show that uncertainty weakens the response to demand and slows down capital accumulation. Minton and Schrand (1999) find evidence that cash flow volatility is costly and leads to lower levels of investment in capital expenditures, R&D and advertising. Beaudry, Caglayan and Schiantarelli (2001) show that macroeconomic uncertainty captured through inflation variability has a significant effect on investment behavior of firms.[6]

Although these studies summarized above have examined various aspects of the linkages between uncertainty and investment none of them have entertained the impact of intrinsic or extrinsic uncertainty and a CAPM-based risk measure in a regression model. Furthermore, our investigation scrutinizes the effects of uncertainty through cash flow to capture the role of financial frictions in explaining firms' investment behavior along with three of the basic elements: Q, cash flow and leverage. Finally, our choice of methodology to compute a measure of uncertainty is different from the rest of the literature and has specific advantages as discussed in section 3.1 below.

In the next section, we discuss the analytical model used to link uncertainty faced by the form to its choice of an optimal investment plan as well as the method that we use to obtain our proxies for uncertainty.

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[5]See Edminston (2004) for other studies that concentrate on the linkages between investment and volatility in taxes.

[6]Some researchers have studied the extent to which a proxy for analysts' forecasts can explain firms' investment behavior; see among others Abel and Eberly (2002) and Bond and Cummins (2004).

3   An extended Q model of firm value optimization

The theoretical model proposed in this paper is based on the firm value optimization problem and represents a generalization of the standard Q models of investment by Blundell, Bond, Devereux and Schiantarelli (1992). The present value of the firm is equated to the expected discounted stream of D_t, dividends paid to shareholders, where $0 < \beta < 1$ is the constant one-period discount factor:

$$V_t = \max E_t \left[\sum_{s=0}^{\infty} \beta^s D_{t+s} \right].$$ (1)

At time t, all present values are known with certainty while all future variables are stochastic. Dividends can be substituted into (1) using the following definition of sources and uses of funds:

$$D_t = \Pi(K_t) - C(I_t, K_t, \zeta_t) - I_t + B_{t+1} - B_t R_t,$$ (2)

where $\Pi(K_t)$ denotes the value of current profits given the beginning of the period capital stock. $C(I_t, K_t, \zeta_t)$ is the real cost of adjusting I_t units of capital, and ζ_t is an additive shock to adjustment costs. The functions $\Pi(K_t)$ and $C(I_t, K_t, \zeta_t)$ are continuous and differentiable. External funds are denoted by B_t and are associated with firm-specific financing costs of R_t, the gross interest rate. All financial measures are expressed in real terms. In order to isolate the role of debt financing we assume that equity financing is prohibitively expensive so that firms prefer debt financing only. Furthermore, managers are assumed to have rational expectations. The firm maximizes equation (1) subject to two constraints:

$$K_t = (1 - \delta)K_{t-1} + I_t,$$ (3)
$$B_{t+1} \geq 0.$$ (4)

The first equation represents evolution of the capital stock K_t where I_t is gross investment expenditures and δ is the rate of capital depreciation. Financial frictions are introduced through the firm-specific cost of funds as described below. It faces the transversality condition which prevents the firm from borrowing an infinite amount and paying it out as dividends:

$$\lim_{T \to \infty} \left[\prod_{j=t}^{T-1} \beta_j \right] B_T = 0, \forall t.$$ (5)

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The first order conditions of this maximization problem for investment, capital and debt are

$$\frac{\partial C_t}{\partial I_t} + 1 = \lambda_t, \tag{6}$$

$$\frac{\partial \Pi_t}{\partial K_t} - \frac{\partial C_t}{\partial K_t} = \lambda_t - (1 - \delta)\beta E_t \lambda_{t+1}, \tag{7}$$

$$E_t[\beta R_{t+1}] = 1 + \mu_t, \tag{8}$$

where the Lagrange multipliers λ_t and μ_t represent the shadow prices associated with the capital accumulation and the borrowing constraint, respectively. Equation (6) sets the marginal cost associated with an additional unit of investment equal to its shadow price. Equation (7) denotes the first-order condition for capital and defines the Euler equation which describes the evolution of λ_t. Equation (8) defines the Lagrange multiplier μ_t which represents the additional cost (over the risk-free rate) that the firm will face in the presence of financial frictions. In a world without financial frictions, $\mu_t = 0$ and $E_t[\beta R_{t+1}] = 1$, implying that firms can borrow at the risk-free rate. Assuming linear homogeneity of the profit function $\Pi(K_t) = (\partial \Pi_t / \partial K_t)K_t$ and the cost function $C(K_t, I_t) = (\partial C_t / \partial I_t)I_t + (\partial C_t / \partial K_t)K_t$, we combine the first order conditions for investment and capital, Equations (6) and (7), to yield

$$\lambda_t(1 - \delta)K_{t-1} = D_t + B_{t+1} - R_t B_t + \beta E_t[\lambda_{t+1}(1 - \delta)K_t]. \tag{9}$$

Solving this equation forward and using the first order condition for debt (8) and the definition of the value of the firm (1), we can show that marginal q_t is equal to the shadow value of an additional unit of capital, λ_t,

$$q_t = \lambda_t = \frac{V_t}{(1 - \delta)K_{t-1}} - \frac{R_t}{(1 - \delta)} \frac{B_t}{K_{t-1}} - \frac{\Theta_t}{K_{t-1}}, \tag{10}$$

where the last term Θ_t/K_{t-1} represents the expectation of the infinite sum $\sum_{i=0}^{\infty} \beta^i (B_{t+i+1}\mu_{t+i})$. This term equals zero when the shadow price of external finance is equal to zero, $\mu_t = \mu_{t+i} = 0 \ \forall \ i$. We define average Q as $Q_t = V_t/K_{t-1}$ and the leverage ratio as B_t/K_{t-1}. For the unlevered firm marginal q is equal to average Q in the case of no borrowing constraint.[7]

Similar to Love (2003), we assume that adjustment costs are quadratic and take the form

$$C(I_t, K_t, \varepsilon) = \frac{b}{2}\left[\left(\frac{I_t}{K_t}\right) - g\left(\frac{I_{t-1}}{K_{t-1}}\right) - a + \varepsilon_t\right]^2 K_t. \tag{11}$$

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[7]Hennessy (2004) obtains a similar result in which average Q overstates marginal q by incorporating post-default returns to investment.

To obtain an investment equation, we rewrite the first order condition (6) making use of the functional form of adjustment costs:

$$\frac{I_t}{K_t} = a - \frac{1}{b} + g \frac{I_{t-1}}{K_{t-1}} + \frac{1}{b(1-\delta)} Q_t - \frac{R_t}{b(1-\delta)} \frac{B_t}{K_{t-1}} - \frac{1}{b} \frac{\Theta_t}{K_{t-1}}. \qquad (12)$$

The last term in Equation (12) captures the role of financial frictions in the firm's capital investment behavior. Many researchers have documented the effects of asymmetric information on firms' ability to access external finance. This literature demonstrates that financially constrained firms show greater sensitivity to the availability of internal finance, proxied by firms' cash flow. We propose that the degree of financial friction will be related not only to the firm's cash flow but also to the degree of uncertainty faced by the firm. Prospective lenders will evaluate their expected return from providing external funds taking into account the firm's likelihood of default, and in doing so will consider not only observable cash flows but also uncertainty related to the firm's environment. As that uncertainty—reflecting both macroeconomic uncertainty and firm-specific uncertainty—varies, the premium charged by lenders over the risk-free rate will systematically vary.

In this formulation, the magnitude of the financial friction facing a firm, Θ_t/K_{t-1}, will be a function of the firm's cash flow interacted with measures of uncertainty:

$$\frac{\Theta_t}{K_{t-1}} = \frac{CF_t}{K_t} \left(a_1 + a_2 \eta_{i,t-1} + a_3 \nu_{i,t-1} + a_4 \varepsilon_{t-1} \right)$$

where CF_t is cash flow. The above form introduces three specific measures of uncertainty: intrinsic uncertainty (η), or uncertainty driven by the firm's stock returns; extrinsic uncertainty (ε), or uncertainty driven by S&P 500 index returns; and the covariance between firm and market returns, ν: a CAPM-based risk measure.[8] Uncertainty would naturally emerge from various sources such as the behavior of prices, wages, consumers' tastes, technology, institutions, exchange rates and others. Given one or more of these sources would be operational when lenders evaluate the firm's creditworthiness, we believe that use of firm-specific daily returns can provide us with a single proxy which embodies all potential sources of uncertainty arising in the firm's environment.[9] Furthermore, using intrinsic and extrinsic uncertainty in our regressions we can determine whether investment behavior is more sensitive to own- or market-specific uncertainty. Also, the covariance

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[8]We explain how these measures are constructed using daily data in section 3.1.

[9]For instance, see Bloom et al. (2001) for a discussion of similar issues.

term helps us evaluate the predictions arising from the CAPM. We include lagged uncertainty measures to capture the effect that investment plans have been formulated based on the prior period's observed levels of uncertainty. While higher levels of cash flow relax borrowing constraints ($a_1 < 0$), higher levels of uncertainties increase financial frictions ($a_2 > 0$, $a_3 > 0$, $a_4 > 0$). Our theoretical model predicts a negative relationship between investment and uncertainty.

Estimation is based on our parameterization of Θ_t/K_{t-1} in Equation (12). Replacing capital by total assets (TA), we obtain the empirical model specification with coefficients as functions of the model's parameters.

$$
\left(\frac{I}{TA}\right)_{it} = \beta_0 + \beta_1 \left(\frac{I}{TA}\right)_{i,t-1} + \beta_2 Q_{it} + \beta_3 \left(\frac{CF}{TA}\right)_{it} + \beta_4 \left(\frac{B}{TA}\right)_{i,t-1} +
$$
$$
(\delta_1 \eta_{i,t-1} + \delta_2 \nu_{i,t-1} + \delta_3 \varepsilon_{t-1}) \times \left(\frac{CF}{TA}\right)_{it} + \kappa_i + \epsilon_{it} \quad (13)
$$

where i indexes the firm, κ_i captures the firm fixed effect and ϵ_{it} denotes the error term. The beginning of period average Q is defined as the market value of the firm (shares plus debt) net of the value of current assets (inventories and financial assets) divided by the book value of total assets of the firm and CF denotes cash flow. Here, we expect β_1, β_2 and β_3 to be positive and β_4 to be negative, as usual. We also expect that the overall effect of the terms involving a product with (CF/TA) to take on a negative value, which we compute at various levels of the measures of uncertainty times their associated coefficients (δ_1, δ_2, δ_3), suggesting a diminishing impact of CF/TA on firm investment behavior. This implies that in times of uncertainty, firm managers will possibly forego investment opportunities with positive net returns. In other words, they become more cautious and perceptive of the turbulence even though the firm has positive cash flows.

All terms are deflated by the consumer price index taking into account the timing of the variables appearing in the numerator and denominator. We should note that the simple definition that we use to construct average Q has been employed by, among others, Doidge, Karolyi and Stulz (2002), Lang and Stulz (1994), Servaes (1996), La Porta, Lopez-de Silanes, Shleifer and Vishny (2002), and Allayannis and Weston (2001).[10]

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[10] Allayannis and Weston (2001) show that various measures including the market-to-book ratio that have been used to proxy for Tobin's Q are highly correlated with each other. Wright (2004) also provides evidence of high correlations among several alternative definitions of Q.

To summarize, our model contains three of the basic elements, Q, cash flow and leverage which have been shown to explain the investment behavior of firms. By using intrinsic and extrinsic uncertainty in our regressions, interacted with a measure of the firm's liquidity, we can determine whether investment behavior is more sensitive to Own- or $Market$-specific uncertainty while the covariance term helps us evaluate the predictions arising from the CAPM. This formulation also allows us to examine whether uncertainty makes managers more 'cautious' in their investment decisions as Bloom et al. (2001) claim.

3.1   Generating volatility measures from daily data

Any attempt to evaluate the effects of uncertainty on the firm investment behavior requires specification of a measure of risk. However, a number of competing approaches for the construction of volatility measures may be found in the empirical literature. The choice of a particular specification to generate uncertainty may have a considerable impact on the empirical findings, since counterintuitive results may be merely reflecting errors of measurement in a proxy for risk. It is possible to employ a simple moving standard deviation of the return series, at the same frequency as the data: for instance, including the past four or eight quarters of changes in the context of quarterly data. However, this measure gives rise to substantial serial correlation in the summary measure. A more sophisticated approach utilises the ability of GARCH models to mimic the "volatility clustering" often found in high-frequency financial series. However, a GARCH model fitted to monthly or quarterly data may find very weak persistence of shocks. Furthermore, a proxy for uncertainty obtained from a GARCH specification will be dependent on the choice of the model and exhibit significant variation over alternatives.

In this study, we utilize daily stock returns and market index returns to compute intrinsic and extrinsic uncertainty via a method based on Merton (1980) from the intra-annual variations in stock returns and aggregate financial market series.[11] This approach provides a more representative measure of the perceived volatility while avoiding potential problems raised above. Also the use of daily returns on the stock provides one with a forward-looking proxy for the volatility of the firms' environment.

In order to employ the Merton methodology to the problem at hand, we must compute the intra-annual volatility of the series from daily data. We

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[11]See Baum, Caglayan and Ozkan (2004) for a more detailed discussion of the procedure along with its merits.

first take the squared first difference of the daily changes in returns (after dividing by the square root of the number of days intervening), which is then defined as the daily contribution to annual volatility:

$$\varsigma_t^d = \left(100 \frac{\Delta x_t}{\sqrt{\Delta \phi_t}} \right)^2 \tag{14}$$

where the denominator expresses the effect of calendar time elapsing between observations on the x process. If data were generated every calendar day, $\Delta \phi_t = 1, \forall t$, but given that data are not available on weekends and holidays, $\Delta \phi_t \in (1, 5)$. The estimated annual volatility of the return series is defined as $\Phi_t [x_t] = \sqrt{\sum_{t=1}^{T} \varsigma_t^d}$ where the time index for $\Phi_t [x_t]$ is at the annual frequency.

An alternative to Merton's procedure (which makes use of squared high-frequency returns) is that proposed by Ghysels, Santa Clara and Valkanov (2004) : the computation of realized absolute variation and bipower variation, which make use of absolute returns. We generate these measures from the firm-level daily data, and find that when aggregated to the annual frequency they were correlated above 0.93 with our Merton-based proxy. Since these measures appear to be rather close substitutes for the Merton-based measures, we do not make further use of them in the empirical work.

The daily returns series are taken from CRSP. For the market index returns, we use returns on the S&P 500 index, inclusive of dividends.

4 Empirical findings

4.1 Data

The estimation sample consists of an unbalanced panel of manufacturing firms for the 1984 to 2003 period drawn from Standard and Poor's Industrial Annual COMPUSTAT database. We utilize COMPUSTAT data items Shares outstanding (item25), Share price (item199), Total assets (item6), Long term debt (item9), Short term debt (item34), Cash flow (item14+item18) and Investment (item128).

We apply a number of sample selection criteria on our original sample of 20,660 firm-years. Non-positive values of total assets, investment, debt, Q and cash were marked as missing. Second, our model should be applied to firms who have not undergone substantial changes in their composition during the sample period (e.g., participation in a merger, acquisition or substantial divestment should be disqualifying). As these phenomena are not

observable in the data, we calculate the growth rate of each firm's real total assets, and trim the annual distribution of this growth rate by the 5th and 95th percentiles to remove firms exhibiting substantial changes in their scale. Third, values of the investment-to-asset, cash flow-to-asset, debt-to-asset ratios and Tobin's Q outside the 5–95th percentile range were judged implausible. Fourth, firms in clear financial distress or those facing substantial liquidity constraints were excluded: two consecutive years of negative cash flows were taken as an indicator of these conditions. Where these appear, we remove them as well as the prior and subsequent cash flows from the sample. These screens collectively reduced the sample to 9,891 firm-years.[12]

One per cent from either end of the annual returns distribution was trimmed to keep returns within bounds prior to computing a measure of uncertainty using data obtained from the CRSP database. Merging with the returns data reduced the sample to 9,752 firm-years, of which 6,762 pertain to firms possessing complete data for all variables that enter the model.

Descriptive statistics for the variables used in the analysis are presented in Table 1. The average (median) investment rate for our sample is about 6% (5.4%): slightly lower than studies that have investigated U.S. manufacturing firm level data since we deflate investment by total assets rather than by the capital stock. From the mean and the median of the sample we see that firms' cash flow is equal to over 11% of the value of their total assets, comparable to the figures in several relevant studies. The average value for Q of 2.39 is higher than its median, 1.57, and generally higher than earlier studies that have used our definition. However, we should also note that earlier work has concentrated on firms with specific characteristics such as size of the firm's total assets or cash flow. The distribution of the debt-to-assets ratio over firms has a mean of 0.26 and a median of 0.25. The last three lines, labeled as η, ε and ν give the basic statistics for the constructed measures of uncertainty obtained from firm stock returns, S&P index returns and the covariance between firm and market returns, respectively.

4.2   The link between uncertainty and capital investment

In what follows we present our results obtained for the full sample using the dynamic panel data (DPD) approach developed by Arellano and Bond (1991), as implemented in Stata by Roodman (2004). All models are estimated in first difference terms to eliminate the fixed effects using the one-

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[12]Empirical results drawn from the full sample yielded qualitatively similar findings; the screened data were used to reduce the potential impact of outliers upon the parameter estimates.

step GMM estimator.

We start our investigation estimating a standard investment model which includes the basic explanatory variables for firm level investment: Q, CF/TA and B/TA along with the lagged dependent variable, $(I/TA)_{t-1}$, as a benchmark. We provide the one-step robust GMM regression results to this standard model in column one of Table 2, with a sample including 606 firms' annual data in an unbalanced panel. Similar to those reported in the literature, the signs of CF/TA, Q and lagged investment are positive and significant while the sign of B/TA is negative and significant, and require no further comment. The J statistic (and the corresponding p-value) is the Hansen–Sargan test statistic and it indicates that the test for overidentifying restrictions is satisfactory. Furthermore, we reject the presence of second-order autocorrelation $(AR(2))$ validating the use of suitably lagged endogenous variables as instruments.[13]

Given satisfactory results obtained from the benchmark model, we introduce our measure of lagged intrinsic uncertainty, interacted with cash flow, into this basic model.[14] Column two of Table 2 provides our results when we introduce the lagged Own (intrinsic) uncertainty measure into our basic framework. Similar to our benchmark model results, the magnitude and significance of the coefficients of Q, CF/TA, B/TA and the lagged dependent variable are not altered.[15] The coefficient for Own uncertainty is negative and significant at the 1% level. This is an interesting finding as Leahy and Whited (1996) report that uncertainty affects the investment behavior through Q (in their analysis the coefficient on their proxy for uncertainty becomes insignificant with the introduction of Q). In our case, even in the presence of Q, intrinsic uncertainty is significant when its effects operate through an interaction with cash flow.

We then add extrinsic uncertainty, interacted with cash flow, to the original equation (excluding the intrinsic measure) with results given in column three of Table 2. Our $Market$ based proxy for uncertainty has a negative impact on firm investment behavior yet it is insignificant. Next, we consider a model in which both intrinsic and extrinsic measures are included in column four of Table 2. When entered jointly, although the coefficient

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[13]The second through fourth lags of $(I/TA)_{t-1}$, Q_t, $(CF/TA)_t$, $(B/TA)_{t-1}$, $(Sales/TA)_{t-1}$ and $Sales_t$ were employed as GMM instruments. In the models including lagged uncertainty measures, second through fourth lags of those measures were also included as GMM instruments.

[14]Use of contemporaneous uncertainty measures yields similar results.

[15]In all our regressions the coefficients of Q, CF/TA and the lagged dependent variable are, as expected, positive and significant.

of the extrinsic measure becomes positive, it is not significantly different from zero while that of intrinsic uncertainty is still negative and significant. This shows that firm-specific uncertainty has a more prominent impact on investment spending than does extrinsic uncertainty.

To evaluate possible interactions between firm-specific and market-based uncertainty, we introduce intrinsic and extrinsic measures of uncertainty along with our measure of CAPM-based uncertainty, $Cov(Own_{ret}, Mkt_{ret})_{i,t-1}$, interacted with cash flow. The results associated with this model are presented in column five of Table 2. This model yields interesting findings. The coefficient on intrinsic uncertainty is once again negative and significant, but that of extrinsic uncertainty is now positive and significant at the 5% level. We also observe that the CAPM-based uncertainty measure is significant and negative, as theory would suggest. This result is quite interesting supporting the implications of CAPM theory and stands in clear contrast to the findings reported by Leahy and Whited (1996) (although their model did not incorporate an interaction with cash flow).

For a firm with a positive CAPM β, the effect of an increase in that β is always negative: but it appears that a higher level of market risk may in itself be stimulative to capital investment spending. This may reflect business cycle factors, in which higher volatility in the stockmarket reflects an expansionary period, with firms expanding production and their capital stock to gain greater opportunities to expand one's presence in that market as options theory would suggest. One may also interpret these results as that when both market uncertainty and the CAPM uncertainty measure are included in the model, the level of market uncertainty serves as a moderating influence on the effects of the CAPM uncertainty measure.

4.3   Measuring the effect of uncertainty

The model of equation (13) expresses both $\partial(I/TA)/\partial\eta$ and $\partial(I/TA)/\partial(CF/TA)$ as quantities dependent on the levels of cash flow and uncertainty, respectively.[16] In order to gauge the extent of variation in $\partial(I/TA)/\partial\eta$ across the sample space, we calculate selected percentiles of the empirical CF/TA distribution (using the point and interval estimates from the last column of Table 2) and evaluate that derivative at those points. The point estimates and standard errors of that derivative are presented in the left side of Table 3. We see that the 5–95 percentile range of CF/TA encompasses almost a fivefold change in firms' liquidity from 0.0394 to 0.1894.

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[16]We could calculate similar quantities for the other two sources of uncertainty in the equation; we focus here on intrinsic uncertainty.

Correspondingly, $\partial(I/TA)/\partial\eta$ varies over that range from -0.0021 to -0.0099. Those point estimates and their 95% confidence interval are illustrated in the left panel of Figure 1. It is evident that the impact of an increase in intrinsic uncertainty on investment is greatest for a firm with a high CF/TA ratio. Although such a firm is least likely to be liquidity constrained, it also may face the greatest pressure to apply its cash flow to uses other than additional capital investment: e.g., share repurchases to increase share price, or additional dividends to shareholders.

In the last three columns of Table 3, we present equivalent estimates of $\partial(I/TA)/\partial(CF/TA)$: the sensitivity of the investment rate to variations in firms' liquidity ratios. Given the interaction terms in the model, this derivative is dependent on the levels of all three uncertainty measures: intrinsic, extrinsic, and CAPM-based. We focus here on the effects of variations of intrinsic uncertainty (η) while holding the other uncertainty measures at their estimation-sample means. Selected percentiles of the η distribution are displayed in Table 3: the 5–95 percentile range encompasses a sevenfold range in intrinsic uncertainty, from 0.26 to 1.94. The corresponding variations in $\partial(I/TA)/\partial(CF/TA)$ are not proportional given the other sources of uncertainty entering their expressions; the 5–95 percentile variation ranges from 0.2889 to 0.2015. Those point estimates and their 95% confidence interval are illustrated in the right panel of Figure 1. The impact of additional liquidity on the investment rate is always positive, but it is mitigated by higher levels of firm-specific uncertainty. This model predicts that reducing the financial frictions facing the firm would have a smaller effect on investment spending for those firms facing higher levels of intrinsic uncertainty. This implies that firm managers become more cautious and perceptive of the turbulent environment and forego potential investment opportunities despite the cash flows the firm is receiving.

5 Conclusions

In this paper we investigate the analytical and empirical linkages between firms' capital investment behavior and financial frictions arising from asymmetric information, proxied by their liquidity and degree of uncertainty. We specifically concentrate on the role of firm specific (intrinsic), market specific (extrinsic) and CAPM-based measures of uncertainty on firms' investment spending in that relationship, allowing for interactions with cash flow. We construct both idiosyncratic and market uncertainty measures using a method based on Merton (1980) from the intra-annual variations in stock re-

turns using firm level stock prices and S&P 500 index returns. Using annual data obtained from COMPUSTAT for manufacturing firms over the period between 1984–2003 we then investigate the linkages between investment and uncertainty.

Our results can be summarized as follows. Employing dynamic panel data regression models, we first show that an intrinsic uncertainty proxy affects investment negatively and significantly. When we introduce our CAPM-based proxy along with the intrinsic and extrinsic measures of uncertainty in our model, we find that both firm-level uncertainty and the CAPM risk measure have significant and negative effects while that of extrinsic uncertainty is positive and significant in this broad model. We find considerable variations in the effects of uncertainty across percentiles of the distribution of firms' liquidity, as proxied by their cash flow-to-assets ratio. Likewise, the effects of variations in liquidity are quite different for firms facing low or high levels of uncertainty. Our analysis shows that the role of cash flow diminishes in importance as firms' managers behave more cautiously and possibly forego investment opportunities with positive net returns in times of heightened uncertainty.

These findings are quite interesting in light of earlier research. For instance, researchers have found that firm-specific or macro-based measures of uncertainty are insignificant in the presence of Q and that CAPM-based uncertainty measures have no significant impact on investment behavior. Here, we show that intrinsic uncertainty is operative and has a negative impact on investment in a model incorporating a measure of Tobin's Q, and our measure of CAPM-based uncertainty has a negative effect on investment while extrinsic uncertainty has a positive impact. Given the robustness of our findings, further research along these lines could shed considerable light on the effects of interactions between uncertainty and firm liquidity when investigating the role of financial frictions on firm's capital investment behavior.

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Figure 1. Estimated sensitivities from interactions model

∂(I/TA) / ∂eta

∂(I/TA) / ∂(CF/TA)

Cash Flow / Assets

eta: proxy for firm-specific uncertainty
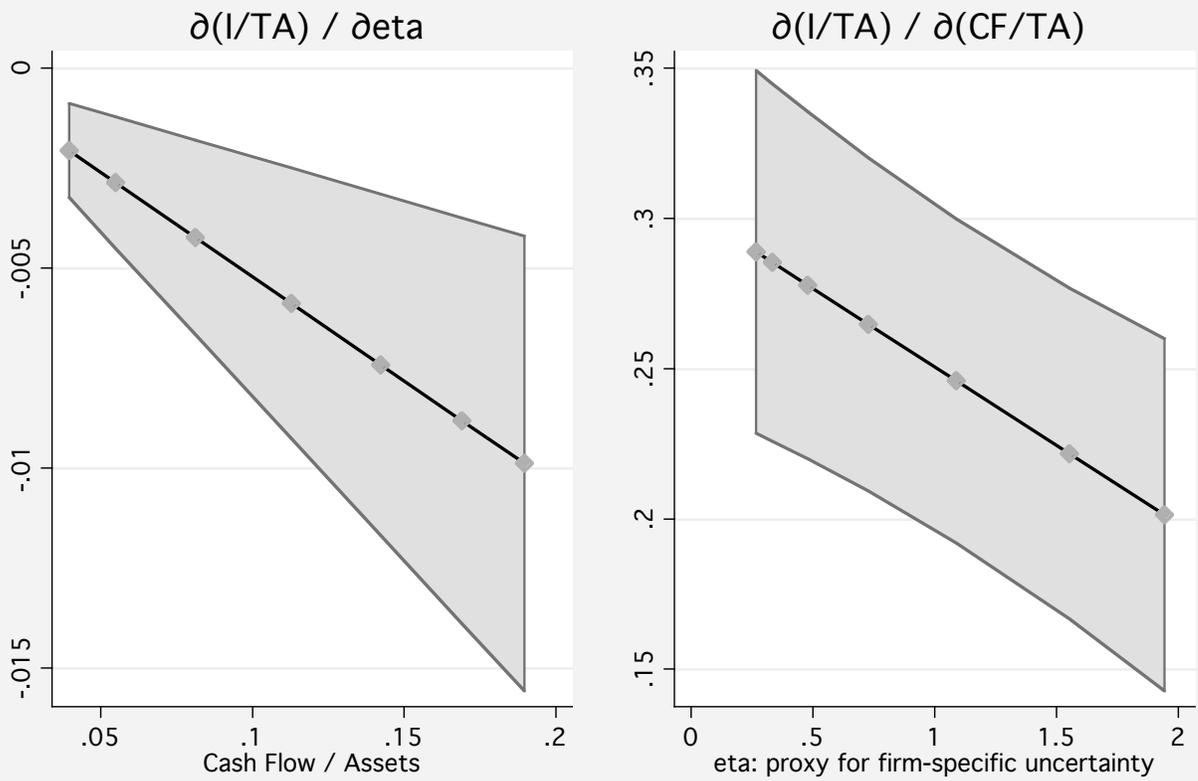
95% confidence interval shaded
Percentiles: 5, 10, 25, 50, 75, 90, 95

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Table 1: Descriptive statistics

	$p25$	$p50$	$p75$	mean	std. dev.
I/TA	0.0358	0.0541	0.0800	0.0603	0.0310
Q	0.9861	1.5683	2.8815	2.3920	2.1569
CF/TA	0.0786	0.1098	0.1421	0.1112	0.0465
B/TA	0.1645	0.2520	0.3442	0.2585	0.1242
η	0.4946	0.7548	1.1851	0.9237	0.6165
ε	0.1051	0.1914	0.2983	0.2277	0.1450
ν	0.0226	0.0489	0.0951	0.0672	0.0612
Firm-years	6762				

Notes: $p25$, $p50$, $p75$ are the quartiles of the variables. I/TA is the ratio of investment to total assets; Q is Tobin's Q; CF/TA is the ratio of cash flow to total assets; and B/TA is the ratio of debt to total assets. The η term is a measure of intrinsic uncertainty, while ε refers to extrinsic uncertainty and ν is the CAPM-based risk measure.

Table 2: Robust GMM estimates of I/TA

	(1)	(2)	(3)	(4)	(5)
$(I/TA)_{t-1}$	0.427***	0.389***	0.441***	0.395***	0.387***
	(0.033)	(0.034)	(0.033)	(0.036)	(0.036)
Q_t	0.001	0.001**	0.001	0.001**	0.002**
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
$(CF/TA)_t$	0.231***	0.269***	0.221***	0.289***	0.290***
	(0.027)	(0.029)	(0.026)	(0.031)	(0.031)
$(B/TA)_{t-1}$	-0.070***	-0.063***	-0.066***	-0.058***	-0.056***
	(0.013)	(0.012)	(0.012)	(0.012)	(0.012)
$CF/TA \times \eta_{t-1}$		-0.030***		-0.049***	-0.052***
		(0.011)		(0.015)	(0.015)
$CF/TA \times \varepsilon_{t-1}$			-0.013	0.045	0.120**
			(0.024)	(0.031)	(0.060)
$CF/TA \times \nu_{t-1}$					-0.221*
					(0.131)
Firm-years	4327	4323	4327	4323	4323
Firms	606	605	606	605	605
J	276.331	309.949	324.892	339.861	370.737
J pvalue	0.617	0.791	0.584	0.735	0.739
AR(2)	-1.587	-1.688	-1.512	-1.590	-1.640
AR(2) pvalue	0.112	0.091	0.131	0.112	0.101

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Notes: All estimates are generated by Arellano–Bond one-step difference GMM. The instrument set is described in the text. J is the Hansen–Sargan test of overidentifying restrictions, while $AR(2)$ is the Arellano–Bond test of second order autocorrelation in the errors.

Table 3: Sensitivity to variations in cash flow and firm-level uncertainty

	CF/TA %ile	$\partial(I/TA)/\partial\eta$	std.err.	η %ile	$\partial(I/TA)/\partial(CF/TA)$	std.err.
$p5$	0.0394	-0.0021	0.0006	0.2644	0.2889	0.0308
$p10$	0.0547	-0.0029	0.0008	0.3312	0.2854	0.0303
$p25$	0.0810	-0.0042	0.0012	0.4775	0.2778	0.0294
$p50$	0.1126	-0.0059	0.0017	0.7259	0.2648	0.0283
$p75$	0.1421	-0.0074	0.0022	1.0859	0.2461	0.0275
$p90$	0.1689	-0.0088	0.0026	1.5503	0.2219	0.0281
$p95$	0.1894	-0.0099	0.0029	1.9410	0.2015	0.0299

Notes: $p5, \ldots, p95$ refer to the 5th,. . . ,95th sample percentiles of CF/TA (column 2) and η (column 5), respectively.