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Abstract

In this paper we investigate the linkages between firms' capital investment behavior and financial frictions arising from asymmetric information, proxied by their liquidity and degree of uncertainty. In our empirical investigation, we use measures of uncertainty derived from firms' daily stock returns and S&P 500 index returns along with a CAPM-based risk measure. Using a panel of U.S. manufacturing firm data obtained from COMPUSTAT over the 1984–2003 period, we specifically find that financial frictions caused by increases in both *intrinsic* and *CAPM*-based measures of uncertainty have a significant negative impact on firms' investment spending.

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 However, as 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 cost of external funds, creating financial frictions. In such circumstances, when uncertainty increases the risk premium that the lenders require to provide funds will increase, affecting firms' capital expenditures. To take this channel into account, we extend the standard Tobin's Q model to incorporate the impact of uncertainty on firms' investment behavior by scrutinizing the role of asymmetric information in that relationship. In this framework, we model financial frictions as a function of the firm's cash flows and the degree of uncertainty they face. In this context, a firm with high cash flow will not be as severely affected by variations in uncertainty, whereas a firm with low cash flow will be more severely constrained. Therefore, it is crucial to consider the interactions between firms' cash flow and various sources of uncertainty to gauge the impact of financial frictions on their capital investment behavior.

The empirical strategy that uncertainty affects firms' investment behavior through its impact on other variables has been employed by several researchers. For instance, Bloom, Bond and Van Reenen (2001) claim that higher uncertainty would reduce the response of firms to demand shocks, making them more cautious. In their empirical analysis they add an interaction term between uncertainty and sales growth to capture this 'caution effect' (authors' wording) and find the interaction term to be highly significant. In a similar line Bond and Cummins (2004) investigate the effects of uncertainty on firm capital investment through its interaction with Q or changes in sales, yet they fail to find any significant effects arising from these interaction terms.

In this paper we follow an innovative approach in defining and computing

¹See Hartman (1972), Abel (1983), Bernanke (1983), Craine (1988), Dixit and Pindyck (1994), Caballero (1999).

measures of uncertainty that proxy for the impact of asymmetric information in the form of financial frictions. To that end, we specifically consider interactions of uncertainty measures with firm-specific cash flow. We concentrate on 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* (extrinsic) uncertainty, driven by S&P 500 index returns,² 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, which is an extension of the standard Q model of firm value optimization.

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.³

Our main findings can be summarized as follows. We find that both intrinsic and extrinsic uncertainty proxies affect investment negatively and significantly. When we introduce our CAPM-based proxy along with the intrinsic and extrinsic measures of uncertainty in our model, we see that both firm level uncertainty and the CAPM risk measure are significant and negative, while the effect of extrinsic uncertainty is now positive and significant, moderating the influence of the CAPM-based uncertainty term. An extended model, allowing for interactions between uncertainty and firm-specific cash

²In this paper we use the terms *Own*, idiosyncratic and intrinsic uncertainty interchangeably. Likewise, *Market* is taken as synonymous with extrinsic uncertainty.

³Leahy and Whited (1996), Bloom et al. (2001) and Bond and Cummins (2004) have also utilized daily stock returns to compute firm-level uncertainty.

flow, appears to be quite successful, implying that the effects of uncertainty may vary meaningfully over levels of firms' cash flow and over time.

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. Considering the fact that fluctuations in aggregate investment are a main driving force behind macroeconomic fluctuations, it is only natural to do so. To further understand the linkages between investment and uncertainty, careful attention has been paid to effects that 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, while Serven (2003) unearths a highly significant negative impact of real exchange rate uncertainty on private investment in a sample of developing countries. Darby et al. (1999) provide evidence that exchange rate uncertainty may or may not depress investment.

Many other researchers have investigated the importance of uncertainty arising from output, prices (inflation), taxes and interest rates. Driver and Moreton (1991) find that while the 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) finds 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 (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. Edmiston (2004) investigates the role of tax uncertainty on investment and finds a significant negative effect between the two.⁴

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 et al. (1980) find that a CAPM-based risk measure yield 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 slow 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 advertisement. Beaudry, Caglayan and Schiantarelli (2001) show that macroeconomic uncertainty captured through inflation variability has a significant effect on investment behavior of firms⁵

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 simultaneously in a regression model. Furthermore, our investigation incorporates the role of several interaction terms to consider for the

⁴See Edmiston (2004) for other studies that concentrate on the linkages between investment and volatility in taxes.

⁵Some 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).

possibility of uncertainty affecting managers' investment decision through its impact on other variables which are shown to be important in explaining firms' investment behavior. 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 firm to its choice of an optimal investment plan as well as the method that we use to obtain our proxies for uncertainty.

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 et al. (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 one-period discount factor, assumed constant for simplicity.

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

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:

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

where $\Pi(K_t)$ denotes the maximized value of current profits taking as 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.

$$K_t = (1 - \delta)K_{t-1} + I_t, \quad (3)$$

$$B_{t+1} \geq 0 \quad (4)$$

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. The corresponding Lagrange multiplier is λ_t representing the shadow price associated with the capital accumulation equation. Financial frictions are introduced through the firm-specific cost of funds as described below. The firm faces the transversality condition which prevents the firm from borrowing an infinite amount and paying it out as dividends:

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

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

$$\frac{\partial C_t}{\partial I_t} + 1 = \lambda_t \quad (6)$$

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

$$E_t [\beta R_{t+1}] = 1 + \mu_t. \quad (8)$$

Equation (6) sets the marginal cost associated with an additional unit of investment equal to its shadow price. The first-order condition for capital defines the Euler equation which describes the evolution of λ_t . The last equation 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 the 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

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

Solving this equation forward and using the first order condition for debt (8) and the definition of the value of the firm, it follows as

$$\lambda_t(1 - \delta)K_{t-1} = V_t - B_t R_t - E_t \left[\sum_{i=0}^{\infty} \beta^i (B_{t+i+1} \mu_{t+i}) \right] \quad (10)$$

Marginal q_t is equal to the shadow value of an additional unit of capital, λ_t ,

$$q_t = \lambda_t = \frac{V_t}{(1 - \delta)K_{t-1}} - \frac{R_t}{(1 - \delta)} \frac{B_t}{K_{t-1}} - \frac{\Theta_t}{K_{t-1}} \quad (11)$$

The last term Θ_t/K_{t-1} represents the expectation of the infinite sum. It 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. Hennessy (2004) obtains a similar result in which average Q overstates marginal q by incorporating post-default returns to investment.

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

$$C(I_t, K_t, \varepsilon) = \frac{b}{2} \left[\left(\frac{I_t}{K_t} \right) - g \left(\frac{I_{t-1}}{K_{t-1}} \right) - a + \varepsilon_t \right]^2 K_t \quad (12)$$

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

$$\frac{I_t}{K_t} = a - \frac{1}{b} + g \frac{I_{t-1}}{K_{t-1}} + \frac{1}{b(1 - \delta)} Q_t - \frac{R_t}{b(1 - \delta)} \frac{B_t}{K_{t-1}} - \frac{1}{b} \frac{\Theta_t}{K_{t-1}} \quad (13)$$

The last term in Equation (13) 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. In our approach 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:

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

where CF_{it} 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.⁶ 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.⁷ Furthermore, using intrinsic and extrinsic uncertainty in our regressions 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. 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 ($a_1 < 1$), the higher levels of uncertainties increase financial frictions ($a_2 > 0$, $a_3 > 0$, $a_4 > 0$). In contrast to Abel and Eberly (1994) 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 (13). Replacing capital by total assets (TA), we obtain the empirical model specification with coefficients as functions of the model’s parameters.

$$\begin{aligned} \left(\frac{I}{TA}\right)_{it} = & \beta_0 + \beta_1 \left(\frac{I}{TA}\right)_{i,t-1} + \beta_2 Q_{it} + \beta_3 \left(\frac{CF}{TA}\right)_{it} + \beta_4 \left(\frac{B}{TA}\right)_{it} + \\ & (\delta_1\eta_{i,t-1} + \delta_2\nu_{i,t-1} + \delta_3\varepsilon_{t-1}) \times \left(\frac{CF}{TA}\right)_{it} + \lambda_i + \epsilon_{it} \quad (14) \end{aligned}$$

⁶We explain how these measures are constructed using daily data in section 3.1.

⁷For instance, see Bloom et al. (2001) for a discussion of similar issues.

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. 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, Vishny (2002), and Allayannis and Weston (2001).⁸ As usual, λ_i captures the firm fixed effect and ϵ_{it} denotes the error term.

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

⁸Allayannis 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 .

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.⁹ 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 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 we then define as the daily contribution to annual volatility:

$$\varsigma_t^d = \left(100 \frac{\Delta x_t}{\sqrt{\Delta \phi_t}} \right)^2 \quad (15)$$

where the denominator expresses the effect of calendar time elapsing between observations on the x process. If data were available 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 $\sigma_t[x_t]$ is at the annual frequency.

An alternative to Merton's procedure (which makes use of squared high-frequency returns) is that proposed by Ghysels et al. (2004): the computation of realized absolute variation and bipower variation, which make use of absolute returns. We generated these measures from the firm-level daily data, and found 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 did 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.

⁹See Baum, Caglayan and Ozkan (2004a) for a more detailed discussion of the procedure along with its merits.

4 Empirical findings

4.1 Data

Our 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. First, we marked non-positive values of total assets, net sales, investment, debt, Q and cash 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). Since we do not directly observe these phenomena, 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, we considered that 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 implausible. Fourth, we wish to exclude firms in clear financial distress or those facing substantial liquidity constraints. We consider two consecutive years of negative cash flows 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.¹⁰

We trimmed 1% from either end of the annual returns distribution 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 that we use in our 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.

¹⁰Empirical results drawn from the full sample yielded qualitatively similar findings; we prefer to use the screened data to reduce the potential impact of outliers upon the parameter estimates.

manufacturing firm level data since we are 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. Firms experienced slightly more than 4% growth in real sales over the period. 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 our 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). Where two-step estimates are presented, their standard errors have been adjusted by the correction proposed by Windmeijer (2005) to ensure their consistency. All models are estimated in first difference terms to eliminate the fixed effects using the GMM estimator.

4.2.1 Estimates of the basic model

We start our investigation estimating a standard investment model which includes the basic explanatory variables for firm level investment: Q , CF/TA , real sales growth 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 603 firms' annual data in an unbalanced panel. The equivalent two-step GMM results are displayed in column one of Table 3. Similar to findings reported in the literature, the signs of CF/TA , Q , real sales growth and the lagged dependent variable are positive and significant while the sign of B/TA is negative and significant in both versions, and require no further comment.

The J p-value is the Hansen–Sargan test statistic, indicating that the test for overidentifying restrictions is satisfactory (as it is in all reported estimates).

Next we introduce our measures of lagged intrinsic and extrinsic uncertainty into this basic model.¹¹ Column two of Tables 2 and 3 provide 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.¹² The coefficient for *Own* uncertainty is negative and significant in both the one-step and two-step estimates of the model. 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.

We then add extrinsic uncertainty to the original equation (excluding the intrinsic measure) with results given in column three of Tables 2 and 3. Our *Market* based proxy for uncertainty has a weak negative impact on firm investment behavior in both sets of estimates, with the magnitude of the impact generally comparable to that of the firm-level uncertainty measure. Given this effect, we consider a model in which both intrinsic and extrinsic measures are included in column four of Tables 2 and 3. When entered jointly, the coefficient of the extrinsic measure loses significance. 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: $Cov(Own_{ret}, Mkt_{ret})_{i,t-1}$. The results associated with this model, corresponding to equation (2) in section 3, are presented in column five of Tables 2 and 3. The coefficient on intrinsic uncertainty is once again negative and significant, but that of extrinsic uncertainty is now positive and significant in the one-step estimates. We observe that the CAPM-based uncertainty measure is significant and negative, as the theory would suggest, in the one-step estimates. This result is quite interesting supporting the implications of CAPM theory and stands

¹¹Use of contemporaneous uncertainty measures yield similar results.

¹²In all our regressions the coefficients of Q , CF/TA and the lagged dependent variable are, as expected, positive and significant.

in clear contrast to the findings reported by Leahy and Whited (1996). It appears that when both market uncertainty and the covariance of firm and market uncertainty are included in the model, the level of market uncertainty serves as a moderating influence on the CAPM uncertainty measure.

Interestingly, the sizable positive effect of real sales growth in the baseline model, controlling for future profitability, drops off to insignificance in any of the specifications including intrinsic uncertainty. Other authors (e.g., Bond et al. (2004)) have found that real sales growth plays an important role in their findings; it appears that this measure may be proxying for some aspects of firm-specific uncertainty in that context.

Having established the negative impact of firm-level and CAPM-based uncertainty on firms' capital investment spending, we now turn to equation (2) to see if there is evidence in favor for complex and nonlinear effects of uncertainty on investment.

4.2.2 Estimates of the extended model

In our extended model, corresponding to equation (2) in section 3, we constrain the effects of intrinsic and extrinsic uncertainty on capital investment to operate in conjunction with the cash flow-to-assets ratio. In this formulation, both $\partial(I/TA)_{it}/\partial(CF/TA)_{it}$ and $\partial(I/TA)_{it}/\partial\eta_{i,t-1}$ (as well as the corresponding derivatives for ε and ν) will vary over the sample, with the levels of uncertainty and the firm's cash flow-to-assets ratio affecting those derivatives' magnitudes. This form of the model should be able to capture the degree to which the effects of uncertainty on investment may be strengthened or weakened by the firm's current financial condition.

In the first column of Tables 4 and 5, we reproduce for comparison the "baseline model" from Tables 2 and 3, respectively, for one-step and two-step estimates. In the second column of Tables 4 and 5, we add the interaction of the CF/TA ratio with intrinsic uncertainty, η , labelled $CF/TA \times \eta_{t-1}$. That coefficient is significant and negative in both sets of estimates. Column 3 presents results for extrinsic uncertainty, while column 4 includes both intrinsic and extrinsic uncertainty interaction terms, with the latter labelled $CF/TA \times \varepsilon_{t-1}$. Similar to the non-interacted forms of this specification, the extrinsic uncertainty term plays no meaningful role in either one-step or two-step estimates of the equation, alone or in conjunction with the intrinsic uncertainty measure.

However, when we add the CAPM uncertainty term, $CF/TA \times covard_{t-1}$ —

as displayed in column five of Tables 4 and 5—all three interacted uncertainty terms appear significant in the one-step estimates. Extrinsic uncertainty—in this case interacted with CF/TA —has a weak positive effect on the I/TA ratio, while the intrinsic uncertainty and CAPM uncertainty measures are significant and negative in the one-step estimates. 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 is reflecting an expansionary period, with firms expanding production and their capital stock. Nevertheless, if the firm’s returns exhibit a higher covariance with those of the market, that greater level of firm-specific risk tends to reduce the rate of capital investment, *ceteris paribus*.

The extended model of equation (2) 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.¹³ 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 5) and evaluate that derivative at those points. The point estimates and standard errors of that derivative are presented in the left side of Table 6. We see that the 5–95 percentile range of CF/TA encompasses almost a fivefold change in firms’ liquidity from 0.0386 to 0.1887. Correspondingly, $\partial(I/TA)/\partial\eta$ varies over that range from -0.0016 to -0.0078. 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 6, 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 in-

¹³We could calculate similar quantities for the other two sources of uncertainty in the equation; we focus here on intrinsic uncertainty.

intrinsic uncertainty (η) while holding the other uncertainty measures at their estimation-sample means. Selected percentiles of the η distribution are displayed in Table 6: the 5–95 percentile range encompasses a sevenfold range in intrinsic uncertainty, from 0.26 to 1.95. 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 0.2436 to 0.1744. 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.

5 Conclusions

Given the significance of fluctuations in capital investment spending in explaining the business cycle, many researchers have investigated the factors that affect firms’ capital investment behavior. In this paper, we specifically concentrate on the role of firm specific (intrinsic), market specific (extrinsic) and CAPM-based measures of uncertainty on firms’ investment spending. We construct both idiosyncratic and market uncertainty measures using a method based on Merton (1980) from the intra-annual variations in stock returns 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 show that an intrinsic uncertainty proxy affects investment negatively and significantly, while extrinsic uncertainty has little effect. 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 are significant and negative. These findings are quite interesting in light of earlier research. For instance, researchers have found that 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 in several of our estimated models.

An extended model in which the effects of uncertainty appear interacted with cash flow also appears to be quite successful, implying that a specification allowing for the effects of uncertainty to vary over firms depending on their liquidity is superior to the simpler model's constant effects. 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. Given the robustness of our findings, further research along these lines should be able to shed considerable light on the interactions of uncertainty and firm's capital investment behavior, and more generally on macroeconomic fluctuations.

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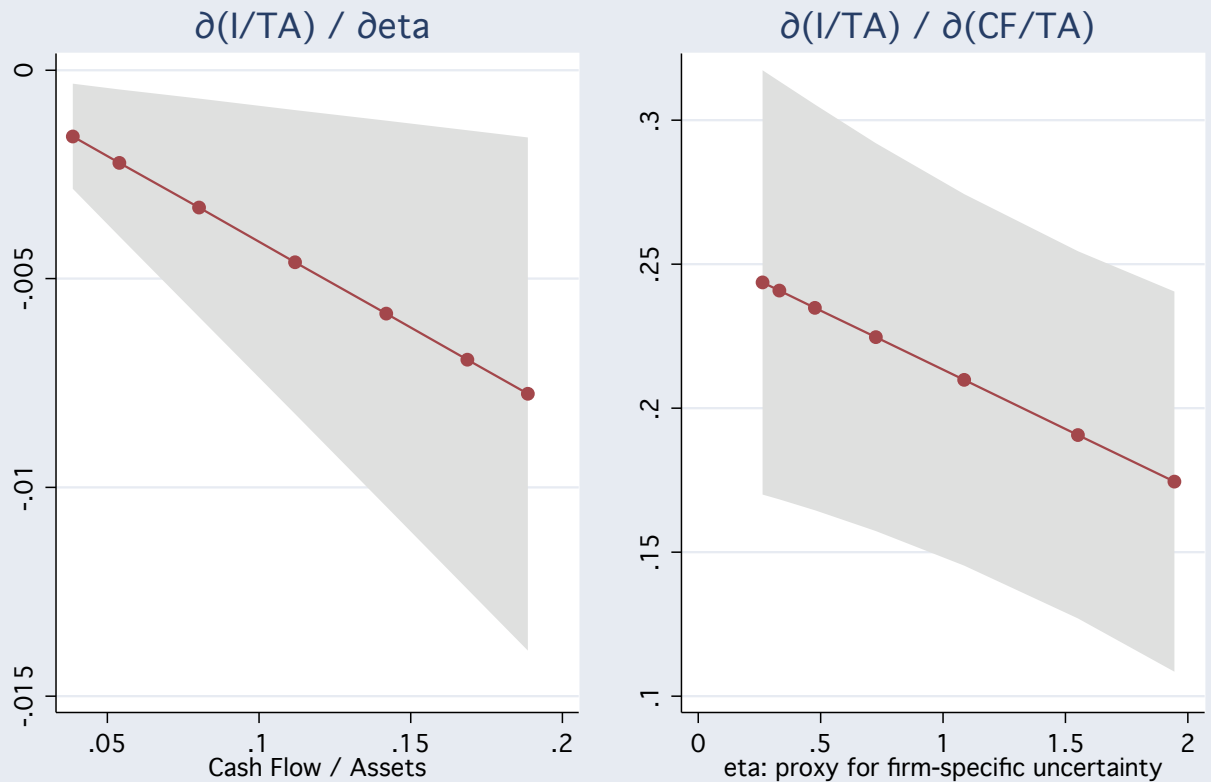
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Figure 1. Estimated sensitivities from interactions model



95% confidence interval shaded
 Percentiles: 5, 10, 25, 50, 75, 90, 95

Table 1: Descriptive statistics

	p25	p50	p75	mean	sd
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
Real sales growth	-0.0301	0.0340	0.1033	0.0412	0.1479
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				

Table 2: Robust one-step GMM estimates

	(1)	(2)	(3)	(4)	(5)
$(I/TA)_{t-1}$	0.416*** (0.037)	0.373*** (0.039)	0.409*** (0.038)	0.385*** (0.038)	0.380*** (0.037)
Q	0.002*** (0.001)	0.003*** (0.001)	0.003*** (0.001)	0.003*** (0.001)	0.003*** (0.001)
CF/TA	0.174*** (0.033)	0.200*** (0.034)	0.194*** (0.035)	0.215*** (0.034)	0.210*** (0.033)
Real sales growth	0.018** (0.008)	0.010 (0.008)	0.011 (0.008)	0.005 (0.008)	0.008 (0.008)
B/TA	-0.070*** (0.012)	-0.053*** (0.013)	-0.066*** (0.012)	-0.058*** (0.012)	-0.058*** (0.012)
η_{t-1}		-0.005*** (0.001)		-0.006*** (0.002)	-0.006*** (0.002)
ε_{t-1}			-0.004 (0.003)	0.004 (0.004)	0.014** (0.007)
ν_{t-1}					-0.031** (0.014)
Firm-years	4315	4311	4315	4311	4311
Firms	603	602	603	602	602
F	69.759	61.370	64.820	54.917	49.114
F pvalue	0.000	0.000	0.000	0.000	0.000
J	304.256	323.461	324.529	343.708	361.474
J pvalue	0.597	0.261	0.248	0.404	0.586
AR(2)	-2.040	-2.127	-1.976	-2.004	-2.086
AR(2) pvalue	0.041	0.033	0.048	0.045	0.037

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

Table 3: Robust two-step GMM estimates

	(1)	(2)	(3)	(4)	(5)
$(I/TA)_{t-1}$	0.425*** (0.042)	0.387*** (0.043)	0.427*** (0.043)	0.397*** (0.041)	0.392*** (0.039)
Q	0.002*** (0.001)	0.002*** (0.001)	0.002** (0.001)	0.002*** (0.001)	0.002*** (0.001)
CF/TA	0.167*** (0.034)	0.192*** (0.035)	0.183*** (0.037)	0.217*** (0.034)	0.209*** (0.033)
Real sales growth	0.020** (0.008)	0.013 (0.009)	0.017* (0.009)	0.009 (0.009)	0.011 (0.009)
B/TA	-0.071*** (0.013)	-0.056*** (0.015)	-0.070*** (0.014)	-0.059*** (0.014)	-0.058*** (0.012)
η_{t-1}		-0.004*** (0.001)		-0.005*** (0.002)	-0.005** (0.002)
ε_{t-1}			-0.005* (0.003)	0.002 (0.004)	0.007 (0.008)
ν_{t-1}					-0.020 (0.016)
Firm-years	4315	4311	4315	4311	4311
Firms	603	602	603	602	602
F	54.954	52.427	51.962	48.448	43.385
F pvalue	0.000	0.000	0.000	0.000	0.000
J	304.256	323.461	324.529	343.708	361.474
J pvalue	0.597	0.261	0.248	0.404	0.586
AR(2)	-2.077	-2.136	-1.985	-2.029	-2.114
AR(2) pvalue	0.038	0.033	0.047	0.043	0.035

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

Table 4: Robust one-step GMM estimates, interacted model

	(1)	(2)	(3)	(4)	(5)
$(I/TA)_{t-1}$	0.416*** (0.037)	0.374*** (0.039)	0.410*** (0.038)	0.385*** (0.038)	0.381*** (0.037)
Q	0.002*** (0.001)	0.003*** (0.001)	0.003*** (0.001)	0.003*** (0.001)	0.003*** (0.001)
CF/TA	0.174*** (0.033)	0.251*** (0.038)	0.200*** (0.035)	0.265*** (0.037)	0.259*** (0.037)
Real sales growth	0.018** (0.008)	0.010 (0.008)	0.011 (0.008)	0.005 (0.008)	0.008 (0.008)
B/TA	-0.070*** (0.012)	-0.052*** (0.013)	-0.066*** (0.012)	-0.057*** (0.012)	-0.058*** (0.012)
$CF/TA \times \eta_{t-1}$		-0.045*** (0.012)		-0.052*** (0.015)	-0.053*** (0.016)
$CF/TA \times \varepsilon_{t-1}$			-0.029 (0.025)	0.032 (0.033)	0.111* (0.058)
$CF/TA \times \nu_{t-1}$					-0.244* (0.126)
Firm-years	4315	4311	4315	4311	4311
Firms	603	602	603	602	602
F	69.759	61.343	64.645	54.847	48.960
F pvalue	0.000	0.000	0.000	0.000	0.000
J	304.256	319.891	325.476	343.868	359.682
J pvalue	0.597	0.309	0.236	0.401	0.612
AR(2)	-2.040	-2.036	-1.960	-1.910	-1.969
AR(2) pvalue	0.041	0.042	0.050	0.056	0.049

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

Table 5: Robust two-step GMM estimates, interacted model

	(1)	(2)	(3)	(4)	(5)
$(I/TA)_{t-1}$	0.425*** (0.042)	0.387*** (0.043)	0.429*** (0.043)	0.397*** (0.041)	0.392*** (0.039)
Q	0.002** (0.001)	0.003** (0.001)	0.002* (0.001)	0.002** (0.001)	0.002** (0.001)
CF/TA	0.167*** (0.034)	0.222*** (0.040)	0.193*** (0.038)	0.259*** (0.038)	0.252*** (0.037)
Real sales growth	0.020* (0.008)	0.014 (0.009)	0.017 (0.009)	0.009 (0.009)	0.011 (0.009)
B/TA	-0.071*** (0.013)	-0.056*** (0.015)	-0.070*** (0.014)	-0.059*** (0.014)	-0.056*** (0.012)
$CF/TA \times \eta_{t-1}$		-0.031* (0.013)		-0.042** (0.015)	-0.041* (0.017)
$CF/TA \times \varepsilon_{t-1}$			-0.037 (0.026)	0.012 (0.033)	0.046 (0.062)
$CF/TA \times \nu_{t-1}$					-0.120 (0.132)
Firm-years	4315	4311	4315	4311	4311
Firms	603	602	603	602	602
F	54.954	51.666	51.290	47.188	43.342
F pvalue	0.000	0.000	0.000	0.000	0.000
J	304.256	319.891	325.476	343.868	359.682
J pvalue	0.597	0.309	0.236	0.401	0.612
AR(2)	-2.077	-2.093	-1.965	-1.958	-2.017
AR(2) pvalue	0.038	0.036	0.049	0.050	0.044

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

Table 6: 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.
$p5$	0.0386	-0.0016	0.0006	0.2631	0.2436	0.0376
$p10$	0.0540	-0.0022	0.0009	0.3305	0.2409	0.0371
$p25$	0.0802	-0.0033	0.0013	0.4775	0.2348	0.0359
$p50$	0.1118	-0.0046	0.0019	0.7262	0.2246	0.0344
$p75$	0.1419	-0.0058	0.0024	1.0859	0.2098	0.0329
$p90$	0.1687	-0.0069	0.0028	1.5510	0.1907	0.0325
$p95$	0.1887	-0.0078	0.0031	1.9461	0.1744	0.0337