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Abstract

This paper examines how profit volatility has influenced firms' decisions over the past four decades. Using Compustat data, we document that: (1) high-investing firms cut their investment rate more sharply than other firms, implying that extensive margin investment decisions - whether to invest in new projects or not - are important for the uncertainty effects; (2) the interaction between firms' financial and real conditions amplifies the negative impact of increased uncertainty on the investment rates. We also develop and calibrate a heterogeneous-firm model that incorporates both real and financial costs. In the model, higher capital adjustment costs increase the investment inaction rate by 31%, while higher financial costs reduce the investment spike rate by 46%. Incorporating irreversible capital into the collateral constraint reduces firms' debt capacity, leading to an increase in the investment inaction rate, cash holdings, and net dividends.

JEL Classification: C31, E22, G31.

Keywords: Capital Investment, Adjustment Costs, Extensive Margin.

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1 Introduction

Over the past four decades, the U.S. corporate sector has experienced a large decline in the average investment rate, dropping from 10.49% in 1980 to 4.80% in 2018. During the same period, average uncertainty regarding the profit growth rate increased from 0.43% to 0.78%.[1] These trends raise the question of the extent to which idiosyncratic profit volatility affects the investment rate. The novelty of this study is to explain the negative relationship between the investment rate and idiosyncratic uncertainty through the interaction of financial with real frictions, whose impact increases as the investment rate rises.

Recent progress has been made in explaining the investment-uncertainty relationship by incorporating new measures of real frictions (see, e.g., Kermani and Ma, 2023; Kim and Kung, 2017; Chirinko and Schaller, 2009) and measures of financial frictions (Alfaro et al., 2024; Almeida et al., 2004) into investment models. However, these frictions have been mostly studied separately, leaving their possible interactions and implications unexplored. Importantly, the impact of frictions varies with the investment rates in Compustat data. In addition, the literature focuses on *average* effects on the investment rate. It is unclear from the literature whether the estimated average effects imply that all firms decrease their investment rates by the same average amount or a few firms decrease investment rates by a large amount. Hence, our study aims to bridge these gaps by empirically and quantitatively exploring the interactions between financial and real frictions, and to estimate the effects of profit volatility on different quantiles of the investment rate distribution. Addressing these research gaps is important for defining and implementing targeted policies, as the distributional analysis of uncertainty effects identifies the firms most sensitive to uncertainty shocks, while the complementarity between frictions suggests that mitigating the negative effects of one friction can help alleviate the negative effects of another.

[1] We use the U.S. Compustat Annual data for the analysis, excluding financial companies and utilities. The investment rate is defined as gross capital expenditure (`capx`, item 128) to the lagged book value of total assets (`at`, item 6). Volatility of a firm is computed as the standard deviation of the profit growth rate (`oibdp`, item 13) in the current and previous four years. The aggregate measure of the typical firm volatility in a given year is obtained by taking the mean across all sample firms in a year. The Pearson correlation coefficient of -0.5669 between the investment rate and uncertainty is statistically significant at 1%.

We characterize the empirical relationship between fixed capital investment and firm-specific uncertainty about the future profit growth rate using annual data from Compustat for the 1980-2018 period, and find that a one-standard deviation increase in the profit uncertainty leads to a drop in the mean annual investment rate by 0.59%, which is in line with the literature's findings that range between 0.38% and 0.96% (see e.g., Alfaro et al., 2024; Liu and Wang, 2021; Panousi and Papanikolaou, 2012; Baum et al., 2008; Leahy and Whited, 1996).[2] Relative to the unconditional mean investment rate of 7%, this is a decline of 6.2% per year. Consistent with the empirical literature, we find that the average effect of uncertainty on the investment rate increases in the presence of capital irreversibility or financial constraints.[3]

We document several novel empirical findings. First, firms from the right tail of the investment rate distribution decrease their investment rates much more strongly than other firms, suggesting that the extensive margin decision of whether to invest or not is important to understand the effects of profit volatility on the average investment rate. The drop in the positive investment spike and the rise in the inaction rate additionally support the importance of the extensive margin effects of uncertainty.[4] Second, the extensive margin investment decisions account for almost half of the decline in the annual investment rate.[5] Third, by estimating quantile regressions, the individual influence of both financial and real frictions on the investment-uncertainty relationship becomes stronger at a higher investment rate. While the response of investment to increased uncertainty along the extensive margin is mostly driven by financial frictions, real frictions have a stronger effect on the inaction rate. Fourth, the interaction between frictions amplifies a negative response of the investment rate to increased uncertainty.[6]

[2]Our OLS regression results closely align with the IV estimates, which utilize a one-year lagged uncertainty measure as an instrumental variable.

[3]We follow the literature in using the crude measures for financial and real frictions. If less than 20% of profits is set aside for dividends, then a firm is financially constrained. If the fixed capital stock to total asset ratio exceeds its medium level in industry, a firm has irreversible capital.

[4]The positive investment spike involves the fraction of firms with an annual investment rate larger than 20%. The inaction rate refers to the fraction of firms with an annual investment rate smaller that 1% in absolute value.

[5]Change in the spike rate is our proxy for the extensive margin investment responses.

[6]All our empirical findings are robust to various measures of the investment rate, uncertainty, and frictions.

Motivated by our empirical evidence, we extend a standard heterogeneous-firm model with additional frictions to evaluate which frictions explain investment behaviour in the last four decades and to understand the role of interconnecting frictions in firms' decisions under uncertainty.[7] First, we incorporate capital irreversibility and fixed capital adjustment costs, together with the existing convex costs. This comprehensive capital cost structure reduces the liquidity value of capital and generates observed capital adjustments along extensive and intensive margins. Second, similar to Melcangi (2024), we combine collateral constraint with partially irreversible capital to affect the collateral value of capital. The combination of frictions makes it more difficult to finance lumpy investment and stimulates a reallocation of resources from capital to cash. This is consistent with a precautionary savings channel.

The main findings of our model are as follows. It accounts for 33% of the decrease in the investment rate and around 80% of the increase in cash holdings. Increased volatility in firm-level productivity from the estimated value of 0.1915 to 0.2085 can capture around 5.9% of the decline in investment rate and 20% of the increase in cash holding. Our findings indicate a 2.2% reduction in the fraction of firms investing in new capital at the extensive margin, while investment in existing capital at the intensive margin decreases by 3.7%. An investment decline at the extensive margin is more sensitive to tighten collateral constraint and costly equity issuance, while more costly capital adjustments have a greater impact on the rise in the inaction rate. Finally, irreversible costs have the role of amplifying the impact of uncertainty on the investment inaction rate, cash reserves, and positive net dividends. These responses could be explained by reduced liquidity and collateral value of capital.

The general intuition behind the role of frictions in transmitting the negative effect of uncertainty on investment is the following. As profit volatility rises, firms are more likely to face shortfalls in internal funds. In the fear of running out of internal funds, financially constrained firms reduce the investment rate and increase a precautionary demand for cash holdings to limit their exposure to financial losses and avoid costly borrowing. Conversely, financially unconstrained firms could absorb increased volatility by reducing either accumulated cash holdings or dividends, without sacrificing investment.[8] Irreversible

[7]Uncertainty shocks are introduced in the model as changes in the variance of firm-specific profit shocks.

[8]If a firm has sufficient internal funds to finance desired investment, regardless of the profit shock realization,

investment implies that all firms face additional costs when adjusting capital stock, inducing larger investment that occurs less frequently.[9] Firms with irreversible capital delay investment in new capital or switch to zero investment to avoid committing to projects with potentially more costly capital adjustments in an uncertain environment. Finally, fully reversible assets allow financially constrained firms to mitigate the impact of costly external funds. Without financial frictions, firms could more easily finance lumpy investment. This study shows that a large number of high-investing firms face increased financial and real difficulties in capital investment, changing the shape of the investment rate distribution.

This study is organized as follows. Section 2 presents the related literature. Section 3 documents the negative relationship between firm-specific uncertainty and investment. Section 4 develops a quantitative model. Section 5 concludes. The Appendix contains information on data sources and robustness checks on empirical evidence.

2 Related Literature

This study is related to two stands of the literature. The first strand investigates the relationship between firm-level uncertainty and fixed capital investment. Theory identifies several channels through which uncertainty impacts investment, including costly external funds arising from information asymmetry (Myers and Majluf, 1984), irreversibility of investment caused by sunk costs (Dixit and Pindyck, 1994), and the convexity of the marginal product of capital in output prices induced by assumptions of perfect competition, constant returns to scale, and absent irreversibility (Abel, 1983). While the first two channels predict a negative relationship, the third channel suggests a positive correlation. Empirical studies generally confirm a negative relationship between firm-level uncertainty and the investment rate for publicly traded firms in the US (see e.g., Alfaro et al., 2024; Kermani and Ma, 2023; Liu and Wang, 2021; Gilchrist et al., 2014; Panousi and Papanikolaou, 2012; Baum et al., 2008;

then the firm is classified as financially unconstrained.

[9] Investment irreversibility induces a reluctance to invest because forward-looking firms do not like to increase investment today if it seems likely they will have to reduce it later (Chirinko and Schaller, 2009). To minimize fixed costs, firms tend to adjust their capital stock only for large profit shocks and remain investment inactive otherwise.

Almeida and Campello, 2007; Bulan, 2005; Minton and Schrand, 1999) and for firms in the UK (Bloom et al., 2007).[10] However, it remains ambiguous from the literature whether the observed *average* decline in the investment rates is driven by a large number of firms or just a few firms. We also emphasize the importance of interconnecting financial and real frictions in the transmission of profit volatility to capital expenditure as the impact of both frictions varies across the investment rate distribution. Almeida and Campello (2007) show that investment–cash flow sensitivity increases in the tangibility of firms' assets only for financially constrained firms. Instead, we propose the quantile regression to determine the importance of the extensive margin investment decisions for investment-uncertainty sensitivity. While this model is implemented in exploring pay-performance sensitivity (Hallock et al., 2010) and pecking order theory (Chay et al., 2015), the analysis of the investment-uncertainty relationship across the investment rates remains unexplored.

The second strand of literature explores the financial implications of the negative investment-uncertainty relationship. While the recent explanation for the investment decline, provided by Alfaro et al. (2024) for example, predicts positive cash holdings, their model generates almost zero change in positive net dividends. In contrast, the combination of collateral constraints and irreversible investment in our model, as suggested by Melcangi (2024), reduces the liquidity and collateral value of capital, resulting in a reallocation of resources from capital to cash. The rise in cash holdings exceeds the decline in dividends net of equity issuance, leading to positive net dividends. In contrast to Falato et al. (2022), which document that the largest part of a rise in cash holdings could be explained by a rise in intangible capital, we show that firm-specific profit uncertainty is also an important factor.

[10] Leahy and Whited (1996) find that the impact of stock price uncertainty on capital investment disappear once average Tobin's Q is considered in the regression model. In contrast, Boyle and Guthrie (2003) document that a firm is more likely to increase investment when cash-flow volatility increases due to future shortage of internal funds. Kim and Kung (2017) show that firms with more redeployable assets increase investment when facing increased uncertainty.

3 Empirical Evidence

This part of our study focuses on answering interconnected questions: What is the impact of profit volatility on the distribution of the investment rate? How do interactions between financial and real frictions influence firms' investment decisions?

Important factors affect the investment-uncertainty relationship over the long-time horizon, including investment opportunity and internal funds. That is, weak investment opportunity and a lack of internal funds may lead to a drop in investment, regardless of the impact of the uncertainty measure. We partial out the impact of such confounding factors and pay attention to a precautionary savings channel through which uncertainty affects investment.[11] Our focus is on the following three empirically testable predictions:

- Prediction 1: Extensive margin investment decision is important for the average effects of profit volatility.

- Prediction 2: Individual influence of both financial and real frictions on the investment-uncertainty relationship becomes stronger at larger investment rates.

- Prediction 3: The impact of profit volatility on irreversible assets increases in the presence of financial constraint.

3.1 Summary Statistics

Using Compustat data, we study decisions of the U.S. firms. The sample period is annual from 1980 to 2018, covering the period of the "Great Moderation" of the 1980s. The starting year of the sample is chosen to be comparable with the literature. We focus on firms' decisions at an annual level because firms generally set their budgets on capital expenditure annually during the budgeting process.

Table 3.1 presents descriptive statistics for firm-specific variables. It reports the mean, median, minimum, maximum, standard deviation, and number of observations. Our main

[11] In Appendix B and Appendix C, we confirm that there persists a long-run negative relationship between the investment rate and uncertainty measures after controlling for the impacts of confounding factors.

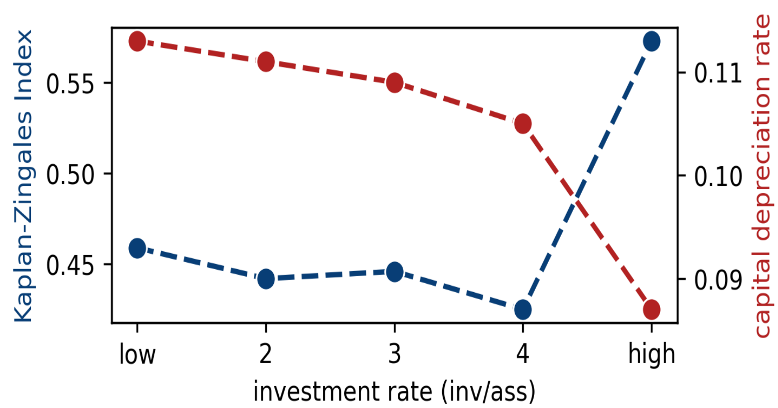
Table 3.1: Summary statistics

Variable	Mean	Std. dev.	Min	Max	Median	Obs.
investment/assets	0.0707	0.0646	0.0079	0.2618	0.0491	91371
vol(profit)	0.8692	1.3565	0.0476	5.3654	0.3084	85100
mkt/book	2.2886	1.6764	0.5202	6.8799	1.7550	81100
sales/assets	1.2506	0.6714	0.3049	2.8195	1.1461	81100
cash/assets	0.1293	0.1397	0.0038	0.4895	0.0728	81100
r10yTCMR	8.9263	6.4569	1.7493	26.9135	7.4282	91400
RGDPgrowth	-0.0019	0.0229	-0.0750	0.0289	0.0037	81100
size	5.9467	1.7494	3.1777	9.3738	5.7934	81100
age	1.9737	0.9737	0.0000	3.4012	2.0794	81100

Table 3.1 presents summary statistics for variables used in regression equation (1). The sample includes Compustat firms from 1980 to 2018. All variables are winsorized. A detailed description of variables is provided in Appendix A.

variables of interest are the investment rate and profit volatility. The summary statistics show that the average firm holds 7% of their assets in investment. Profit volatility, is on average, 0.87, which is rather close to Liu and Wang (2021). On average, sampled firms have good growth prospects in the sample period. More specifically, average Tobin's Q is 2.29 and the sales-to-asset ratio is 1.25, which are slightly above those in Liu and Wang (2021).

Figure 3.1: Financial and real conditions of firms across investment quintiles



Data source: Compustat (1980-2018). corr(KZindex,dep) = -0.11

Figure 3.1 shows that the impact of financial and real conditions of firms (blue and red dots) varies across the investment rate distribution; they are stronger for high-investing firms. This simple univariate analysis motivates us to study uncertainty effects beyond the average investment rate. In addition, the opposing patterns in conditions, especially moving to a high investment group, suggests that ignoring their complementarity underestimates the true effects of idiosyncratic uncertainty. The increase in average Kaplan-Zingales index within the Q5 investment group indicates that some high-investing firms heavily rely on external funds in financing their high growth opportunities, pushing up the average index. At the same time, high-investing firms suffer from higher capital adjustment costs as the low depreciation rate means that it is more expensive to adjust capital quickly.

3.2 Empirical Setting

Similar to Gilchrist et al. (2014) and Panousi and Papanikolaou (2012), we estimate the investment-uncertainty relationship using the following reduced-form investment equation:

$$\frac{inv_{i,t}}{ass_{i,t-1}} = \beta_0 + \beta_1 \cdot \sigma_{i,t-1} + \beta_2' \cdot X_{i,t-1} + \eta_t + \gamma_i + \epsilon_{i,t} \tag{3.1}$$

Equation (3.1) is our baseline specification. Investment in property, plant and equipment (PPE) of firm i in year t, $inv_{i,t}/ass_{i,t-1}$, is scaled by the beginning-of-period total assets $ass_{i,t-1}$ to control for large cross-sectional differences in assets. This scaling makes the investment of firms comparable.[12] Profit volatility is measured as the standard deviation of the firm's profit growth over the recent five years, i.e. the lagged uncertainty variable refers to a realized shock before making investment decisions.[13] We consider lagged profit volatility $\sigma_{i,t-1}$ to alleviate concerns about a reverse impact of investment on the uncertainty measure. There are two main differences relative to Gilchrist et al. (2014) and Panousi and Papanikolaou (2012). First, we do not consider the log specification of variables in order to capture the possibility of a non-linear relationship between investment and uncertainty variables. Second, they construct a metric of idiosyncratic volatility using data on stock

[12] Larger firms tend to have a proportionally larger investment than smaller firms.

[13] The lagged volatility is supported by the high persistence of the volatility series (see Figure 5.11 in Appendix J).

returns. There is a potential concern about variability in stock returns that captures the noise unrelated to fundamentals (see Bloom et al., 2007 for more details).

$$X_{i,t-1} \in \left\{ \frac{mkt_{i,t-1}}{book_{i,t-1}}, \ \frac{sale_{i,t-1}}{ass_{i,t-1}}, \frac{cash_{i,t-1}}{ass_{i,t-1}}, \ log(asset_{i,t-1}), \ log(age_{i,t-1}) \right\}.$$

$X_{i,t-1}$ controls for firm-specific investment opportunities, financial condition and demographic characteristics of firms. Specifically, $X_{i,t-1}$ contains average Tobin's Q, real sales growth rate, cash, size and age of firm i. Profit volatility may capture the effects of poor investment opportunities that are missed by the average Tobin's Q. To address this omitted variable bias, we consider the sales-to-asset ratio as an additional control variable. Firm age refers to number of years since a firm enters the sample, while firm size is measured by total assets.

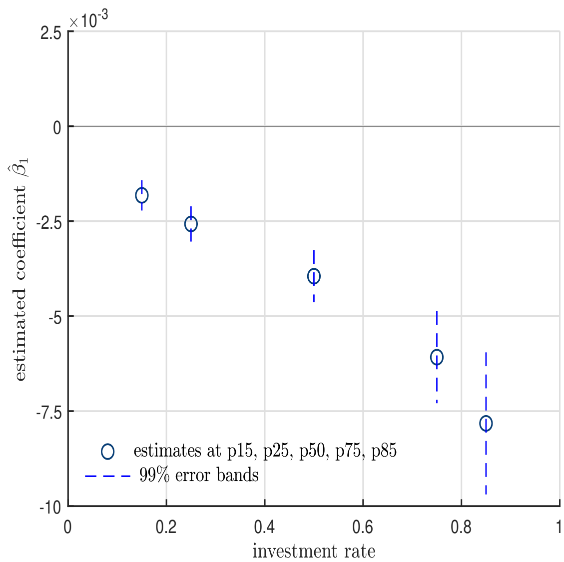
Firm fixed-effects γ_i control for systematic differences in the average investment rates across firms but remaining constant over time. Time fixed-effects η_t capture the impacts of macro factors that are common across firms but vary over time. With time fixed effects, we effectively demean each observation by its time average. Hence, we cannot include macro factors together with time FE in the regression, such as real output growth and real risk-free interest rate. That is, aggregate time-series variables have no explanatory power in regressions that include time fixed effects. All control variables are measured as of $t-1$ to mitigate concerns regarding endogeneity. Time lags between the investment rate and explanatory variables are also needed to enable lags in investment implementation. Equation (3.1) is annually estimated using ordinary least squares.

3.3 Regression Results

Impact of Profit Volatility

The literature focuses on the *average* effects of uncertainty on the investment rate, estimating that a one-standard deviation increase in firm-level uncertainty leads to a drop in the mean annual investment rate in the range between 0.38% and 0.96% (see e.g., Alfaro et al., 2024; Liu and Wang, 2021; Panousi and Papanikolaou, 2012; Baum et al., 2008; Leahy and Whited, 1996). Our estimates of the baseline equation (3.1) of -0.0044 suggest that uncertainty reduces the mean investment rate by 0.59%.[14] It remains unclear from the literature whether the estimated average effects imply that all firms decrease the investment rates by the same average amount or a few firms decrease the investment rates by a large amount. From a policy perspective, conducting distributional analysis is important for defining and implementing targeted policies as it identifies firms that are most sensitive to uncertainty shocks.

Figure 3.2: Estimated impact of uncertainty across investment levels



dependent var = inv/ass
impact of $\sigma = -0.0044^{***}$

dependent var = frac(|inv/cap| < 0.01)
impact of $\sigma = 0.005^{***}$

dependent var = frac(inv/cap $\geq$ 0.2)
impact of $\sigma = -0.018^{***}$

Figure 3.2 shows that firms from the right tail of the investment rate distribution (75th and 85th percentiles) decrease the investment rates much more strongly than firms from the left tail (25th and 15th percentiles), implying that the extensive margin decision of whether to invest or not is important to understand the average response of the investment rate. The drop in the positive investment spike rate and the rise in the inaction rate additionally support the importance of the extensive margin investment decision for the average effects of profit volatility.[15] The empirical literature does not distinguish investment responses along intensive and extensive margins.

To determine the importance of the extensive margin (whether to invest) relative to the intensive margin (how much to invest), we perform the following accounting exercise.

[14] In Appendix D we provide a detailed regression analysis of the average investment responses.

[15] The spike rate involves the fraction of firms with an annual investment rate larger than 20%. The inaction rate refers to the fraction of firms with an annual investment rate smaller than 1% in absolute value.

The average investment rate in period t is represented as the weighted average of spike and non-spike investment rates:

$$i_t = \gamma_t \cdot i_t^s + (1 - \gamma_t) \cdot i_t^{ns},$$

where i_t^s and i_t^{ns} is the investment rate conditional on spike and nonspike, respectively; γ_t is the fraction of firms with a positive investment spike. The impact of uncertainty on the average investment rate is[16]

$$\frac{\partial E(i_t)}{\partial \sigma_t} = \underbrace{E(\gamma_t)\frac{\partial E(i_t^s)}{\partial \sigma_t} \; + \; (1 - E(\gamma_t)) \cdot \frac{\partial E(i_t^{ns})}{\partial \sigma_t}}_{\text{intensive margin}} + \underbrace{\frac{\partial E(\gamma_t)}{\partial \sigma_t}\Big(E(i_t^s) - E(i_t^{ns})\Big)}_{\text{extensive margin}}$$

The intensive margin captures how uncertainty affects the *magnitude* of the investment rate within two groups of firms: those with an investment spike and nonspike. The corresponding investment responses are then weighted by the average fraction of firms that belongs to each group of firms. The extensive margin captures how uncertainty affects the *composition* of firms, i.e. the fraction of firms with the spike rate. The uncertainty effects along the extensive margin are adjusted by the investment gap between firms engaging in spike investment and those in non-spike states. In Compustat data, this investment gap is positive and large, indicating that high-investing firms contribute significantly more to overall capital accumulation than other firms in the economy. Overall, we find that the extensive margin component accounts for 45% of the average annual decline in the investment rate.

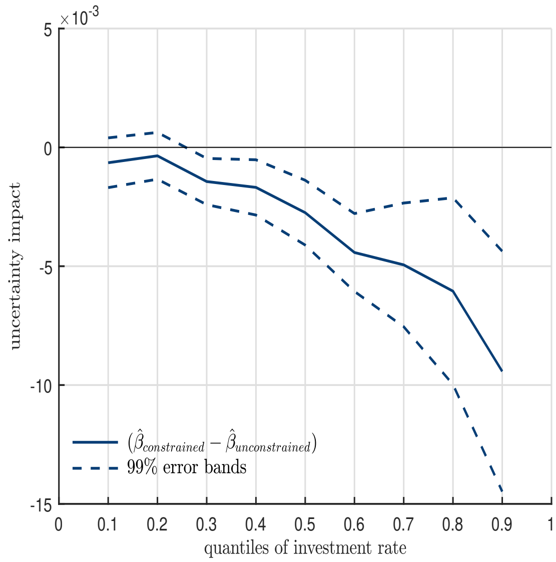
Heterogeneous Impact of Profit Volatility

Our next step is to compute the heterogeneous impact of profit volatility on the investment rates across different groups of firms: constrained and unconstrained. To do so, we perform two steps. First, every year, firms are divided into a *financially* constrained (unconstrained) group on the basis of the exogenous threshold of a dividend-to-profit ratio. If a firm spends less than 20% of its operating profit on dividends, then it is located in the financially constrained group, and vice-versa. Second, within each (un)constrained group, firms are sorted into ten

[16] The decomposition of the extensive and intensive margin components of the uncertainty impact on the average investment rate is provided in Appendix D.

equal-sized groups on the basis of their investment rate. Our results are robust to alternative proxies for financial constraints, including Kaplan-Zingales index, Whited-Wu index, assets, and cash holdings (see Appendix E). A similar procedure is conducted for analyzing real friction. We sort firms with irreversible investment if their capital intensity ratio exceeds a median level of the two-digit NAICS industry.[17]

Figure 3.3: Investment heterogeneity under uncertainty: Impact of financial constraints



Responses within *constrained* firms:

dependent var = frac($|inv/cap| < 0.01$)

impact of $\sigma = 0.0046^{***}$

dependent var = frac($inv/cap \geq 0.2$)

impact of $\sigma = -0.0153^{***}$

Notes: The blue solid line shows the difference between investment responses to uncertainty between constrained and unconstrained firms across different levels of investment. The dashed lines refer to the 99% confidence intervals generated using robust standard errors.

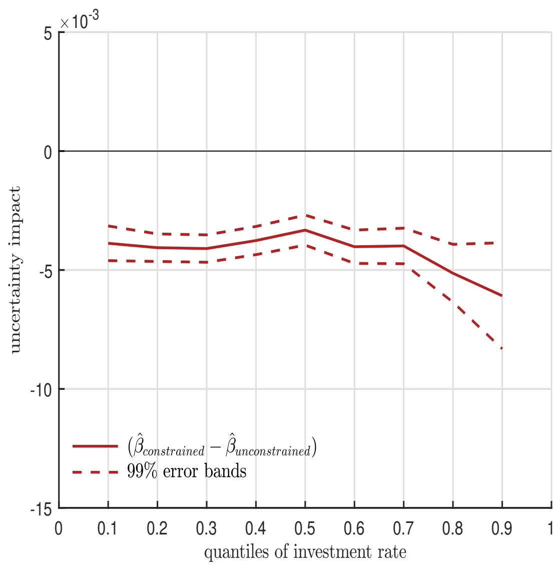
The empirical literature extensively explores the role of frictions on transmitting the effects of uncertainty on the *average* investment rate. Consistent with the literature, Figure 3.3 indicates that, on average, financially constrained firms reduce the investment rate more than unconstrained firms. This difference in average effects between firms is statistically significant. The intuition is that ex-ante financially constrained firms have limited access to external funds, and thus they heavily depend on internal funds to finance their investment. In the fear of running out of internal funds when profit volatility increases, they reduce the investment rate and increase a precautionary demand for cash holdings to limit their exposure

[17] In Appendix A, we consider the low depreciation rate as an alternative measure of investment irreversibility.

to financial losses and avoid costly borrowing. Conversely, unconstrained firms can increase borrowing or decrease dividends to smooth their investments.

The novel evidence from Figure 3.3 shows that financially constrained firms with the high investment rates respond more strongly to uncertainty than other firms in the sample. This is because firms with the high investment rates have more to lose when future profits are lower than expected.[18] A significant drop in the investment spike rate and a rise in zero investment additionally support the significance of the extensive margin investment decision within financially constrained firms for the average investment decline.

Figure 3.4: Real frictions and investment rate distribution



Responses within *constrained* firms:

dependent var = frac($|inv/cap| < 0.01$)

impact of $\sigma = 0.0055^{***}$

dependent var = frac($inv/cap \geq 0.2$)

impact of $\sigma = -0.0038^{***}$

Notes: The red solid line shows the difference between investment responses to uncertainty between capital adjustment constrained and unconstrained firms across different levels of investment. The dashed lines refer to the 99% confidence intervals generated using robust standard errors.

Figure 3.4 indicates that, on average, constrained firms delay irreversible investments or switch to zero investment more than unconstrained firms in order to avoid committing to projects with potentially more costly capital adjustments if profit conditions worsen. The difference in responses is larger at higher quantiles of the investment rate distribution.

[18]The theoretical argument for the stronger impact of the financial friction at higher quantiles of the investment rate distribution is that the costs of cutting investment in terms of foregone returns become lower than the costs of external funds.

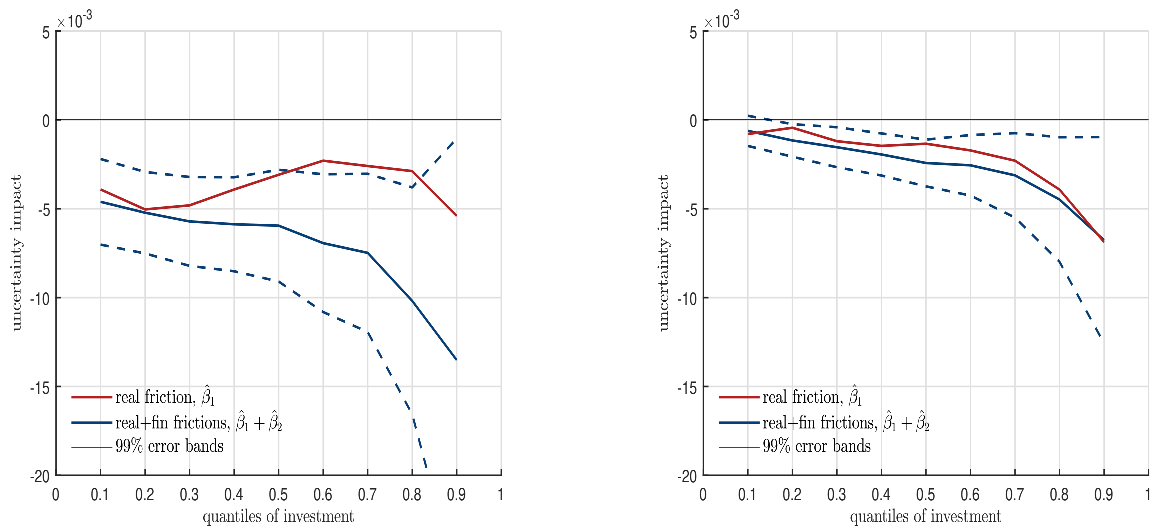
In summary, quantile regression estimates reveal that the influence of both frictions on the investment-uncertainty relationship is stronger at higher levels of investment. While the investment response of constrained firms to increased uncertainty along the extensive margin is mostly driven by financial frictions, real frictions have a stronger effect on the inaction rate. Financial frictions lead to a stronger change in the shape of the investment rate distribution than real frictions.

Interaction Between Financial and Real Frictions

To quantify the impact of the interaction between frictions, we first sort firms into capital adjustment constrained and *un*constrained groups on the basis of the *capital intensity ratio* (real friction) and then estimate the impact of uncertainty on the investment rate conditional on the *dividend constraint* (financial friction):

$$\frac{inv_{i,t}}{ass_{i,t-1}} = \beta_0 + \beta_1 \sigma_{i,t-1} + \Big(\beta_2 \sigma_{i,t-1} + \beta_3\Big) \cdot \mathbb{1}\big(\frac{div_{i,t}}{ear_{i,t}} \leq 0.20\big) + \beta_3' X_{i,t-1} + \gamma_i + \eta_t + \epsilon_{i,t} \quad \text{if } cir \in \{1, 0\}$$

Figure 3.5: Effects of financial and real frictions on the investment-uncertainty relationship



(a) **ir**reversible investment ($cir = 1$)

(b) reversible investment ($cir = 0$)

In Figure 3.5, the interaction between the two frictions shows that the impact of uncertainty on investment remains relatively stronger for firms with irreversible assets. Within capital adjustment constrained firms, our estimates indicate that the financial constraint amplifies the negative impact of profit volatility on irreversible assets. Conversely, this impact is negligible for firms with fully reversible assets. This is because the reversible assets increase the firms' ability to obtain external funds, allowing them to absorb uncertainty shocks.

Constrained firms with high investment rates show significantly stronger investment responses than other firms. Ignoring the interaction between the financial and the real conditions of firms underestimates the true effects of uncertainty. In addition, complementarity between conditions is important for defining a targeted policy, as addressing the negative effects of the financial condition alleviates the negative effects of the real condition.

Robustness Checks and Endogeneity Issues

We perform several robustness checks of our baseline regression results obtained in Figure 3.2 and we obtain quantitatively similar results. For instance, Table 5.5 (part K in the Appendix) explores alternative measures of the investment rate, investment opportunity, and a financial position of a firm. In Table 5.6, we investigate the influence of different time windows of profit volatility. Risky projects with a shorter horizon have stronger negative effects on the investment rate. Additionally, profit volatility is replaced with employment and sales volatility, showing that the latter measures have slightly weaker impacts on the investment rate. In Table 5.7, after controlling for profit levels (the first moment), investment sensitivity to increased profit volatility (the second moment) is more pronounced among firms with high irreversible investment and low dividends. The findings about the investment sensitivity to demand are consistent with Kermani and Ma (2023).

In Appendices B and G, we document that the downward trend in the average investment rate from 1980 to 2018 persists even when considering alternative investment measures. These measures control for the effects of depreciation, inflation, capital stock, and liquidity. Similarly, in Appendix C, we show that the upward trend in profit volatility remains robust after controlling for demographic factors. Finally, the validity of using quantile regression estimates is provided in Appendix E.

The OLS estimation of equation (3.1) may face two potential sources of endogeneity: reverse causality and omitted variables. We consider lagged profit volatility to address reverse causality. Furthermore, the omission of productivity shocks can simultaneously influence both investment and profit volatility. For instance, a positive productivity shock stimulates current capital investment and induces more volatile profit.[19] To mitigate this concern, we instrument our profit volatility variable with its lagged version, allowing us to partial out the effects of shocks.[20] Our IV regression results are presented in Table 5.8 in Appendix K. Investment responses do not change when profit volatility is instrumented with one lagged year, but they become weaker as the lagged years increase. By splitting the sample into constrained and unconstrained groups minimizes potential endogeneity concerns because homogeneous group removes variation in financial or real frictions.

Finally, we estimate the impact of profit volatility on cash holding. The results from Figure 5.14 in Appendix K indicate that when uncertainty about future profits increases, high-investing firms tend to reduce the investment rate and increase cash holdings for a precautionary reason.

4 Model Environment

We develop a dynamic general equilibrium model with heterogeneous firms and a representative household. The model aims to evaluate which frictions explain investment behaviour in the last four decades and to understand the role of interconnecting frictions in investment decisions under uncertainty. We focus on a precautionary motive - a traditional explanation for decreased investment - which would suggest that cash reserves and positive net dividends should increase when uncertainty increases.[21]

Firms make dynamic decisions on capital, net borrowing, net dividends, and static decisions on labor demand to maximize the expected discounted equity value of shareholders. Shareholders own firms and decide on consumption, labor supply and savings to maximize the utility.

[19] Given capital adjustment costs, this effect may persist over time.

[20] Our non-parametric estimates in Appendix F predict that the uncertainty pattern follows a persistent process, supporting the use of lagged firm-specific uncertainty as an instrument for profit uncertainty.

[21] Financial responses of cash reserves and positive net dividends serve as a buffer against the increased probability of negative profit shocks.

4.1 Productivity and Technology

Since firms ex-ante face the same decision problems, we refer to a single firm without the loss of generality. Firms are ex-post heterogeneous once they are hit by an idiosyncratic productivity shock. The next period, firm-level productivity z' is generated by a Markov chain with transition function $\Gamma(z', z)$. We assume that $Pr\{z' = z_j | z = z_i\} = \Gamma_{ij} \geq 0$ and $\sum_j \Gamma_{ij} = 1$ for each $i = 1, \ldots, n_z$. An exogenous shock to productivity is observed by the manager at the beginning of the period and follows a log AR(1) process:

$$lnz' = \rho \cdot lnz + \sigma_\epsilon \cdot \epsilon', \quad \epsilon' \overset{iid}{\sim} \mathcal{N}(0, 1), \tag{4.1}$$

where the productivity shocks ϵ' are independent across firms and are normally distributed with mean zero and standard deviation σ_ϵ. The persistence of idiosyncratic productivity satisfies $\rho \in (0, 1)$. Equation (4.1) indicates that today's volatility σ_ϵ determines the distribution of tomorrow's productivity $z'(\sigma_\epsilon)$. High volatility today induces a more spread distribution of tomorrow's productivity, i.e. firms face a higher probability of both positive and negative productivity levels. Given that the volatility is identical for all firms, an increase in σ_ϵ affects all firms.

Following the realization of idiosyncratic productivity z in each period, firms use predetermined capital stock k and labor rented from a competitive labor market n to produce a homogeneous good y. We assume that $y(k, z) := F(k, n; z) = zk^{\alpha_k} n^{\alpha_n}$, where $0 < \alpha_k + \alpha_n < 1$. Therefore, output is produced using a decreasing return to scale production technology, which implies that there is an upper bound $\bar{k}$ on the optimal level of capital stock. We assume a competitive consumption goods market, and thus the price of consumption goods is the same for all firms and normalized to one. Operating profit function is defined as:

$$\Pi(k, z) := \max_{n \geq 0} \; F(k, n, z) - wn(k, z), \tag{4.2}$$

where w is a wage rate determined by labor market clearing. We assume that there is no aggregate uncertainty. By the law of large numbers, all aggregate quantities, including the risk-free rate, are deterministic over time.

4.2 Frictions

This section incorporates frictions in the model through costly adjustment of capital investment (real frictions) and costly external funds in terms of equity flotation costs and collateral constraints (financial frictions). Empirical evidence shows that decisions on whether to invest in new projects account for 45% of the effects of uncertainty, motivating the use of non-convex capital adjustment costs in the model economy. In addition, tighter financial conditions amplify the negative impact of profit volatility on irreversible assets, motivating the modeling of the interaction between irreversible capital and collateral constraints.

In each period, the firm begins with a pre-determined capital stock k, while a constant fraction δ of capital stock depreciates. Investment in capital is determined by the choice of next-period capital k' as $i(k,k') = k' - (1-\delta)k$. As in Melcangi (2024), Alfaro et al. (2024) and Bloom (2009), the capital stock is partially irreversible and is subject to convex and fixed adjustment costs. The partially irreversible capital stock refers to capital specificity such that for each unit of capital, only $0 \leq \nu < 1$ fraction is useful for other firms. Investment is also more risky as firms will not invest in the current period if it seems likely that they need to disinvest when facing future negative shocks. Additionally, convex capital adjustment costs $\psi > 0$ prevent the firm from a quick response to productivity shocks. Capital partial adjustment costs function with the associated convex part is defined as:

$$AC^{PC}(k,k') = \begin{cases} \frac{\psi}{2} \cdot \frac{(k' - (1-\delta)k)^2}{k}, & k' \geq (1-\delta)k \\ -\nu \cdot i(k,k') + \frac{\psi}{2} \cdot \frac{(k' - (1-\delta)k)^2}{k}, & k' < (1-\delta)k \end{cases} \tag{4.3}$$

When new capital stock is either installed or sold, a fixed fraction $\theta > 0$ of capital is lost. The fixed disruption costs are important to make capital investment lumpy, i.e. the firm changes capital investment only for large productivity shocks. They are scaled by capital such that if the firm produces more, these costs do not outgrow the benefits of increasing production. Capital fixed adjustment costs function is then represented as:

$$AC^{F}(k,k') = \theta \cdot k \cdot \mathbb{1}_{\{k' \neq (1-\delta)k\}} \tag{4.4}$$

The firm can save in cash when $b \leq 0$, generating risk-free taxable interest rate r_f. If $b > 0$, the firm borrows external funds by issuing a one-period (short-term) discount bond. Note that the firm can hold either outstanding debt or save in cash, but it cannot do both. According to the U.S. tax code, a firm pays tax on profits τ_c, and receives tax rebates from economic depreciation and interest payments. Available internal funds are:

$$CF(k, b, z) = \Pi(k, z) - \tau_c \cdot \underbrace{(\Pi(k, z) - \delta k - r_f b)}_{income\ tax\ bill} + (1 - \delta)k - (1 + r_f)b \tag{4.5}$$

Equation (4.5) implies that the firm can increase internal funds (cash flow) through either an expansion of its capital stock or by increasing savings. When cash flows are insufficient to cover investment needs, the firm can cover financial deficit by borrowing external funds from either the credit market $b' > 0$ or the equity market $d < 0$.[22] If cash flows are larger than investment needs (financial surplus), the firm uses the rest of available funds for paying dividends to shareholders $d > 0$. Therefore, the budget constraint is defined as:

$$d = CF(k, b, z) - k' - AC^{PC}(k, k') - AC^{F}(k, k') + b'$$

The ability to borrow is subject to the limited enforceability of debt constraints and equity issuance costs. For the non-defaultable debt to be risk-free, the firm needs to repay its debt to the lender by selling capital in the worst case scenario. Similar to Melcangi (2024), the collateral constraint is defined as:

$$b \leq \eta \cdot (1 - \nu) \cdot k, \quad 0 < \eta < 0$$

where η denotes the pledgeability of capital. The above equation implies that only the undepreciated fraction of capital can be pledged. The lender can sell the seized capital at a lower resale price. Notice that the parameter η is common across firms and is time invariant.

We also assume that equity issuance incurs flotation costs ϕ:

$$\Phi(d) = \begin{cases} \phi \cdot |d|, & d \leq 0 \\ d, & d > 0 \end{cases} \tag{4.6}$$

[22] Debt is tax preferable over equity issue due to tax deductibility of interest payments. Therefore, firms can decrease their taxable income by issuing more debt.

The firm cannot reduce dividends without limits. Otherwise, costless external finance will make the financial problem of the firm negligible. Similarly, without a costly equity market, the firm could easily circumvent the debt market by issuing new equity.

4.3 The Firm Problem

The firm decides on investment in capital k', net borrowing b' and net dividends d in order to maximize the expected present value of the stream of future net dividends to shareholders. Shareholders receive positive net dividends, but also need to pay costs $\Phi(d)$.
The value function is defined as:

$$V(k,b,z) = \max_{\{k',b',d\}} \; d - \Phi(d) + \beta E_{z'|z} V(k',b',z') \tag{4.7}$$

subject to:

$$d = CF(k,b,z) - k' - AC^{PC}(k,k') - AC^{F}(k,k') + b' \tag{4.8}$$

$$b \leq \eta \cdot (1-\nu) \cdot k \tag{4.9}$$

Individual income tax rate is denoted as τ_i, and annual discount factor is $\beta = 1/(1+r_f(1-\tau_i))$. The firm problem is limited upward by $\bar{b}$ for cash holdings, $\bar{k}$ for capital and $\eta(1-\nu)\bar{k}$ for collateral. The continuation firm value is:

$$E_{z'|z} V(k',b',z') = \int_{z'} V(k',b',z') d\Gamma(z',z)$$

Although borrowing is tax preferable to equity issuance, which is observed from $CF(k,b,z)$ in equation (4.5), capital specificity makes borrowing less collateralizable in equation (4.9).

Timing of Events: In each period, a firm begins with a capital stock k, cash holdings $b < 0$, or debt obligations $b > 0$. After observing idiosyncratic productivity shocks, the firm decides on labor, and together with existing capital, produces output and generates revenue. The firm observes current idiosyncratic uncertainty σ_ϵ, and forms expectations about next-period idiosyncratic productivity using the Markov chain. The firm then decides on new capital k' and new debt b', and pays its wage bills and current debt obligations.

4.4 The Household Problem

There is a unit mass of households that chooses consumption, labor supply and investment in firm shares. Households own all firms and receive dividend payments in each period. Since households can perfectly insure against firm-specific uncertainty, their decisions are described by a representative household.

The household utility maximization problem is defined as:

$$\max_{\{C_t,N_t\}} U(C_t, N_t) = \sum_{t=0}^{\infty} \beta^t \left(log(C_t) - h\frac{N_t^2}{2} \right), \tag{4.10}$$

subject to:

$$C_t + \int p_t \chi_{t+1} d\mu_t \ \leq \ (1-\tau_i) w_t N_t + \int (d_t \cdot \mathbb{1}_{\{d_t>0\}} + p_t - p_{t-1}) \chi_{t+1} d\mu_t + T_t, \tag{4.11}$$

where $\beta \in (0, 1)$ is the household's discount factor, C_t is consumption, N_t is labor supply, $h > 0$ denotes the disutility of working. The household buys new shares χ_{t+1} at price p_t and obtains after-tax dividends and capital gains for shares bought at price p_{t-1}. T_t is the lump-sum government transfer, and μ_t is the measure of firms over idiosyncratic states (k_t, b_t, z_t). The equation (4.11) implies that the household's spending on consumption and investment cannot exceed the sum of after-tax labor income and returns from financial assets.

4.5 Government Transfers

The government collects revenue from taxing the labor income of the household and taxing corporate profits, and rebates them back to the household in a lump-sum manner. The budget constraint of the government is

$$T = \tau_i w N + \tau_c \int (\Pi(k, b, z) - \delta k - r_f b)\, \mu(dk, db, dz) \tag{4.12}$$

4.6 Optimal Firm Policies

In this section, we analyze the optimal investment and financial policy of a firm. The value function is not concave and differentiable due to the fixed cost of capital adjustment. However, for simplicity, we assume that $V(\cdot)$ exhibits concavity and differentiability. Optimal policies enable us to explore the precautionary channel: the trade-off between illiquid and partly collateralizable assets (capital) and liquid but unproductive assets (cash and positive net dividends) in the face of the increased uncertainty. This trade-off is largely influenced by the real and financial adjustment costs. Real frictions make returns to capital investment asymmetric, while financial frictions do not allow firms to easily avoid financial constraints.

Optimal Financial Policy

The first-order conditions of the maximization problem (4.7) with respect to b' is:

$$\underbrace{(1-\Phi_{b'}(d))}_{MB_{borrowing}} = \underbrace{\beta \int \Big((1+(1-\tau_c)r_f)\cdot(1-\Phi_{b'}(d')) + \lambda'\Big) d\Gamma(z',z)}_{MC_{borrowing}}, \tag{4.13}$$

where λ is a Lagrange multiplier associated with the constraint (4.9). If $b \leq 0$, there is negative net borrowing, and thus the firm is saving. The left term of (4.13) is the marginal benefit (cost) of an additional unit of debt (saving), while the right term represents the marginal cost (benefit) of debt (saving).

The left term implies that, holding investment policy and productivity fixed, the marginal benefit of debt is higher when additional borrowing is used for reducing costly equity issuance $1+\phi$. The right term represents the marginal cost of paying the debt obligations $1+(1-\tau_c)r_f$ in the next period. Servicing higher next-period debt obligations will reduce cash flow tomorrow, and thus increase a probability of issuing costly equity. On the one hand, if the firm expects to issue new equities in the next period, the cost of additional debt in the current period is higher.[23] On the other hand, higher expected dividends in the next period could be used to pay debt and avoid costly equity issuance, and thus reduce the marginal cost of debt. Notice that firms can also use debt to reduce their corporate income tax bill.

The first order condition with respect to dividends is:

$$\Phi_d(d) = \begin{cases} 1+\phi, & d \leq 0 \\ 1, & d > 0 \end{cases} \tag{4.14}$$

[23] If the firm expects positive productivity shocks tomorrow, accumulating liquid assets (higher negative net borrowing) in the current period enables the firm to finance future investment opportunities without tapping into the costly equity market.

The marginal value of cash flow to shareholders is one plus equity costs in face of negative net dividends or one for positive net dividends.

Optimal Investment Policy

The first order condition of the maximization problem (4.7) with respect to k' is:

$$\frac{1}{1+r_f(1-\tau_i)} \cdot \int \Big((1-\Phi_{k'}(d')) \cdot (CF_{k'}(k',b',z') - AC^{PC}_{k'}(k',k'') - AC^{F}_{k'}(k',k'',z')) + \lambda' \cdot \eta \cdot (1-\nu) \cdot (1-\delta)\Big) d\Gamma(z',z) = (1-\Phi_{k'}(d)) \cdot \Big(AC^{PC}_{k'}(k,k') + AC^{F}_{k'}(k,k',z)\Big) \tag{4.15}$$

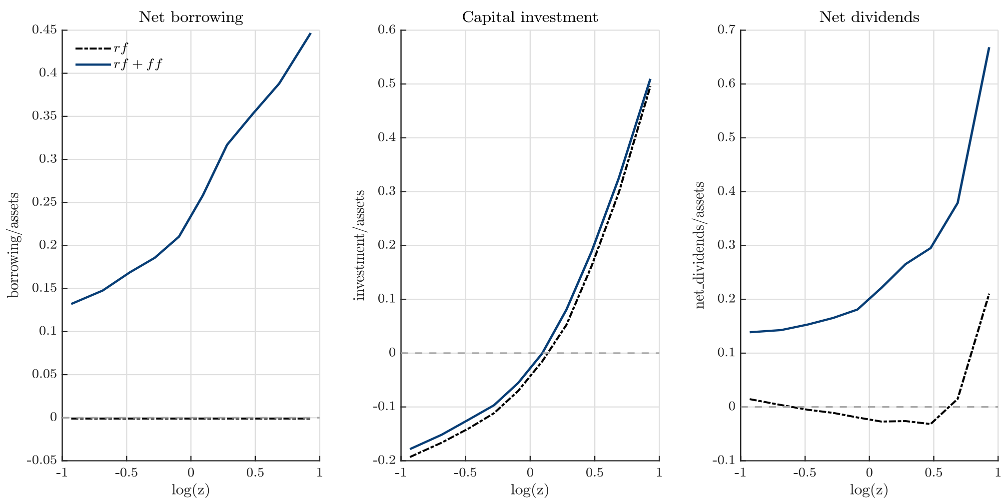
The left-hand side of equation (4.15) represents the marginal benefit of investing in an additional unit of capital MB_k, while the right-hand side is the marginal cost of capital investment MC_k. Holding productivity fixed, the left term indicates that an additional unit of next-period capital increases future internal funds $CF_{k'}$ net of capital adjustment costs and relaxes the collateral constraint. The right term implies that investing in current capital stock either reduces current dividends or increases equity issuance. Notice that real frictions, characterized by partial and fixed capital adjustment costs ($AC^{PC}_{k'}(\cdot)$, $AC^{F}_{k'}(\cdot)$, ν), diminish the liquidity and collateral values of capital, *ceteris paribus*.

The primary role of partial capital adjustment costs is to make the marginal product of capital a concave function in productivity. Although both good and bad states of the productivity shocks are equally likely, firms are more sensitive to adverse outcomes. On the one hand, a high productivity shock increases MB_K primarily through $CF_{k'}$, stimulating firms to increase current investment in capital that limits the rise in MB_K. On the other hand, following a low productivity shock, $AC^{PC}_{k'}$ limits the decline in MB_K when selling capital. Hence, the increased profit volatility leads to a decrease in capital investment.[24] Moreover, with the fixed capital adjustment costs, firms tend to remain investment inactive and (dis)invest only for large enough shocks. Therefore, firms need to incorporate the possibility that a negative shock requires the sale of capital at a lower value and triggers the fixed adjustment cost.

[24] The relevance of capital irreversibility for determining profit volatility's impact is contingent upon the presence of an intertemporal trade-off between current and future capital investment. In our model, this assumption is justified by a DRTS technology.

The impact of increased firm-specific uncertainty on investment is ambiguous analytically when we consider the combination of financial and real frictions. This is because financial frictions directly increase the difficulties of financing capital expenditure through interest rates for loans, collateral constraint, and equity issuing costs. It becomes more difficult for firms to finance the costs of investment inaction such as wage bills, capital depreciation, and foregone returns.

Figure 4.1: Policy functions in initial steady state



Notes: All policy functions are shown for different log levels of productivity shocks and median levels of capital stock and savings. Total assets include capital stock and cash holdings. Negative investment indicates that depreciation erodes the existing capital stock.

Figure 4.1 depicts decision rules in the initial steady state for the average firm with net borrowing, capital investment and net dividends (dividends minus equity issuance) at various levels of productivity. Holding uncertainty about future profit constant, we examine two cases: one with only real frictions and another with both real and financial frictions. Considering real frictions, firms with low productivity have low capital liquidity, which limits their capacity to generate sufficient internal funds. Consequently, these firms respond by issuing new equity (negative net dividends) and reducing capital investment. High-productivity firms can afford to pay dividends to shareholders. When financial frictions ($\phi > 0,\ \eta > 0$) are added to real frictions, firms substitute equity financing with borrowing due to the tax benefits and increase capital investment.

4.7 Stationary Equilibrium

A Stationary Recursive Competitive Equilibrium (SRCE) is a set of quantities $\{C, N, k', b', d, n\}$, prices $\{p, w, r\}$, life utility and value functions $\{U, V\}$, cross-sectional distribution of firms over state $\mu(k, b, z)$, and capital adjustment costs $\{AC^F, AC^P\}$ such that:

- Given w^*, $V(k, b, z; w^*)$, $k'(k, b, z; w^*)$, $b'(k, b, z; w^*)$, $d(k, b, z; w^*)$, $n(k, b, z; w^*)$ solve the firm's problem.
- Given w^*, $U(C, N)$, C and N solve the household's problem.
- The stationary distribution is $\mu^*(k, b, z; w^*)$.
- The labor market clears: $\bar{N} = \int n(k, b, z; w^*)d\mu(k, b, z; w^*)$.
- The equity market: χ'=1.
- The goods market clears: $Y(\mu^*; w^*) = C(\mu^*; w^*)+I(\mu^*; w^*)+AC^F(\mu^*; w^*)+AC^P(\mu^*; w^*)$.

We exclude financial adjustment costs from the goods market clearing conditions as they do not represent real costs. The costs related to issuing new equities (ϕ) is attributed to households. A general equilibrium setting allows wages to adjust such that the impact of the uncertainty becomes weaker compared to a partial equilibrium model.

4.8 Quantitative Analysis

In this section, we calibrate the model to rationalize investment responses to increased uncertainty and study their implied financial implications. As the model does not have an analytical solution, we solve it numerically. For that purpose, we use value function iteration on a discrete grid with interpolation.

4.8.1 Calibration

There are two groups of parameters. The first group of outside parameters is either set according to the literature or has a data counterpart. The second set of inside parameters is estimated using the simulated method of moments, minimizing the weighted sum of squared differences between model-generated and observed data moments. To evaluate the impact of the increased uncertainty and frictions on the investment rate over time, we divide the sample into two periods. The first period corresponds to the 1980-1998 period (early period) in which the model is estimated in a steady state by matching moments from Compustat data for publicly-listed U.S. firms. For the 1999-2018 period (late period), we re-estimate the same parameters using moments specific to this period.

The group of outside parameters for the early and late periods are reported in Table 4.1. We follow Hennessy and Whited (2005) in setting corporate and individual income tax rates.[25] The key variable of interest is firm-level profit volatility, σ_ϵ.[26] We construct the firm-specific volatility as the estimated residual from the regression of operating profit on capital, controlling for time fixed effects.[27] The estimated values of σ_ϵ amount to 0.1915 (early period) and 0.2038 (late period). These estimates are within the range used in the literature: 0.116 in Melcangi (2024) and 0.209 in Alfaro et al. (2024). The capital depreciation rate is set to 0.069 as in Zhao (2020) because the measure of capital depreciation in Compustat data is too high. Finally, the annual risk-free interest rate is fixed at 4%, which is a common assumption in the literature. Firms' annual discount factor is set at 0.973 to ensure that cash holdings of some firms do not completely absorb the financial constraints.

The remaining six parameters are jointly estimated using the simulated method of moments:

$$\gamma = \{\psi,\ h,\ \nu,\ \theta,\ \phi,\ \eta\} \tag{4.16}$$

All parameters from (4.16) jointly affect various model moments. Still, some parameters have a larger impact on a specific moment. Estimated parameters with targets for the early period (1980-1998) and the late period (1999-2018) are reported in Table 4.2. The mean and standard deviations are cross-sectional. Overall, the model can reproduce the key features of the data.

[25]Production input parameters, persistence of productivity process and uncertainty are directly estimated to avoid making the program too slow when looping in estimation routine.

[26]The productivity AR(1) process in (4.1) is discretized by Tauchen and Hussey (1991). This method generates a grid of 10 points and a Markov transition matrix.

[27]Fixed effects in our simple regression capture changes in aggregate productivity, inflation, etc.

Table 4.1: Outside parameters

Parameters	Description	$Value^e$	$Value^l$	Source
τ_c	Corporate profit tax rate	0.460	0.460	Hennessy and Whited (2005)
τ_i	Income tax rate	0.296	0.296	Hennessy and Whited (2005)
α_k	Capital share in production	0.326	0.326	Compustat data
α_n	Labor share in production	0.650	0.650	Compustat data
ρ	Persistence of log productivity	**0.774**	**0.792**	Compustat data
σ_ϵ	Std. dev. of innov to log prod	**0.191**	**0.208**	Compustat data
δ	Capital depreciation rate	0.069	0.069	Zhao (2020)
r_f	Risk-free interest rate	0.040	0.040	Typical
β	Annual discount factor	0.973	0.973	$1/(1 + r_f(1 - \tau_i))$

Notes: Columns 3 and 4, denoted as $Value^e$ and $Value^l$, refer to the parameter values for the early period (1980-1998) and late period (1999-2018), respectively.

Convex capital adjustment costs is disciplined by matching the standard deviation of the annual investment-capital ratio, directly having an effect on the intensive margin of investment.[28] The observed volatility of the investment rate decreases from 0.114 to 0.091 between 1980 and 2018. The estimated ψ increases from 2.013 to 2.340 to match this trend. The frequency of positive investment spikes is informative about the fixed costs of capital adjustment as a higher θ stimulates firms to make fewer and larger investments.[29] In 1980, 19.5% of firms had lumpy investment, while this significantly reduced to 12.3% in 2018. The estimated θ increased from 5.9% to 6.2% between 1980 and 2018 to reflect this trend. The partial irreversibility ν is disciplined by the fraction of investment inaction. Firms tend to remain investment inactive for a longer period, increasing this moment from 1.31% in 1980 to 2.09% in 2018. We estimate ν around 2%, which is in the range of 1% from Ayres and Raveendranathan (2023) and 34% from Alfaro et al. (2024) and Melcangi (2024).

As for the collateral constraint, we target the average cash-assets ratio between periods. This moment is informative about a tendency of firms to accumulate cash in the face of increased uncertainty as access to external financing is limited and costly. An additional

[28]Larger investment in machines and equipment induces larger planning and evaluation costs.

[29]Fixed costs can be observed as technological constraints as firms face production disruptions when installing new capital, regardless of how much new capital is bought.

problem for firms is the partial adjustment costs as more irreversible assets reduce the collateral value of capital. The estimated drop in η parameter indicates that cash holdings experienced a significant rise from 6.1% to 10.8%. Next, the average equity-capital ratio is informative about the equity flotation cost ϕ. Our model is limited to match the observed rise in equity financing. The preferences for leisure h is identified by the equilibrium labor supply of 0.3, which corresponds to the average fraction of time spent on the labor market.

Table 4.2: Estimated parameters and targeted moments

	early (1980-1998)		late (1999-2018)					
Targeted Moments	Model	Data	Model	Data	Parameter	Description	early	late
std(inv/cap)	0.127	0.114	0.110	0.091	ψ	Convex capital adj costs	2.013	2.340
frac(inv/cap≥0.20)	0.184	0.195	0.105	0.123	θ	Fixed capital adj costs	0.059	0.062
frac(|inv/cap|<0.01)	0.029	0.013	0.046	0.021	ν	Partial capital adj costs	0.022	0.024
mean(cash/ass)	0.090	0.107	0.135	0.168	η	Collateral constraint	0.322	0.251
mean(equity/cap)	0.057	0.061	0.052	0.108	ϕ	Equity costs	0.390	0.415
labor share	0.314	0.300	0.282	0.300	h	Leisure preference	6.559	7.018

Notes: Total assets involves capital stock and cash holdings. The parameters are separately estimated for the early and late period. We use Compustat data for the analysis.

4.8.2 Model Fit

We evaluate the validity of the model by comparing the model-generated moments with nontargeted data moments. In Table 4.3, we show that while the model explains about one-third of the observed reduction of the investment rate in the data, it is much more successful in matching financial patterns.

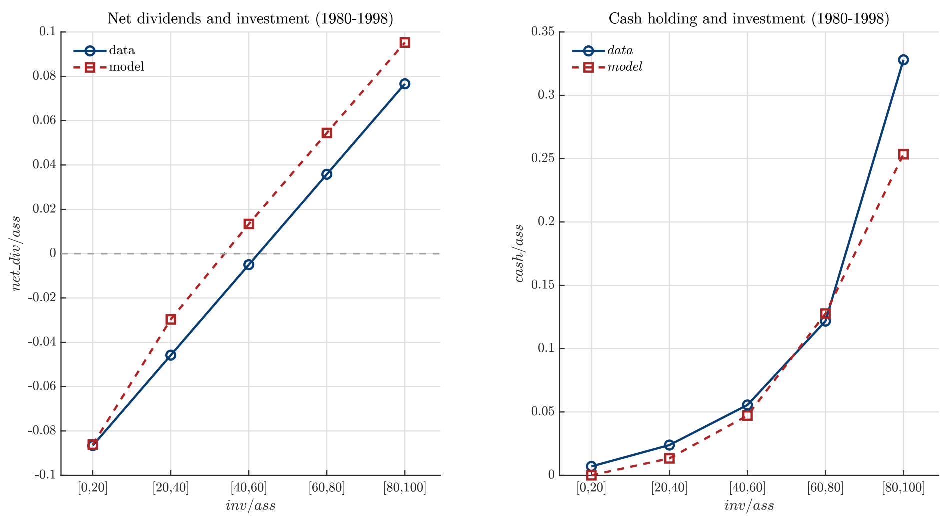
Figure 4.2 and Figure 4.3 show that the model is successful in matching the non-targeted net dividends and cash holdings through the 1980-2018 period. First, the figures suggest that firms with a greater investment in capital tend to generate higher internal funds, which can be used for higher positive net dividends and cash holdings. These financial metrics serve as a buffer against increased idiosyncratic uncertainty about future profits. Second, firms in the lowest investment bins face financial constraints, resulting in negative net dividends. A good model fit with data supports the reliability of using the model in determining the role of frictions in propagating the financial effects of uncertainty shocks.

Table 4.3: Model fit: Model vs. Data

	early (1980-1998)		late (1999-2018)	
Nontargeted Moments	Model	Data	Model	Data
mean(inv/cap)	0.131	0.138	0.124	0.110
mean(inv/ass)	0.123	0.081	0.109	0.053
mean(netdiv/ass)	0.100	0.110	0.149	0.181
std(inv/ass)	0.125	0.075	0.105	0.060
std(cash/ass)	0.104	0.134	0.111	0.184

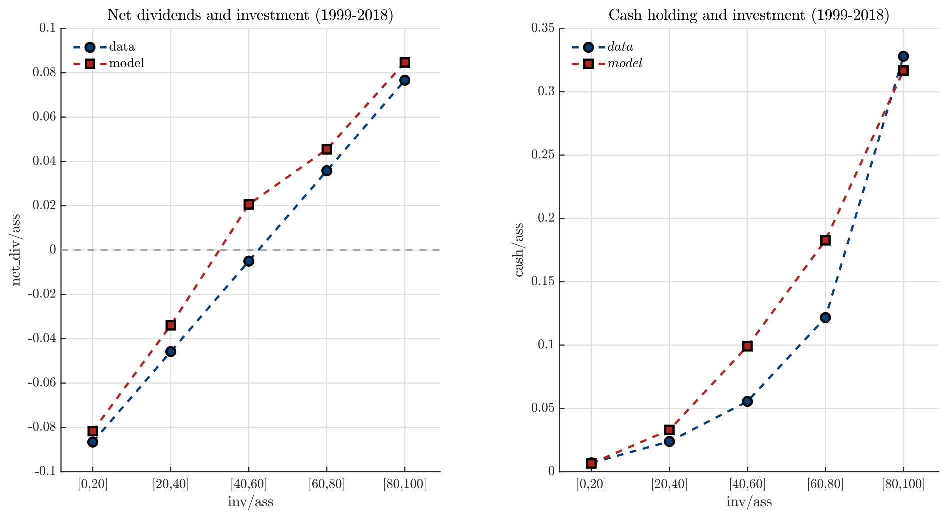
Notes: Total assets involves capital stock and cash holdings. Net dividends equals dividends minus equity issuance and plus cash holdings. The parameters are separately estimated for the early and late period. We use Compustat data for the analysis.

Figure 4.2: Net dividends and cash holdings vs. investment (early period)



Notes: Figure 4.2 displays net dividends and net borrowing across five bins for the 1980-1998 period. The first bin contains firms with investment-asset ratio below the 20th percentile, and the last bin includes firms above the 80th percentile. In data, net dividends are computed as total dividends minus equity issuance plus share repurchases, and then normalized by total assets.

Figure 4.3: Net dividends and cash holdings vs. investment (late period)



Notes: Figure 4.3 displays cash holdings across five bins of the investment rate for the 1999-2018 period. The first bin contains firms with investment-asset ratio below the 20th percentile, and the last bin includes firms above the 80th percentile.

4.8.3 Quantitative Results

In this section, we conduct several counterfactual experiments to evaluate the quantitative importance of uncertainty and frictions in explaining the downward trend in investment between 1980 and 2018, and to examine the roles of frictions in amplification and propagation of shocks on financial variables.

The Impact of Uncertainty

In our accounting exercise, we start by increasing volatility in firm-level profitability from the estimated value of 0.1915 to 0.2085, while all other model parameters are fixed at their initial values. This simple experiment can exogenously quantify the contribution of uncertainty. Table 4.4 shows that the model matches the trends in investment and precautionary savings observed in data. Specifically, the increased uncertainty accounts for around 6% of the decrease in the investment rate. This evidence is consistent with our empirical observation in Section 3.3.

In Table 4.4, we observe that, following the increased uncertainty about future profitability, fewer firms choose large investment and more firms make negligible or zero

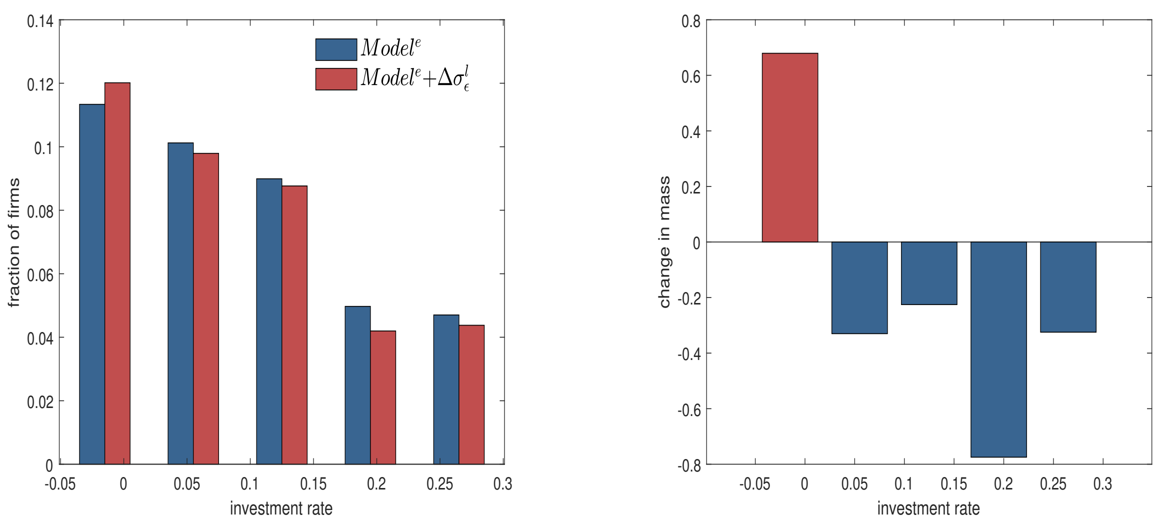
Table 4.4: The impact of uncertainty, 1980-2018

Statistics	$Model^e$	$Model^e$+$\Delta\sigma_\epsilon^l$
mean(inv/ass)	0.1229	0.1204
frac(inv/cap>0.20)	0.1843	0.1822
frac(|inv/cap|<0.01)	0.0291	0.0348
mean(cash/ass)	0.0897	0.1001
mean(netdiv/ass)	0.0999	0.1085

Notes: $Model^e$ is the model estimated for the early period 1980-1998, while $\Delta\sigma_\epsilon^l$ takes the uncertainty value from the late period 1999-2018. We keep all other parameters at their initial values from the early period.

investment. Figure 4.4 shows the effects of uncertainty shocks on the distribution of the investment rates, suggesting that firms indeed tend to avoid large capital commitments and remain inactive to keep their financial flexibility. We also decompose the effects of uncertainty on the investment rate into the extensive and intensive margins. Consistent with the empirical evidence in Section 3.3, our model predicts that the extensive margin accounts for 37% of the changes in the annual investment rate.

Figure 4.4: Profit volatility and the distribution of investment rates



(a) investment rate distribution

(b) change in distribution

The Impact of Frictions

Next, we separately consider the effect of frictions. In Table 4.5, real friction parameters take values from the late 1999-2018 period, whereby all other parameters are held fixed at their initial values from the early period. While the fixed capital adjustment costs are the common factor in the literature to explain the spike rate, our model shows that the increased fixed costs also generate the counterfactual prediction that the inaction rate should decrease. We reconcile this prediction through higher convex capital adjustment costs. The fixed costs also largely explain the rise in cash holdings and net dividend payments. The direct effects of irreversible capital costs in the model are negligible.

Table 4.5: Decomposition of *real* frictions, 1980-2018

Statistics	$Model^e$	$Model^e$ $+\Delta\nu^l$	$Model^e$ $+\Delta\theta^l$	$Model^e$ $+\Delta\psi^l$	$Model^e$ $+\Delta(\nu^l,\theta^l,\psi^l)$	$Model^l$	$Data^e$	$Data^l$
mean(inv/ass)	0.1229	0.1230	0.1134	0.1116	0.1115	0.1087	0.0806	0.0527
frac(inv/cap>0.20)	0.1843	0.1840	0.0989	0.0980	0.0978	0.1051	0.1954	0.1229
frac(|inv/cap|<0.01)	0.0291	0.0287	0.0184	0.0379	0.0381	0.0462	0.0131	0.0209
mean(cash/ass)	0.0897	0.0897	0.1199	0.1090	0.1094	0.1353	0.1072	0.1679
mean(netdiv/ass)	0.0999	0.1004	0.1387	0.1294	0.1315	0.1492	0.1098	0.1806

Notes: $Data^e$ contains values of statistics for the early period (1980-1998), while $Data^l$ is related to the late period (1999-2018). Parameters ν, θ and ψ are related to partial irreversibility costs, fixed and convex capital adjustment costs, respectively.

In Table 4.6, we observe that either a tighter collateral constraint or an increase in equity costs reduces the investment rate. Our findings indicate that financial frictions have an impact on the investment rate equal to that of the combined real frictions. However, investment responses to increased uncertainty at the extensive margin (the spike rate) are slightly better explained by financial frictions, while real frictions account for the increase in the inaction rate. Finally, Table 4.7 shows the role of the irreversible costs in the collateral constraint. It amplifies the impact of uncertainty on investment inaction, cash reserves and positive net dividends due to reduced collateral value of capital. This response is consistent with a precautionary savings channel. The investment inaction rate increases by 20%.

Table 4.6: Decomposition of *financial* frictions, 1980-2018

Statistics	$Model^e$	$Model^e$ $+\Delta\phi^l$	$Model^e$ $+\Delta\eta^l$	$Model^e$ $+\Delta(\phi^l,\eta^l)$	$Model^l$	$Data^e$	$Data^l$
mean(inv/ass)	0.1229	0.1132	0.1128	0.1115	0.1087	0.0806	0.0527
frac(inv/cap>0.20)	0.1843	0.0993	0.0987	0.0998	0.1051	0.1954	0.1229
frac(|inv/cap|<0.01)	0.0291	0.0186	0.0209	0.0200	0.0462	0.0131	0.0209
mean(cash/ass)	0.0897	0.1227	0.1250	0.1327	0.1353	0.1072	0.1679
mean(netdiv/ass)	0.0999	0.1402	0.1430	0.1514	0.1492	0.1098	0.1806

Notes: $Data^e$ contains values of statistics for the early (1980-1998) period, while $Data^l$ is related to the late (1999-2018) period. Parameters ϕ and η are related to equity flotation costs and collateral constraint, respectively.

Table 4.7: Role of irreversibility costs in the collateral constraint

Statistics	$Model^e$	$Model^e$ $+\nu^e=0$	$Model^l$ $+\nu^l=0$	$Model^l$
mean(inv/ass)	0.1229	0.1267	0.1160	0.1087
frac(inv/cap>0.20)	0.1843	0.1839	0.1046	0.1051
frac(|inv/cap|<0.01)	0.0291	0.0323	0.0450	0.0462
mean(cash/ass)	0.0897	0.0883	0.1256	0.1353
mean(netdiv/ass)	0.0999	0.0985	0.1389	0.1492

Notes: $Data^e$ contains values of statistics for the early (1980-1998) period, while $Data^l$ is related to the late (1999-2018) period. Parameters ν^e and ν^e are related to irreversibility costs in the collateral constraint for the early and late periods, respectively.

5 Conclusion

This paper explores a negative relationship between firm-level uncertainty about future profit and fixed capital investment. Using Compustat data, we focus on U.S. public firms over the past four decades. Two main takeaways of this paper suggest that (1) the distributional analysis of uncertainty is important to understand investment responses in an uncertain environment, and (2) interconnecting frictions is important for capturing spillover effects between frictions.

In a quantile regression model, we find that high-investing firms cut their investment rate more than other firms in the economy. This implies that the decision of whether to invest in a new project is as important as the decision of how much to invest. Two statistics, including the drop in the positive investment spike and the rise in the inaction rate, support the importance of the extensive margin effects of uncertainty. We also document that the effect of increased volatility on irreversible investment decreases in the presence of financial constraint. Next, we develop and calibrate a heterogeneous-firm model to explore the financial implications of the negative investment-uncertainty relationship. A comprehensive capital cost structure helps to capture an increased fraction of firms that have small or zero investment, while costly external funds can help to account for a decreased fraction of firms with lumpy (large, one-time) investment. In anticipation of future profit shocks, firms reduce capital investment and increase demand for cash holdings. Incorporating irreversible capital into the collateral constraint reduces firms' debt capacity, amplifying the positive responses of the investment inaction rate, cash holdings, and net dividends to increased uncertainty.

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Appendix

A: Variable Construction

This section describes the firm-specific and aggregate variables used in our empirical analysis. The construction of variables follows the literature (see, e.g., Ottonello and Winberry, 2020; Almeida and Campello, 2007), and is based on annual firm-level (Compustat) data and industry-level (NIPA, FFA) data. Compustat satisfies important requirements of our study: it contains a long panel, which allows us to exploit within-firm variation; it has rich balanced information.[30] The regression sample covers the period from 1980 to 2018 for all publicly-traded firms. The beginning of the sample period is chosen mostly to be comparable with the literature.

Firm-level Variables, Based on Public Firms from Compustat Annual Data

1. Investment. We incorporate four measures of the investment rate to facilitate comparison with previous studies. Our main dependent variable is the nominal investment rate. First, the benchmark investment rate is defined as gross capital expenditure (`capx`, item 128) to the lagged book value of total assets (`at`, item 6). Capital expenditure involves investment in tangible capital stock, including property, plant and equipment (`PPE`). For the panel data analysis, we normalize investment by lagged total assets in order to absorb large firm-level heterogeneity present in the data. Differences in firm size may cause heteroskedasticity in investment. This ratio is a common practice in microeconometric studies. The model counterpart of the investment rate is

$$inv\ rate = \frac{i_t}{k_t + \mathbb{1}_{(b_t<0)} b_t},$$

where total assets involves capital stock k_t and cash holdings $\mathbb{1}_{(b_t<0)} b_t$.

Second, we follow the approach by Ottonello and Winberry (2020) to define capital investment as $\Delta log(k_{i,t+1})$, where $k_{i,t+1}$ is the tangible capital stock of firm i at the end of year t. The first value of $k_{i,t+1}$ is set to a level of the gross property, plant and

[30] For detailed instructions on accessing Compustat data via the Wharton Research Data Services (WRDS), please refer to our `stata` code.

equipment (`ppegt`, item 7) for each firm and year in which this value appers. Afterwards, the dynamics of $k_{i,t+1}$ are computed using the net property, plant and equipment (`ppent`, item 8). A linear interpolation is used to deal with missing observations of `ppent`. The interpolation is not used if two or more consecutive observations are missing. Gross capital investment is then adjusted by the depreciation rate to derive net investment. Annual depreciation rates for industries are computed as the depreciation-to-stock ratio. BEA, Fixed Asset Table contains information on stock, investment and depreciation. Stock variable includes equipment, structure and intellectual property. Depreciation rates are disaggregated at the 2-digit (1997 NAICS) industry level. In the model, the net investment rate is

$$net\ inv\ rate = \frac{i_t - \delta_t k_t}{k_t + \mathbb{1}_{(b_t<0)} b_t},$$

where δ_t denotes the depreciation rate.

Third, we consider the capital expend property, plant and equipment (`capxv`, item 30) normalized by the lagged book value of total assets as a measure of the investment rate.

Fourth, investment is measured as the ratio of current capital expenditures `capx` scaled by lagged `ppent`, as in Almeida and Campello (2007).

2. Firm-level uncertainty. The uncertainty measure is defined as the rolling standard deviation of the firm-level growth rate of earnings (`oibdp`, item 13):

$$\sigma_{i,t} = \left[\frac{1}{5}\sum_{\tau=-4}^{0}(\lambda_{i,t+\tau} - \bar{\lambda}_{i,t})^2\right]^{1/2},$$

where we define earnings growth as in Alfaro et al. (2024):

$$\lambda_{i,t} = \frac{2\cdot(\texttt{oibdp}_{i,t} - \texttt{oibdp}_{i,t-1})}{\texttt{oibdp}_{i,t} + \texttt{oibdp}_{i,t-1}},$$

and the moving average growth rate of earnings between year $t-4$ and year t for a firm i is defined as

$$\bar{\lambda}_{i,t} = \frac{1}{5}\sum_{\tau=-4}^{\tau=0}\lambda_{i,t+\tau}$$

An annual average of earnings volatility across all firms in the sample is used as an aggregate measure of firm volatility in a given year:

$$\sigma_t = \frac{1}{N_t}\sum_{i=1}^{N_t}\sigma_{i,t}$$

To further validate the observed the upward trend in firm-level volatility observed in data, we also consider the standard deviation of sales (`sale`, item 12) and employment (`emp`, item 29). We move our sample back up to 1976 to construct a backward-looking measure of uncertainty for our starting year 1980. Specifically, the standard deviation of the profit growth rate over the 1976-1980 period is used as the observation on profit volatility for year 1980. We create an uncertainty measure over five-year overlapping periods, spanning from 1976-1980, 1977-1981, ..., to 2014-2018.

3. Tobin's Q is measured as the ratio of the lagged ex-dividend market value of equity to the lagged book value of liabilities (`ceq`, item 60). The market value of equity is the product of the total number of common equity outstanding (`csho`, item 25) and the closing equity price at the end of the fiscal year (`prccf`, item 199):

$$Q = \frac{\texttt{csho} \cdot \texttt{prccf}}{\texttt{ceq}}$$

The above formulation of Tobin's Q is common in the literature (see, e.g., Gourio and Miao, 2010). The average Tobin's Q for physical capital serves as a proxy for the marginal product of capital, providing insights into future firm-level investment opportunities. Given the importance of investment opportunity in our analysis, we also explore an alternative measure of Tobin's Q. Following Almeida and Campello (2007). Tobin's Q is computed as

$$Q = \frac{\texttt{csho} \cdot \texttt{prcc} + \texttt{at} - \texttt{ceq} - \texttt{txdb}}{\texttt{at}},$$

where `txdb` refers to deferred taxes (item 74), the book value of equity is the sum of `ceq` and `txdb`, and close price (`prcc`, item 24).

4. Sales variable is computed as the ratio of lagged sales (`sale`, item 12) to lagged total assets. It serves as an additional measure of firm-level opportunity, which is needed to address concerns about measurement error in Tobin's Q.

5. Cash holdings (liquidity) are calculated as the sum of lagged cash and short-term investment (`che`, item 1), normalized by lagged total assets. Cash is the sum of

currency, deposits and cash equivalents (commercial paper that is near maturity). Short-term investments is the sum of trading, held-to-maturity and available-for-sale securities that will be sold within one year. The model counterpart of liquidity is $\mathbb{1}_{(b_t<0)}b_t$.

6. Firm size is measured as the log of lagged total assets.

7. Firm age is the number of years since a firm enters the sample. We take the log of lagged firm age.

8. Earnings are computed as the first lag of operating income before depreciation (`oibdp`, item 13) divided by the second lag of total assets. Operating income is also used as a measure of the marginal product of capital. The variable `oibdp` is obtained as sales minus operating costs. Operating costs consist of the cost of goods sold (`cogs`, item 41) and selling, general and administrative expense (`xsga`, item 189). In the literature, earnings refers to (a) earnings before interest, taxes, depreciation and amortization (*EBITDA*), and (b) earnings before interest and taxes (*EBIT*). In the model, operating surplus is
$$EBITDA = \frac{\Pi_t}{k_t + \mathbb{1}_{(b_t<0)}b_t}.$$

9. Operating cash-flow (surplus) is measured as the first lag of operating income before depreciation (`oibdp`, item 13) minus lagged interest expenses (`xint`, item 15) and minus lagged income taxes (`txt`, item 16), all divided by the second lag of total assets:
$$CF = \frac{\texttt{oibdp} - \texttt{xint} - \texttt{txt}}{\texttt{at}}.$$
The numerator of this metric is equivalent to the sum of income before extraordinary items (`ib`, item 18) and depreciation and amortization (`dp`, item 14). The model counterpart of operating surplus is
$$CF = \frac{y_t - w_t n_t - \tau_t^{income}}{k_t + \mathbb{1}_{(b_t<0)}b_t}.$$

10. Dividends are measured as the sum of preferred dividends (`dvp`, item 19) and common dividends (`dvc`, item 21).

11. Equity repurchases are defined as purchase of common and preferred stock (`prstkc`, item 115).

12. Equity issuance is defined as sale of common and preferred stocks (`sstk`, item 108).

13. Book leverage is measured as

$$lev^b = \frac{\texttt{dltt} + \texttt{dlc}}{\texttt{dltt} + \texttt{dlc} + \texttt{ceq}},$$

where long-term debt refers to `dltt` (item 9), while debt in current liabilities is `dlc` (item 34).

14. Market leverage is measured as

$$lev^m = \frac{\texttt{dltt} + \texttt{dlc}}{\texttt{dltt} + \texttt{dlc} + \texttt{mkt}}.$$

15. Net leverage is measured as

$$lev^n = \frac{\texttt{dltt} + \texttt{dlc} - \texttt{che}}{\texttt{dltt} + \texttt{dlc} + \texttt{ceq}}.$$

Investment-to-earnings ratio is defined as

$$\frac{gross\ inv}{gross\ CF} = \frac{\texttt{capx}}{\texttt{oibdp} - \texttt{xint} - \texttt{xtxt}}, \text{ and}$$

$$\frac{net\ inv}{net\ CF} = \frac{\texttt{capx} - \delta \cdot \texttt{ppegt}}{\texttt{oibdp} - \texttt{xint} - \texttt{xtxt} - \delta \cdot \texttt{ppegt}}.$$

Sample Selection for Firm-level Variables

1. Sector criterion. We exclude firms from the following sectors: finance, insurance and real estate ($\texttt{sic} \in [6000, 6999]$), utility ($\texttt{sic} \in [4900, 4949]$). Since these sectors face additional government regulations, they may have different investment behaviour than that of non-excluded firms. For instance, decisions of financial firms are affected by capital adequacy regulations that are irrelevant for nonfinancial public firms.

2. Firm-origin criterion. We consider firms incorporated in the United States (`fic=="USA"`).

3. We drop firm-year observations that satisfy one of the following criteria:
   (a) Negative and missing value of capital, total assets, sales, stock price, outstanding common shares, book value of shares;
   (b) Observations with gross capital less than $5 million and total assets less than $1 million in order to avoid rounding errors;
   (c) Acquisitions (`aqc`, item 129) larger than 5% of total assets;
   (d) Less than a 5-year old firm since the firm entered the sample;
   (e) Growth rate of real sales beyond -1 and 1.

Transformation of Firm-level Variables

1. Deflated using the BLS implicit price deflator;
2. Winsorized using the fifth and ninety-fifth percentiles as thresholds in order to reduce the impact of outliers. Following Crouzet and Eberly (2019), we control for missing observation before winsorization.

Aggregate-level Variables

Aggregate data for the US economy is obtained from the FFA accounts and NIPA through FRED. We consider the following variables: aggregate investment is defined as private nonresidential fixed investment (`PNFI`); implicit price deflator (`A008RD3Q086SBEA`); real gross domestic product (`GDPC1`); unemployment rate (`UNRATE`); implicit price deflator for all employed persons (`IPDNBS`); consumer price index for all urban consumers (`CPIAUCSL`); CBOE Volatility Index (`VIXCLS`); Federal funds effective rate (`FEDFUNDS`); Market Yield on U.S. Treasury Securities at 3-Month Constant Maturity (`DGS3MO`); Market Yield on U.S. Treasury Securities at 1-Year Constant Maturity (`DGS1`); Market Yield on U.S. Treasury Securities at 5-Year Constant Maturity (`DGS5`); Market Yield on U.S. Treasury Securities at 10-Year Constant Maturity (`DGS10`).

Real Constraints

Irreversibility suggests that PPEs are specific to the firm, and thus may have only little value to some other firms. Consequently, resale prices could be significantly below its replacement costs, i.e. most of capital expenditure is sunk. We consider two common measures of irreversible investment in the literature. The irreversibility dummy takes a value of one if the firm's capital intensity ratio *cir* is above the median *cir* of two-digit NAICS industry. In the spirit of Chirinko and Schaller (2009), an irreversible asset is assigned one if the depreciation rate is below the median depreciation rate of the industry.

$$\text{capital intensity ratio}: \ cir = \begin{cases} 1 & \text{if} \ \frac{capital}{assets} \geq median_{ind}(\frac{capital}{assets}) \\ 0 & \text{o.w.} \end{cases}$$

$$\text{Chirinko and Schaller (2009)}: \quad cir = \begin{cases} 1 & \text{if} \quad deprec < median_{ind}(deprec) \\ 0 & \text{o.w.} \end{cases}$$

Financial Constraint

The rational behind using firm size as a good observable measure of financial constraint is that small firms are typically young, less well known, and thus more vulnerable to capital market imperfections. The KZ-index is a relative measurement of reliance on external financing. Companies with higher KZ-index scores are more likely to experience difficulties when financial conditions tighten, as they may have difficulties in financing their ongoing operations.

$$KZindex = -1.001909 \times CF + 0.2826389 \times Q + 3.139193 \times lev^n$$
$$-39.3678 \times div - 1.314759 \times CH$$

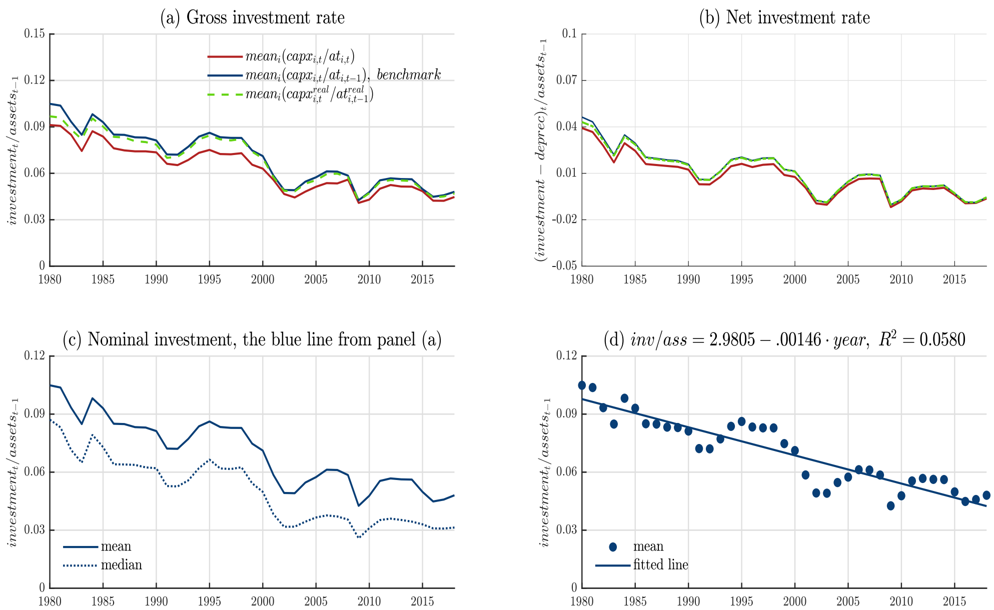
where CF is cash flow, Q is Tobin's Q, lev^n is net leverage, div is total dividends, CH is cash holdings.

$$WWindex = -0.091 \times CF - 0.062 \times div + 0.021 \times totlev$$
$$-0.044 \times size + 0.102 \times med_{ind}(sales) - 0.035 \times realsalegrowth$$

where CF is cash flow, div is an indicator that takes one if the firm pays dividends, $totlev$ is book leverage, $size$ is the log of total assets, $med_{ind}(sales)$ is two-digit industry sales growth.

B: Alternative Measures of the Investment Rate

Figure 5.1: Measures of aggregated firm-level capital investment, 1980-2018



Notes: The investment rate is defined as gross capital expenditure (`capx`, item 128) to the book value of total assets (`at`, item 6). Capital expenditure involves investment in tangible capital stock, including property, plant and equipment (PPE). Depreciation is obtained as a multiplication between depreciation rate and gross PPE. Variables are deflated by inflation price deflator. Variables are also winsorized. Data source: U.S. Compustat Annual, excluding financial companies and utilities; U.S. Bureau of Economic Analysis (BEA).

Figure 5.1, Panel (a) is useful for two purposes: (1) to check whether the downward trend in the investment rate of the average firm persists even after considering alternative measures of the investment rate; (2) to evaluate the influence of assets on the investment rate over time. The benchmark investment rate is colored blue, while counterfactuals include red line and green dashed line. The green line is the real counterpart of the investment rate. A small deviation of the green line from the blue line refers to a relatively stable inflation rate over the observed sample period. Relative to the blue line, the red line presents a decrease in the investment rate for a given capital expenditure. This implies that total assets increased from period $t-1$ to t. The gap between the red line and the blue line is mostly pronounced in the first half of the sample. The gap could indicate the importance of the financial position of the average firm in transmitting the influence of the uncertainty measure on the investment rate.[31]

Figure 5.1, Panel (b) presents a small gap between the gross and net investment rates over the 1980-2018 period. This observation reduces concerns that a high depreciation rate may quickly dimish capital stocks (see Gutiérrez and Philippon, 2016 for similar observation).

In Figure 5.1, Panel (c) we compare the mean and median values of the aggregated investment rate to address concerns that the trend in investment is driven by a few but very large firms due to positive skewness of the investment distribution. There is no major difference between the mean and median value of aggregated investment, implying that there are no large outliers in our sample, and thus there is no serious skewness of investment distribution. However, Figure 5.8 and Figure 5.10 show that we still need a quantile regression analysis of the investment-uncertainty relationship.

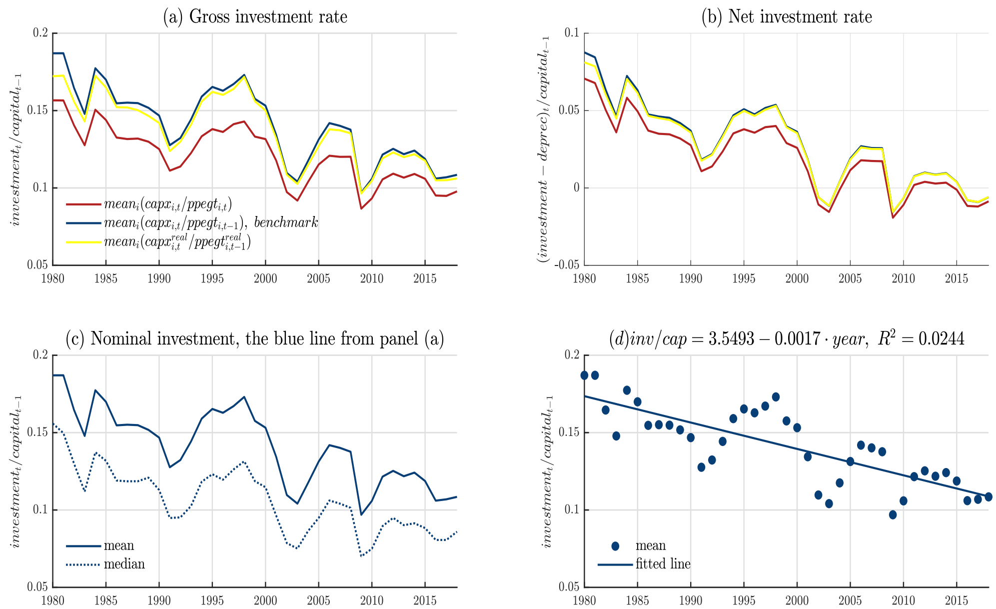
In Figure 5.1, Panel (d) we estimate a simple regression of the investment-asset ratio on a constant and time trend in order to confirm the presence of a statistically significant trend in the investment rate. Such simple regressions are only useful to characterize the evolution of investment during the sample period. It also indicates that we should include year fixed-effects to control for time variation in the investment rate. The coefficient of the time trend for the average investment rate corresponds to a yearly decrease of 0.15%, which is statistically significant. The R-squared of the regression is around 6%.

Figure 5.2 presents a downward trend in the investment-capital ratio, mirroring the trend observed in the investment-asset ratio from Figure 5.1.

While Figure 5.1 shows the evolution of the average investment ratio, Figure 5.3 (red dashed line) shows the evolution of average investment ratio weighted by assets. When considering the aggregate investment to aggregate assets, the decreasing trend persists. Fig-

[31] The importance of financial position of firms for the investment rate, particularly liquidity as a non-investment component of assets, is depicted in Figure 5.3 and Figure 5.13 (Panel (b) and Panel (c)).

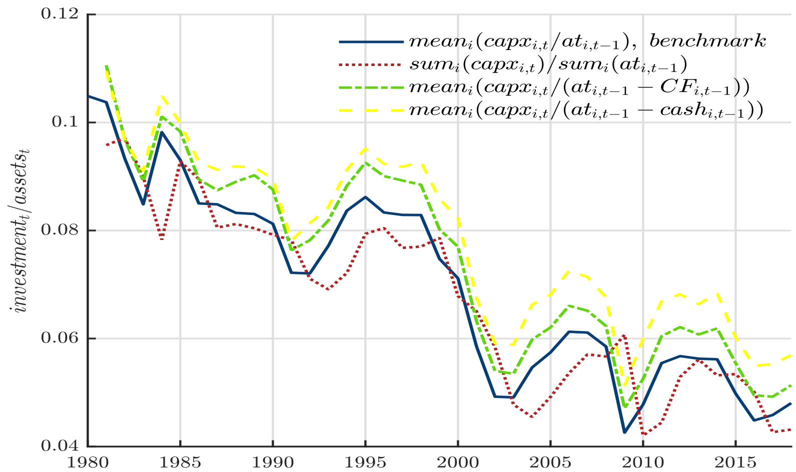
Figure 5.2: Measures of aggregated firm-level capital investment, 1980-2018



Notes: The investment rate is defined as gross capital expenditure (`capx`, item 128) to gross property, plant and equipment (`ppegt`, item 7). Capital expenditure involves investment in tangible capital stock, including property, plant and equipment (PPE). Depreciation is obtained as a multiplication between the depreciation rate and gross PPE. Variables are deflated by inflation price deflator. Variables are also winsorized. Data source: U.S. Compustat Annual, excluding financial companies and utilities; U.S. Bureau of Economic Analysis (BEA).

ure 5.3 shows that cash holdings has the strongest impact on the investment rate. Green and yellow lines include counterfactual exercises in which we isolate a component of assets that is not affected by liquidity measures (cash-flow and cash holdings). We then check the impact of residual assets on the investment rate. These exercises provide the initial indication of the importance of liquidity measures in determining the strength of the indirect channel of uncertainty on investment. We partial out the impact of liquidity measures on the investment-uncertainty relationship in Appendix G.

Figure 5.3: Alternative measures of aggregated investment rate, 1980-2018



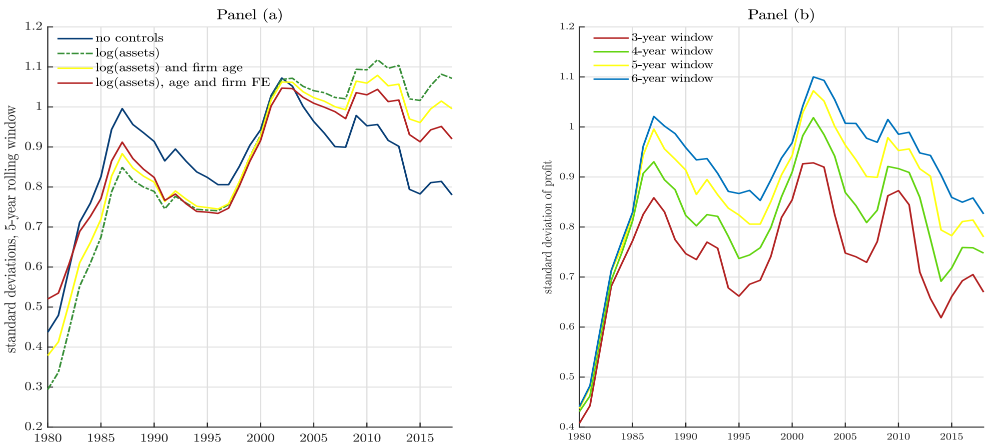
Notes: The investment rate is defined as gross capital expenditure (`capx`, item 128) to gross property, plant and equipment (`at`, item 6). Capital expenditure involves investment in tangible capital stock, including property, plant and equipment (PPE). Cash-flow (CF) is measured as operating income before depreciation (`oibdp`, item 13) minus interest expenses (`xint`, item 15) and minus income taxes (`txt`, item 16), divided by total assets. Cash holdings is defined as the sum of lagged cash and short-term investment (`che`, item 1) divided by total assets. Variables are also winsorized. Data source: U.S. Compustat Annual, excluding financial companies and utilities.

C: Uncertainty Measure

We focus on a lagged measure of uncertainty to alleviate concerns about a reverse impact of investment behavior on profit volatility. This approach is also applied by Kermani and Ma (2023) and Ottonello and Winberry (2020). In computing the time-series measure of uncertainty, we exclude the average growth rate for the firm in the window. This allows us to control for firm-specific aspects that affect profit growth rates.

A potential concern about the profit volatility is that its upward trend is the result of changes in the composition of the firm sample over time. Under this scenario, the upward trend in firm specific uncertainty could be simply driven by a larger share of smaller and younger firms, whose profits are by construction more volatile. To address this issue, we perform several robustness checks to ensure that there is no composition bias. Our task is to isolate a component of volatility that is not explained by demographic factors (size and age),

Figure 5.4: Measures of aggregated firm-level uncertainty, 1980-2018



Notes: Construction of uncertainty measure is provided in Appendix A. Variables are winsorized.

Data source: U.S. Compustat Annual, excluding financial companies and utilities.

and then check movements in residual uncertainty. Figure 5.4, Panel (a) illustrates the upward trend in profit volatility. Up to 2002, factors including size (measured by assets), age and firm FE (fixed effects) have a positive impact on profit volatility. Relatively larger and older firms took more risky projects and pushed up the average uncertainty until 2002. Afterwards, the internet boom opened the space for a much larger number of small and young firms to enter the market. Panel (b) of Figure 5.4 presents uncertainty measures over different time windows.

D: Baseline Regression Results and Extensive Margin

The results from Table 5.1 support the literature finding that firm-level uncertainty has negative effects on *average* fixed capital investment.

All OLS estimated variables from Table 5.1 have expected signs and are statistically significant. Specification (1) refers to the classic investment regression. It shows a larger impact of the persistent demand for firm's output than average Tobin's Q. This result is common in the literature. Specification (2) highlights strong and negative effects of profit volatility on the investment rate, *ceteris paribus.* Year fixed-effects from Specification (3) have quite similar results of an investment-uncertainty relationship to the one with the real interest rate and real GDP growth rate from Specification (6). In Specification (4), larger and older firms tend to decrease investment relatively more than other firms as they are less productive. Results of our baseline model are presented in Specification (5). It implies that a one-SD(1.3565) increase in profit volatility leads to a 0.5917%(=1.3565 $\times$ 0.0044) decrease in the average investment rate. Beside its statistical significance, the estimated coefficient is also economically significant. Given the unconditional mean annual investment rate of 7.07%, this is a decline of 6.22%(=-0.0044/0.0707) per year. The literature's findings on the impact of firm-level uncertainty on the investment rate fall in the range of 0.38% and 0.96% (see e.g., Alfaro et al., 2024; Liu and Wang, 2021; Panousi and Papanikolaou, 2012; Baum et al., 2008; Leahy and Whited, 1996). Although the results from Table 5.1 are not directly comparable to the literature due to different uncertainty measures and empirical frameworks, they could still give an indication of how firm-level uncertainty affects the investment rate.

Specification (5) of Table 5.1 shows that controlling for cash holdings does not alter the impact of uncertainty on investment. That is, the impact of profit volatility on investment is the first order relevant compared to its indirect impact on investment through average cash holdings. We also quantify the impact of the profit volatility on investment for different levels of cash holdings. In addition to a continuous measure of cash holdings expressed in levels, we introduce a discrete measure of cash holdings.[32] Results of additional analyses are presented in Table 5.4. The estimated coefficients imply that the negative impact of volatility on investment is much weaker with higher cash holdings.

[32]Note that the discrete measure is sensitive to the choice of an exogenous threshold.

Table 5.1: Fixed-effects regression estimates

investment/asset	(1)	(2)	(3)	(4)	(5)	(6)
vol(profit)		-0.0047***	-0.0039***	-0.0044***	-0.0044***	-0.0039***
		(0.0003)	(0.0003)	(0.0003)	(0.0003)	(0.0003)
mkt/book	0.0070***	0.0066***	0.0075***	0.0072***	0.0071***	0.0075***
	(0.0003)	(0.0003)	(0.0002)	(0.0002)	(0.0002)	(0.0002)
sale/asset	0.0265***	0.0263***	0.0163***	0.0127***	0.0135***	0.0188***
	(0.0012)	(0.0012)	(0.0010)	(0.0011)	(0.0011)	(0.0011)
cash/asset					0.0160***	0.0188***
					(0.0032)	(0.0031)
size				-0.0074***	-0.0071***	
				(0.0007)	(0.0007)	
age				-0.0037***	-0.0037***	
				(0.0007)	(0.0007)	
r10yTCMR						0.0028***
						(0.0001)
RGDPgrowth						0.1185***
						(0.0100)
Num. of obs.	81076	81076	81076	81076	81070	81070
R-sq(within)	0.0674	0.0771	0.1564	0.1639	0.1647	0.1403
Num. of firms	7178	7178	7178	7178	7178	7178
Firm FE	yes	yes	yes	yes	yes	yes
Year FE	no	no	yes	yes	yes	no

Table 5.1 presents OLS estimation results from regression model (1). The sample contains Compustat firms from 1980 to 2018. Dependent variable $inv_{i,t}/asset_{i,t-1}$ is annual investment in PPE, while $vol(profit)_{i,t-1}$ is the key independent variable related to the annual standard deviation of profit growth over the recent five years. Size is the natural logarithm of total assets, age is number of years since a firm enters the sample, and $r10yTCMR$ is 10-year real Treasury constant maturity rates. Time FE is not reported in Table 5.1, while firm FE is eliminated using the within transformation. Robust standard errors reported in parentheses are clustered at the firm level. Asterisks refer to significance levels: ***=1%, **=5%, *=10%.

Extensive Margin Investment Decisions

The average investment rate (i_t) is the weighted sum of investment spike (i_t^s) and nonspike (i_t^{ns}):

$$E[i_t] = E[\gamma_t \cdot i_t^s] \; + \; E[(1-\gamma_t) \cdot i_t^{ns}]$$

The fraction of firms with investment spike is denoted by γ_t. Investment spike refers to an investment rate that exceeds 20%. We know that $E[\gamma_t \cdot i_t^s] = E[\gamma_t] \cdot E[i_t^s] + cov(\gamma_t, i_t^s)$. Using the linearity of expectation, $E[(1-\gamma_t)i_t^{ns}] = E[i_t^{ns}] - E[\gamma_t i_t^{ns}]$, and substituting in $E[\gamma_t i_t^{ns}] = E[\gamma_t]E[i_t^{ns}] + cov(\gamma_t, i_t^{ns})$, we obtain $E[(1-\gamma_t)i_t^{ns}] = E[i_t^{ns}] - (E[\gamma_t]E[i_t^{ns}] + cov(\gamma_t, i_t^{ns}))$. Finally, the average investment rate is expressed as

$$E[i_t] = E[\gamma_t] \cdot E[i_t^s] + cov(\gamma_t, i_t^s) + (1 - E[\gamma_t]) \cdot E[i_t^{ns}] - cov(\gamma_t, i_t^{ns})$$

Differentiating the above expression with respect to uncertainty:

$$\frac{\partial E[i_t]}{\partial \sigma_t} = \underbrace{E[\gamma_t]\frac{\partial E[i_t^s]}{\partial \sigma_t} + (1 - E[\gamma_t]) \cdot \frac{\partial E[i_t^{ns}]}{\partial \sigma_t}}_{\text{intensive margin}} + \underbrace{\frac{\partial E[\gamma_t]}{\partial \sigma_t}\Big(E[i_t^s] - E[i_t^{ns}]\Big) + \frac{\partial cov(\gamma_t, i_t^s)}{\partial \sigma_t} - \frac{\partial cov(\gamma_t, i_t^{ns})}{\partial \sigma_t}}_{\text{extensive margin}}$$

Two covariance terms are excluded from the analysis as they have a negligible contribution.

E: Financial and Real Frictions

Impact of Frictions

In this section we focus on quantifying the impact of two frictions on the investment-uncertainty relationship. On one hand, it is costly to borrow external funds, either in the equity market from shareholders or in the capital market. Equity financial costs include flotation costs, such as commissions paid to brokers, legal fees and accounting costs. Firms also have limited access to borrowing due to collateral in capital markets. On the other hand, firms cannot easily sell previously acquired capital goods due to their specificity. Installing a new production line requires high planning costs, installation costs, and costs related to learning new production process, which cannot be recovered if a project fails.

We test whether the negative relationship between profit volatility and investment is stronger for financially constrained firms and those with irreversible assets through two steps. First, following Fazzari et al. (1988) we use a dividend-to-profit ratio as an ex-ante indicator to determine the degree of financial constraint that firms face. Firms are sorted into financially constrained if they spend less than 20% of their profits on dividends. Second, equation (3.1) is estimated separately for the financially constrained and unconstrained groups of firms. We conduct a similar procedure for exploring the influence of the real constraint on investment. Capital intensity ratio serves as our benchmark proxy for investment irreversibility. The assumption is that the more tangible ratio of fixed investment to total assets, the more difficult it is to recover net property, plant and equipment relative to intangible capital.

Results from Table 5.2 illustrate how the investment-uncertainty relationship varies with the level of financial constraints and the degree of irreversible investment. Specifically, increasing dividends above a threshold or decreasing the tangibility of capital below a threshold amplifies both the negative effects of the profit volatility on investment and the positive effects of cash reserves on investment. This suggests that dividends and reversible capital may serve as a buffer against adverse profit shocks.

Results from Columns (4) and (5) are consistent with the real options theory (Dixit and Pindyck, 1994), which predicts that firms with more tangible investment optimally choose to postpone investment in the face of higher uncertainty.[33]

[33] The role of irrevesibility is empirically documented in Panousi and Papanikolaou (2012), Bulan (2005), Leahy and Whited (1996), among many others. Real option theory predicts that increased uncertainty raises the option value of waiting to invest in new projects more than it raises expected marginal profit, which leads to the higher investment threshold and reduced current investment. Accordingly, the investment decisions of the firm requires involving the costs related to the ability to reverse projects in the future.

Table 5.2: Effects of uncertainty and frictions

investment/asset	(1)	(2)	(3)	(4)	(5)
vol(profit)	-0.0044^{***}	-0.0045^{***}	-0.0014	-0.0063^{***}	-0.0028^{***}
	(0.0003)	(0.0003)	(0.0010)	(0.0004)	(0.0003)
mkt/book	0.0071^{***}	0.0075^{***}	0.0040^{***}	0.0094^{***}	0.0052^{***}
	(0.0002)	(0.0003)	(0.0006)	(0.0004)	(0.0003)
sale/asset	0.0135^{***}	0.0127^{***}	0.0203^{***}	0.0170^{***}	0.0099^{***}
	(0.0011)	(0.0011)	(0.0033)	(0.0019)	(0.0012)
cash/asset	0.0160^{***}	0.0183^{***}	0.0125^{*}	0.0452^{***}	0.0126^{***}
	(0.0032)	(0.0033)	(0.0073)	(0.0061)	(0.0033)
size	-0.0071^{***}	-0.0073^{***}	-0.0038^{*}	-0.0094^{***}	-0.0067^{***}
	(0.0007)	(0.0007)	(0.0022)	(0.0012)	(0.0007)
age	-0.0037^{***}	-0.0039^{***}	0.0007	-0.0069^{***}	-0.0016^{**}
	(0.0007)	(0.0008)	(0.0029)	(0.0013)	(0.0007)
Sample	all	dpr $\leq$ 0.20	dpr $>$ 0.20	$cir > med(cir)$	$cir \leq med(cir)$
R-sq(within)	0.1647	0.1686	0.1079	0.1788	0.1291
Num. of obs.	81070	71218	9796	40533	40537
Firm FE	yes	yes	yes	yes	yes
Year FE	yes	yes	yes	yes	yes

Table 5.2, Column (1) presents our benchmark OLS regression results from model (1). Columns (2) and (3) determine the impacts of financial frictions. Columns (4) and (5) determine the impacts of real frictions. The sample contains Compustat firms from 1980 to 2018. Dependent variable $inv_{i,t}/asset_{i,t-1}$ is annual investment in PPE, while $vol(profit)_{i,t-1}$ is the key independent variable related to the annual standard deviation of profit growth over the recent five years. Capital intensity ratio $cir_{i,t-1} = \texttt{ppent}_{i,t-1}/\texttt{at}_{i,t-1}$ is the lagged net property, plant and equipment normalized by lagged total assets. Irreversibility dummy takes a value of one if firms' cir is above the median cir of two-digit NAICS industry, and such firms have irreversible investment. Financial friction is determined by dividend-to-profit ratio $dpr_{i,t-1} = (\texttt{dvp}_{i,t-1} + \texttt{dvc}_{i,t-1})/\texttt{oibdp}_{i,t-1}$ is the lagged total dividends normalized by lagged operating profit. Robust standard errors presented in parentheses are clustered at the firm level. Asterisks refer to significance levels: ***=1%, **=5%, **=10%.

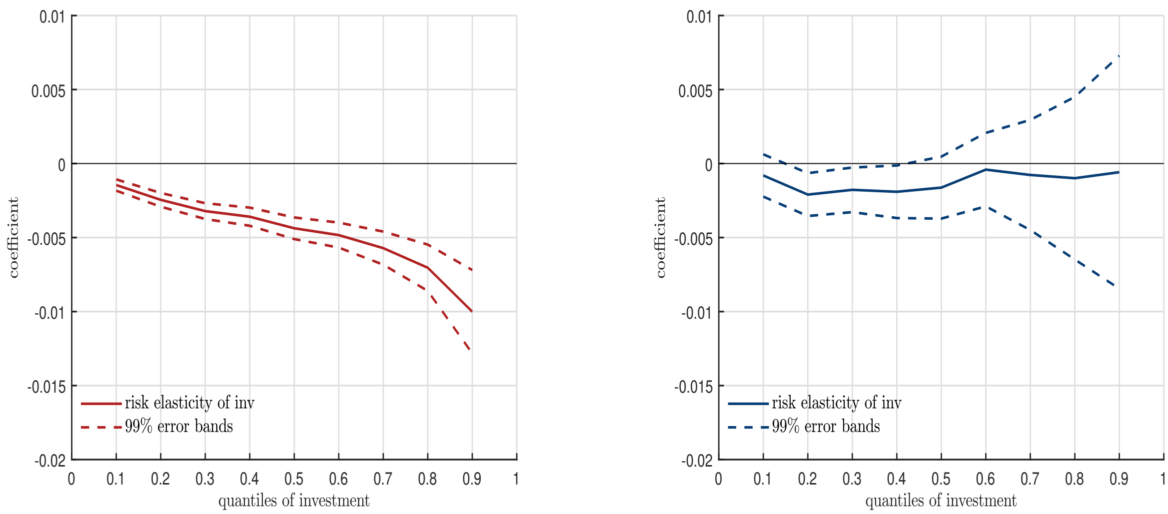
Heterogenous Impact of Frictions

Figure 5.5 shows that the impact of profit volatility on investment increases with the level of investment among constrained firms (see Panel a). The costs of cutting investment, in terms of foregone returns, become smaller at higher investment relative to the costs of external funds.[34] As for unconstrained firms, the impact of idiosyncratic uncertainty on investment

[34]This theoretical argument implicitly assumes that firms operate a DRTS technology, a common assumption

is marginally significant at low levels of investment (see Panel b). That is, uncertainty shocks strongly affect firms operating around the dividend threshold. Although the dividend threshold is exogenous, we find a robust result when other measures of financial friction are considered (see estimates below).

Figure 5.5: Financial frictions and levels of investment



(a) fin constrained: $dpr \leq 0.2$

(b) fin unconstrained: $dpr > 0.2$

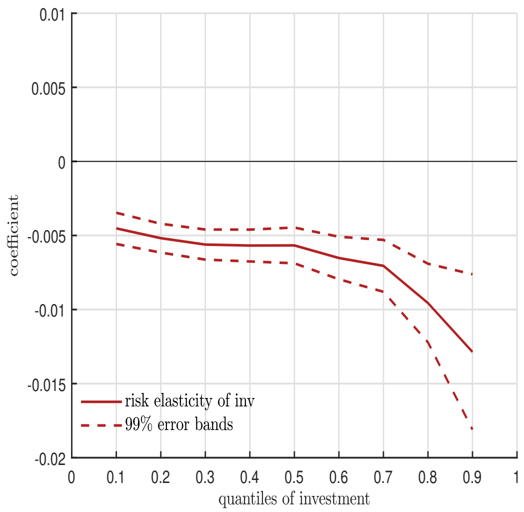
Figure 5.5 plots the responsiveness of investment to profit volatility at different investment quantiles for the two financial groups of firms. Dividend-to-profit ratio $dpr_{i,t-1} = (\texttt{dvp}_{i,t-1} + \texttt{dvc}_{i,t-1})/\texttt{oibdp}_{i,t-1}$ is the lagged total dividends normalized by lagged operating profit. Financial dummy takes a value of one if firms spend less than 20% of their profits on dividends, and such firms are classified as financially constrained.

In Panel (a) of Figure 5.6, we observe that as the level of investment rises, the fixed costs of adjusting capital become larger than the marginal product of capital, resulting in a higher sensitivity of investment to uncertainty. Since firms simply do not like uncertainty about future profits because of the possibility to get stuck with an excessive stock of capital in the future, they are willing to delay investment in new investment projects (see Panel b). Figure 5.9 supports the negative relationship between investment and uncertainty when the

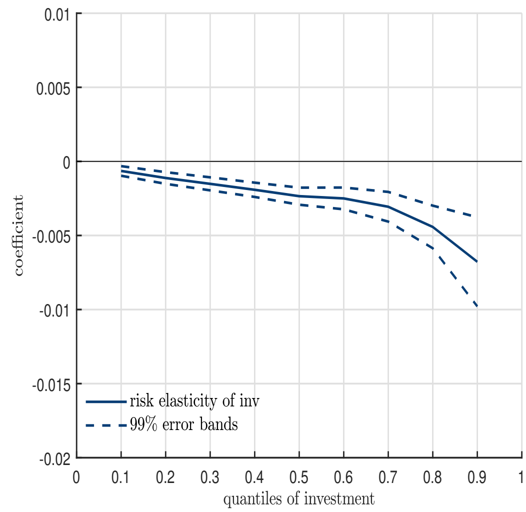
in the literature. Additionally, heightened uncertainty may increase the costs of external financing because more risky projects induce higher costs of evaluating projects, as empirically documented by Minton and Schrand (1999). External funds are costly due to a degree of asymmetric information between managers and the market about the true value of a firm. This capital market imperfection is more pronounced for small firms because they are less covered by the popular press.

depreciation rate is instead used as a proxy for real friction. Although the capital intensity ratio and depreciation levels are crude measures of real frictions, the regression results remain consistent with findings from previous studies (see e.g., Kermani and Ma, 2023 and Kim and Kung, 2017).

Figure 5.6: Real frictions and levels of investment



(a) irreversible inv: $cir > med(cir)$



(b) reversible inv: $cir \leq med(cir)$

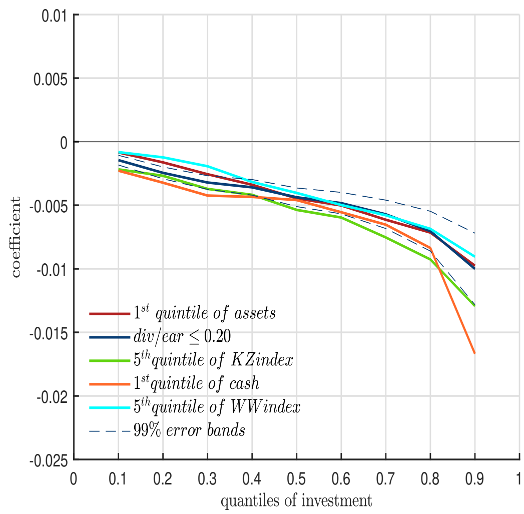
Figure 5.6 plots the responsiveness of investment to profit volatility at different investment quantiles for firms with (ir)reversible assets. Capital intensity ratio $cir_{i,t-1} = \texttt{ppent}_{i,t-1}/\texttt{at}_{i,t-1}$ is the lagged net property, plant and equipment normalized by lagged total assets. Irreversibility dummy takes a value of one if firms' cir is above the median cir of two-digit NAICS industry, and such firms have irreversible investment.

Robustness Checks on Frictions

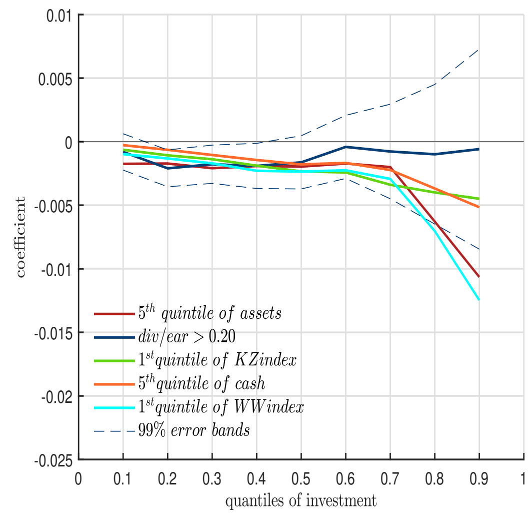
We show the influence of increased firm-specific profit volatility on fixed investment conditional on various proxies of financial and real constraints. More specifically, we consider size measured by assets, KZ (Kaplan-Zingales) index, cash holdings, and WW (Whited-Wu) index as alternative proxies of financial constraint. Figure 5.7 and Figure 5.9 present robust responses of investment to increased uncertainty.

Figure 5.8 and Figure 5.10 plot the coefficient estimates on profit volatility at different investment quantiles, contingent on financial and real constraints, respectively. The estimated coefficients for the quantile regression (red line) vary largely at the tails of the investment distribution, diverging from those obtained using OLS regression (green line). Therefore,

Figure 5.7: Other measures of financial frictions



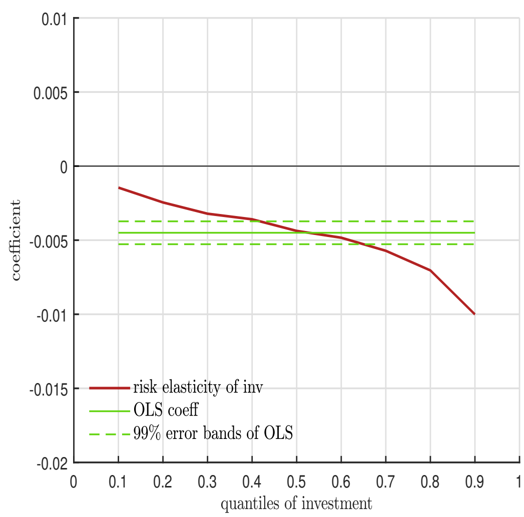
(a) fin constrained firms



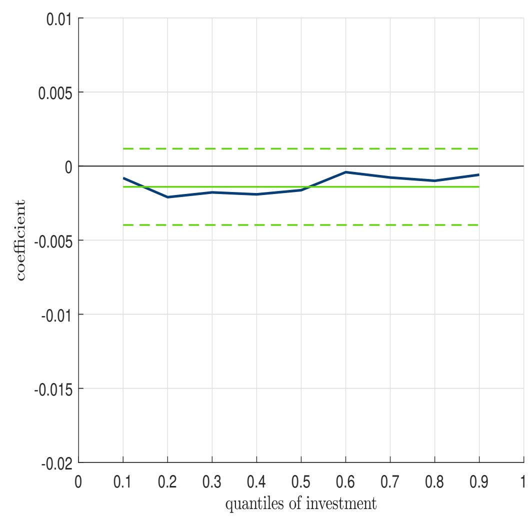
(b) fin unconstrained firms

Note: Construction of the constraints is available in Appendix A.

Figure 5.8: Quantile regressions vs OLS regressions



(a) fin constrained ($div/prof \leq 0.2$)

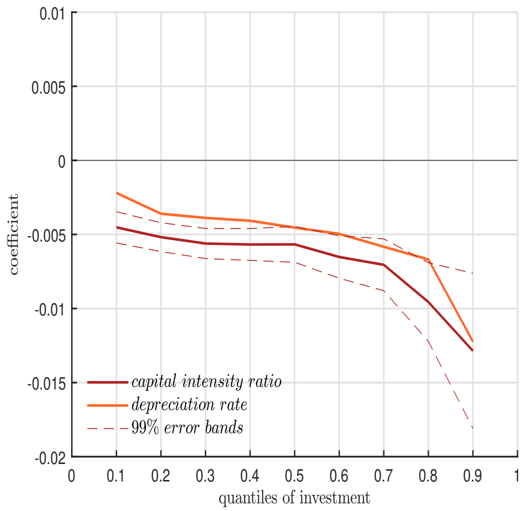


(b) fin unconstrained ($div/prof > 0.2$)

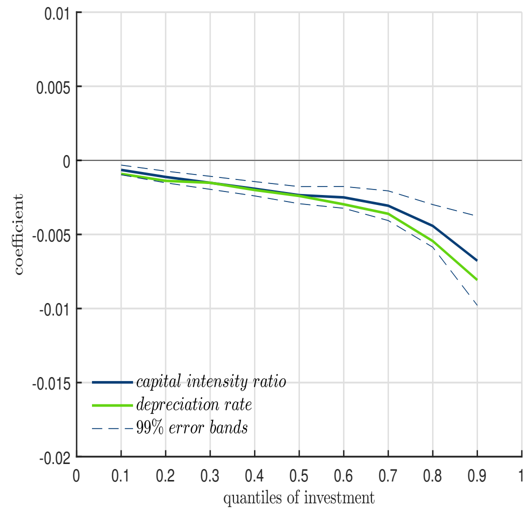
Note: Construction of the constraints is available in Appendix A. The OLS estimated coefficients are -0.0045 and -0.0014 for left and right Panel, respectively. We apply 300 bootstrap replications in computing Quantile Regression point estimates and standard errors.

the use of quantile regression is justified by showing that the estimated quantile regression coefficients lie outside the confidence intervals of OLS regression estimates.

Figure 5.9: Other measures of real frictions



(a) irreversible inv



(b) reversible inv

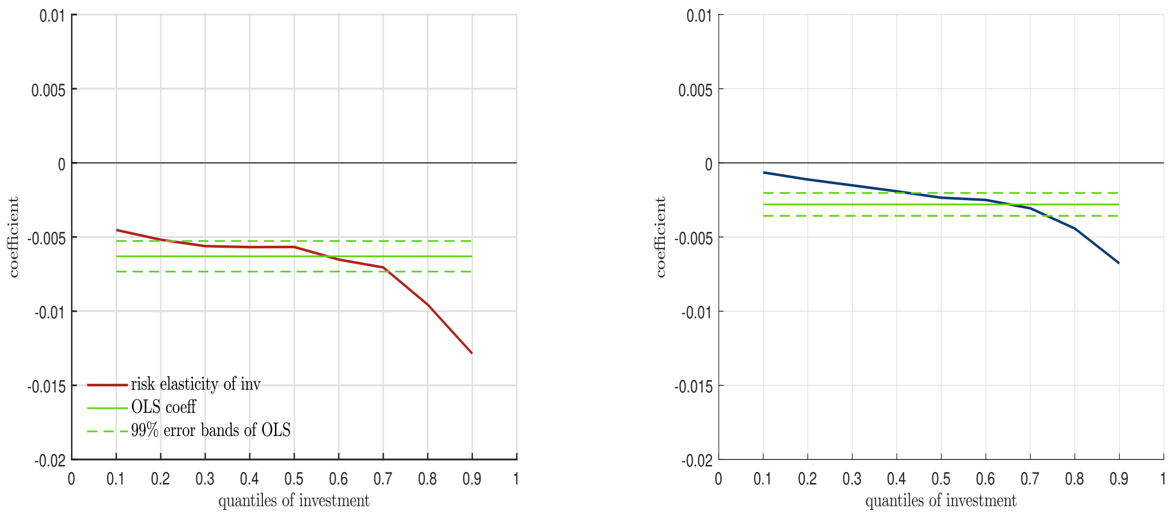
Note: Construction of the constraints is available in Appendix A.

F: Predictability of Profit Volatility

Our non-parametric estimates predict that when a firm faces increased uncertainty about profitability in the recent 5 years, the firm is likely to experience increased profit volatility in the subsequent year. Figure 5.11 shows that changes in profit volatility are predictable. The uncertainty pattern follows a persistent process as we expect any positive change to sustain in the future. This persistence implies a slow convergence to its historical averages, potentially due to higher capital market imperfections (asymmetric information problem) induced by higher uncertainty itself. Negative responses in profit volatility are rather small and statistically insignificant.

We estimate kernel regressions (2.17) and (2.18) such that we first partial out the effects of firm-specific and macro controls for investment opportunities and demographic factors on both current uncertainty and future uncertainty. Afterwards, we run a simple kernel regression of future uncertainty residuals on the current uncertainty residuals using an

Figure 5.10: Quantile regressions vs OLS regressions



(a) irreversible inv

(b) reversible inv

Note: Construction of the constraints is available in Appendix A. The OLS estimated coefficients are -0.0063 and -0.0028 for left and right panels, respectively. We apply 300 bootstrap replications in computing Quantile Regression point estimates and standard errors.

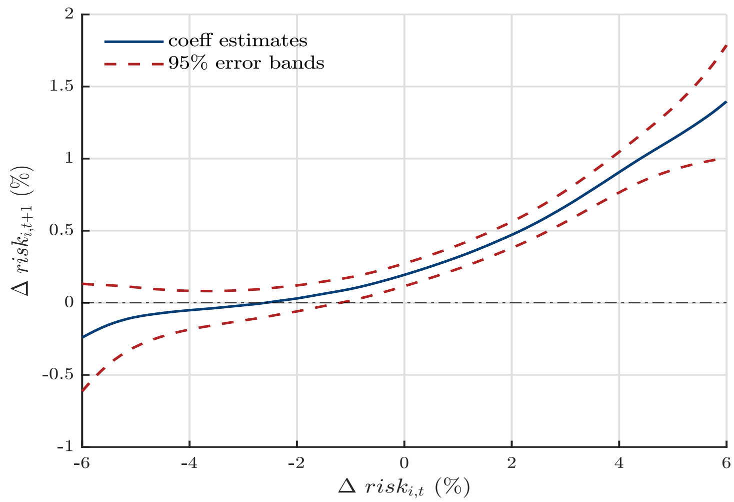
Epanechnikov kernel. Our procedure imposes linearity in the relationship between current uncertainty and controls or future uncertainty and controls while allowing the data to uncover any remaining nonlinearity between future and current uncertainty.

$$\sigma_{i,t+1} = \alpha + \beta' \cdot X_{i,t} + \gamma \cdot real\_10yTCMR_t + \theta \cdot rgdp\_gr_t + \epsilon_{i,t} \tag{2.17}$$

$$\sigma_{i,t} = \alpha + \beta' \cdot X_{i,t} + \gamma \cdot real\_10yTCMR_t + \theta \cdot rgdp\_gr_t + \epsilon_{i,t} \tag{2.18}$$

The vector of control variables includes market-to-book ratio, sale-to-asset ratio, cash-asset ratio, log(assets), log(age). Variable $real\_10yTCMR_t$ refers to real U.S. 10-year Treasury Constant Maturity Rate, while $rgdp\_gr_t$ implies real GDP growth rate.

Figure 5.11: Predictability of profit volatility in data

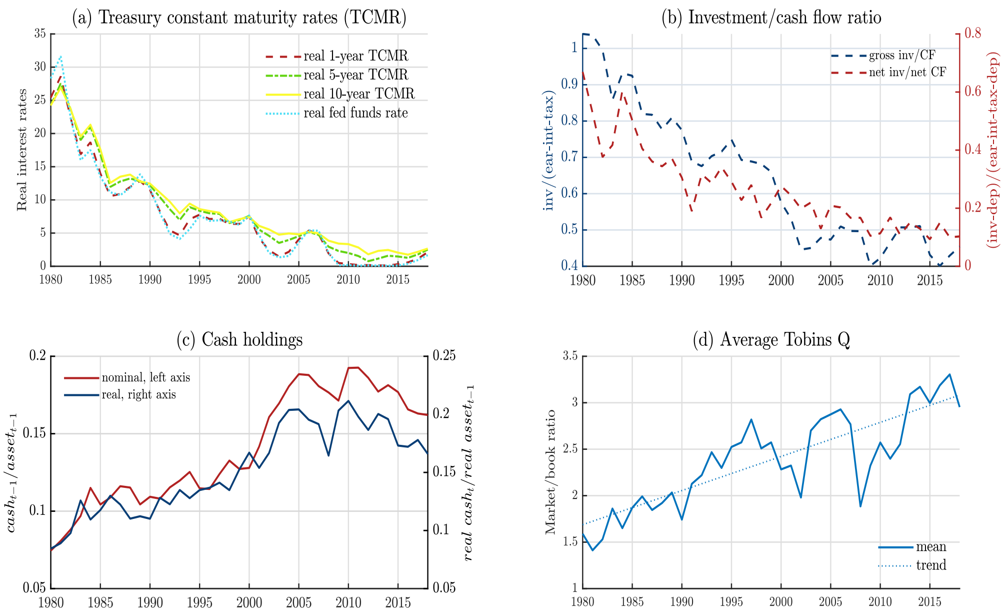


Notes: Variables $\Delta\sigma_{i,t} = \sigma_{i,t} - \sigma_{i,t-1}$ and $\Delta\sigma_{i,t+1} = \sigma_{i,t+1} - \sigma_{i,t}$. Periods $t-1$ and $t+1$ imply moving one year backward and forward, not moving 8 years backward and forward. The uncertainty measures are trimmed at 10% and 90%. Data source: U.S. Compustat Annual, excluding financial companies and utilities.

G: Traditional Drivers of the Investment Rate

This section investigates the traditional factors that could explain why firms underinvest, i.e. invest in capital below its first-best level. Figure 5.12, Panel (a) shows the evolution of real interest rates. To sustain capital market functionality, expansionary monetary policies steadily reduce real interest rates up to the zero lower bound in the last decade. The real 10-year government bond yield acts as a proxy for the real user cost of capital. However, a downward trend in capital investment implies that cheap and accessible financing provides a small direct stimulus to investment. One might think that capital expenditure is low due to a lack of internal funds. Panel (b) illustrates that this is not the case since the investment-cash flow ratio steadily falls due to a stronger rise in cash flow. Panel (c) reinforces this trend, revealing a strong increase in nominal and real cash holdings over the past four decades. Finally, weak investment opportunities imply that firms may not expect returns from expanding capital stock to exceed their risk-adjusted cost of capital. However, Panel (d) shows relatively high returns on capital via the average Tobin's Q, though it exhibits a highly cyclical pattern.

Figure 5.12: Interest rates, cash holdings and investment incentives, 1980-2018

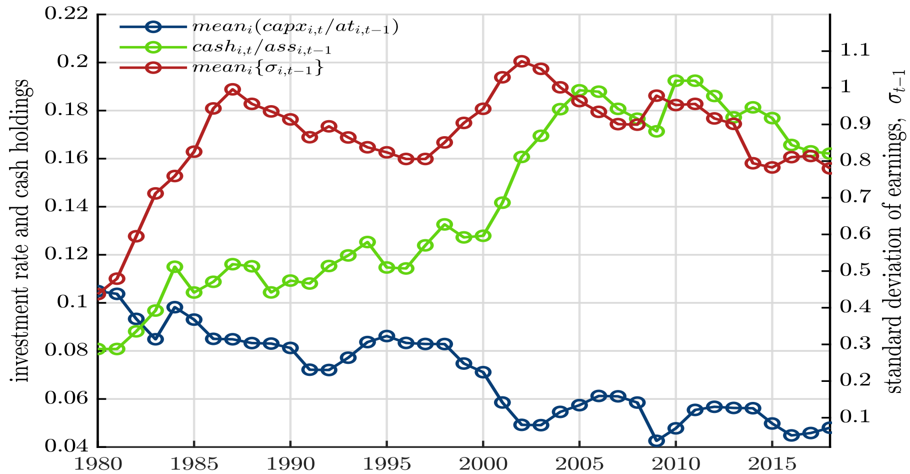


Note: Variables are deflated by BLS implicit price deflator. Data sources: U.S. Compustat Annual and BEA.

H: Capital Investment and Cash Holdings

Why did public firms in the US reduce capital investment and accumulate large cash? We claim that a large precautionary demand for cash holdings, induced by financial and real frictions, is the key reason. Different firms save for different reasons in anticipation of adverse profit shock realization. On the one hand, relatively younger and smaller firms increase cash holdings to avoid having to finance future investment with costly external equity. On the other hand, older and relatively larger firms save to avoid accumulating irreversible capital in the future as it induces large adjustments costs. Our previous Figure 5.4 shows that a rising trend in average uncertainty until 2002 is driven by larger firms. The strong drop in dividend taxes in 2003 could reduce their precautionary concerns, mitigating the rise in cash holdings and the reduction in capital expenditure.

Figure 5.13: Aggregated firm-specific investment, cash holdings and uncertainty



Note: Intertemporal behaviour of firms is important to understand the connections among capital investment, cash holdings and profit volatility. Data source: U.S. Compustat Annual.

Table 5.3: Pearson correlation

	inv_ass_{-1}	$sd(ear)_{-1}$	$cash\_ass_{-1}$
inv_ass_{-1}	1.0000		
$sd(ear)_{-1}$	-0.5669^{***}	1.0000	
$cash\_ass_{-1}$	-0.8876^{***}	0.5254^{***}	1.0000

Visual inspection of the data in Figure 5.13 and simple correlation analysis in Table 5.3 indicate a strong negative relationship between idiosyncratic uncertainty and investment among publicly-traded firms in the United States over the past four decades. Over the same period, large cash holdings is observed across firms, potentially contributing to capital underinvestment.

J: Importance of Cash Holdings for Investment

Cash holdings provide firms with financial flexibility to exploit future investment opportunities. In our sample, higher profit volatility induces firms to reduce current investment to finance future investment via cash holdings. Consequently, they gradually accumulate capital stock. Firms with low cash holdings are forced to reduce investment, while firms with high cash holdings could absorb increased uncertainty, and thus raise their capital expenditure. The opposite outcomes occur with cash-flow.

Table 5.4 presents several specifications, with Specification (1) serving as our benchmark. It shows that higher profit volatility leads to lower capital expenditure, regardless of cash levels. In Specification (2), the coefficient on uncertainty represents the negative effect of uncertainty on investment when cash holdings are at their mean level. The coefficient on the interaction term indicates that firms with more than average cash holdings respond by increasing investment. The net effect of uncertainty on investment, net effect $= -0.0057 + 0.0079 \cdot cash/ass$, indicates that for firms with cash larger than 72% of total assets the interaction term exceeds the direct negative effect, making the net effect positive. In Specification (3), the negative effects of uncertainty on investment are also largely mitigated with higher cash holdings when considering a discrete measure of cash holdings (CH). Squared cash holdings (CH^2) in Specification (4) control for a potential non-linear relationship between investment and CH. On average, there is a hump-shaped relationship between investment and cash, with a turning point at 32%. Firms probably decide to payout dividends because of the high opportunity costs of holding large cash reserves. More leveraged firms in Specification (5) reduce investment on average. In Specification (6), firms with more cash flow decrease investments in the face of higher profit uncertainty, which is consistent with findings from Minton and Schrand (1999).

Table 5.4: Investment, uncertainty and cash holdings

investment/asset	(1)	(2)	(3)	(4)	(5)	(6)
vol(profit)	-0.0044^{***}	-0.0057^{***}	-0.0052^{***}	-0.0059^{***}	-0.0052^{***}	-0.0028^{***}
	(0.0003)	(0.0003)	(0.0003)	(0.0003)	(0.0003)	(0.0003)
LCH			-0.0043^{***}			
			(0.0007)			
HCH			-0.0001			
			(0.0008)			
vol(profit) × LCH			-0.0004			
			(0.0004)			
vol(profit) × HCH			$.0025^{***}$			
			(0.0004)			
cash/ass	0.0160^{***}	0.0013		0.0471^{***}	-0.0722^{***}	
	(0.0032)	(0.0032)		(0.0055)	(0.0046)	
vol(profit) × cash/ass		0.0079^{***}		0.0090^{***}	0.0069^{***}	
		(0.0010)		(0.0010)	(0.0010)	
$(cash/ass)^2$				-0.0851^{***}		
				(0.0079)		
leverage					-0.0701^{***}	
					(0.0032)	
CF/ass						0.1123^{***}
						(0.0072)
vol(profit) × CF						-0.0167^{***}
						(0.0019)
R-sq(within)	0.1647	0.1655	0.1668	0.1680	0.1825	0.1818
Num. of obs.	81070	81070	81076	81070	80802	77219
Num. of firms	7178	7178	7178	7178	7171	7086
Controls	yes	yes	yes	yes	yes	yes
Firm FE	yes	yes	yes	yes	yes	yes
Year FE	yes	yes	yes	yes	yes	yes

Table 5.4 reports the indirect effects of uncertainty measure on the investment rate via cash holdings. The sample is Compustat firms from 1980 to 2018. Dependent variable $inv_{i,t}/asset_{i,t-1}$ is annual capital expenditure, and $vol(profit)_{i,t-1}$ is the annual standard deviation of profit growth over the recent five years. Control variables, which include $mkt_{i,t-1}/book_{i,t-1}$ and $sale_{i,t-1}/asset_{i,t-1}$, $ln(asset)_{i,t-1}$ and $ln(age)_{i,t-1}$, are significant and have predicted signs. LCH is the lowest (1-3) decile of $cash_{i,t-1}/asset_{i,t-1}$. Cash-flow is computed as CF=profit-interest expenses-income taxes. The turning point for cash holding is -(0.0549/(2*(-0.0851))=0.32. Robust standard errors presented in parentheses are clustered at the firm level. Asterisks refer to significance levels: ***=1%, **=5%, *=10%.

K: Additional Robustness Checks

Table 5.5: Fixed capital investment and firm-level uncertainty

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	inv/ass	inv	inv/ass2	inv/cap	inv/ass	inv/ass	inv/ass
vol(profit)	-0.0044***	-2.3266***	-0.0043***	-0.0167***	-0.0038***	-0.0015***	-0.0014***
	(0.0003)	(0.3692)	(0.0003)	(0.0009)	(0.0003)	(0.0003)	(0.0003)
mkt/book	0.0071***	0.0958***	0.0067***	0.0260***		0.0044***	0.0056***
	(0.0002)	(0.0376)	(0.0002)	(0.0007)		(0.0003)	(0.0003)
sale/ass	0.0135***	1.0816***	0.0141***		0.0116***	0.0066***	0.0045***
	(0.0011)	(0.2034)	(0.0011)		(0.0011)	(0.0011)	(0.0012)
cash/ass	0.0160***	2.6179***	0.0193***		0.0009	0.0072**	-0.0119***
	(0.0032)	(0.5169)	(0.0031)		(0.0032)	(0.0034)	(0.0034)
size	-0.0071***		-0.0076***		-0.0076***	-0.0093***	-0.0079***
	(0.0007)		(0.0007)		(0.0007)	(0.0008)	(0.0008)
age	-0.0037***	-9.9812***	-0.0036***	-0.0152***	-0.0027***	-0.0019*	-0.0023**
	(0.0007)	(1.4375)	(0.0007)	(0.0022)	(0.0007)	(0.0011)	(0.0011)
size2		34.9564***					
		(1.6287)					
sale/cap				0.0096***			
				(0.0004)			
cash/cap				0.0173***			
				(0.0011)			
size3				-0.0347***			
				(0.0020)			
mkt/book2					0.0200***		
					(0.0005)		
CF/ass						0.1902***	0.1612***
						(0.0058)	(0.0058)
booklev							-0.0401***
							(0.0021)
Num. of obs.	81070	69954	81069	81070	77661	68369	68217
R-sq(within)	0.1647	0.1026	0.1759	0.2206	0.1813	0.1945	0.2078
Firm FE	yes	yes	yes	yes	yes	yes	yes
Year FE	yes	yes	yes	yes	yes	yes	yes

Table 5.5, Column (1) is our baseline specification. In Columns (2)-(4), we replace `capx/at` with the net investment rate as in Ottonello and Winberry (2020), `capxv/at` and `capx/ppent`, respectively. Firm size is measured by size1=`at`, size2=replacement value of capital, size3=`ppent`. Columns (5)-(7) consider alternative measure of investment opportunity and check the impact of cash flow and book leverage. Time FE is not reported, while firm FE is eliminated using the within transformation. Robust standard errors reported in parentheses are clustered at the firm level. Asterisks are significance levels: ***=1%, **=5%, *=10%.

Table 5.6: Different uncertainty measures and rolling windows

investment/assest	(1)	(2)	(3)	(4)	(5)	(6)	(7)
mkt/book	0.0070***	0.0070***	0.0071***	0.0071***	0.0071***	0.0073***	0.0073***
	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)
sale/ass	0.0131***	0.0133***	0.0135***	0.0136***	0.0137***	0.0133***	0.0129***
	(0.0011)	(0.0011)	(0.0011)	(0.0011)	(0.0011)	(0.0011)	(0.0011)
cash/ass	0.0151***	0.0157***	0.0160***	0.0161***	0.0162***	0.0162***	0.0180***
	(0.0032)	(0.0032)	(0.0032)	(0.0032)	(0.0032)	(0.0032)	(0.0032)
size	-0.0069***	-0.0070***	-0.0071***	-0.0071***	-0.0071***	-0.0058***	-0.0058***
	(0.0007)	(0.0007)	(0.0007)	(0.0007)	(0.0007)	(0.0007)	(0.0007)
age	-0.0040***	-0.0038***	-0.0037***	-0.0035***	-0.0035***	-0.0043***	-0.0041***
	(0.0007)	(0.0007)	(0.0007)	(0.0007)	(0.0007)	(0.0007)	(0.0007)
vol(profit)3y	-0.0054***						
	(0.0003)						
vol(profit)4y		-0.0049***					
		(0.0003)					
vol(profit)5y			-0.0044***				
			(0.0003)				
vol(profit)6y				-0.0041***			
				(0.0003)			
vol(profit)7y					-0.0039***		
					(0.0003)		
vol(emp)						-0.0299***	
						(0.0030)	
vol(sale)							-0.0470***
							(0.0036)
Num. of obs.	81070	81070	81070	81070	81070	78654	81070
R-sq(within)	0.1676	0.1661	0.1647	0.1639	0.1633	0.1619	0.1618
Firm FE	yes	yes	yes	yes	yes	yes	yes
Year FE	yes	yes	yes	yes	yes	yes	yes

Table 5.6, Columns (1)-(5) consider the influence of different time windows of profit volatility, while all other variables are defined as in Table 5.1. Columns (6)-(7) replace profit volatility with employment and sale volatility, respectively. Time FE is not reported, while firm FE is eliminated using the within transformation. Robust standard errors reported in parentheses are clustered at the firm level. Asterisks refer to significance levels: ***=1%, **=5%, *=10%.

Table 5.7: Effects of uncertainty and profits

investment/asset	(1)	(2)	(3)	(4)	(5)	(6)	(7)
vol(profit)	-0.0044***	-0.0012***	0.0002	0.0003	0.0017	-0.0000	-0.0002
	(0.0003)	(0.0003)	(0.0003)	(0.0003)	(0.0013)	(0.0005)	(0.0003)
mkt/book	0.0071***	0.0038***	0.0035***	0.0039***	0.0021***	0.0049***	0.0029***
	(0.0002)	(0.0002)	(0.0002)	(0.0003)	(0.0007)	(0.0004)	(0.0003)
sale/ass	0.0135***	0.0051***	0.0052***	0.0046***	0.0166***	0.0055***	0.0043***
	(0.0011)	(0.0011)	(0.0011)	(0.0012)	(0.0037)	(0.0018)	(0.0012)
cash/ass	0.0160***	0.0012	0.0009	0.0024	0.0075	0.0166***	0.0055
	(0.0032)	(0.0032)	(0.0032)	(0.0034)	(0.0071)	(0.0060)	(0.0034)
size	-0.0071***	-0.0100***	-0.0100***	-0.0105***	-0.0040*	-0.0122***	-0.0092***
	(0.0007)	(0.0007)	(0.0007)	(0.0008)	(0.0023)	(0.0013)	(0.0008)
age	-0.0037***	-0.0019*	-0.0019*	-0.0023**	0.0021	-0.0054***	0.0003
	(0.0007)	(0.0010)	(0.0010)	(0.0011)	(0.0039)	(0.0018)	(0.0010)
profit		0.1494***	0.1779***	0.1835***	0.0972***	0.2347***	0.1088***
		(0.0045)	(0.0060)	(0.0064)	(0.0171)	(0.0087)	(0.0066)
profit × vol(profit)			-0.0443***	-0.0477***	-0.0394**	-0.0570***	-0.0223***
			(0.0044)	(0.0046)	(0.0190)	(0.0069)	(0.0047)
Sample	all	all	all	dpr $\leq$ 0.20	dpr $>$ 0.20	$cir > med(cir)$	$cir \leq med(cir)$
Observations	81070	71764	71764	62619	9094	35852	35912
R-squared	0.1647	0.1959	0.1986	0.2020	0.1171	0.2235	0.1462
Firm FE	yes	yes	yes	yes	yes	yes	yes
Year FE	yes	yes	yes	yes	yes	yes	yes

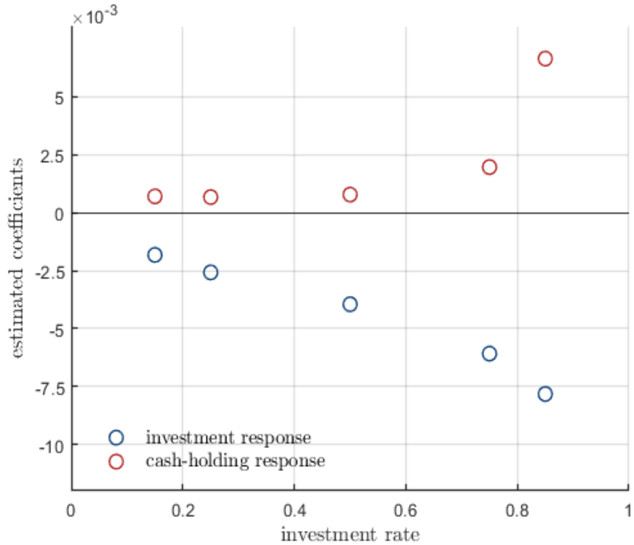
Table 5.7, Columns (1) is our baseline regression specification. Column (2) controls for the impacts of the first moment of profits. Column (3) explores the influence of both the first and second moments of profits. Columns (4)-(7) measure the investment sensitivity to demand, conditional on the level of financial constraint and the degree of irreversible investment, as in Kermani and Ma (2023). Time FE is not reported, while firm FE is eliminated using the within transformation. Robust standard errors reported in parentheses are clustered at the firm level. Asterisks refer to significance levels: ***=1%, **=5%, *=10%.

Table 5.8: Instrumenting profit volatility with past profit volatility

investment/asset	(1)	(2)	(3)	(4)
vol(profit)	-0.0044***	-0.0044***	-0.0030***	-0.0018*
	(0.0003)	(0.0004)	(0.0005)	(0.0011)
mkt/book	0.0071***	0.0070***	0.0068***	0.0068***
	(0.0002)	(0.0003)	(0.0003)	(0.0003)
sale/ass	0.0135***	0.0140***	0.0150***	0.0162***
	(0.0011)	(0.0012)	(0.0013)	(0.0014)
cash/ass	0.0160***	0.0143***	0.0133***	0.0132***
	(0.0032)	(0.0033)	(0.0035)	(0.0037)
size	-0.0071***	-0.0070***	-0.0069***	-0.0064***
	(0.0007)	(0.0008)	(0.0008)	(0.0010)
age	-0.0037***	-0.0034***	-0.0034**	-0.0043**
	(0.0007)	(0.0011)	(0.0014)	(0.0018)
Num. of obs.	81043	75281	65745	58049
R-sq(within)	0.1647	0.1604	0.1533	0.1519
Firm FE	yes	yes	yes	yes
Year FE	yes	yes	yes	yes
Instrument		1y lag	2y lag	3y lag

Table 5.8, Column (1) contains our baseline OLS regression results. Uncertainty about profit growth rate is instrumented with one, two, and three lagged years. The IV regression results are presented in Columns (2)-(4). Time FE is not reported, while firm FE is eliminated using the within transformation. Robust standard errors reported in parentheses are clustered at the firm level. Asterisks refer to significance levels: ***=1%, **=5%, *=10%.

Figure 5.14: Investment and cash-holding responses to uncertainty



Notes: Blue dots present point estimates from the OLS regression of the investment rate on firm-level profit growth volatility. These regression results are obtained from equation (3.1) at different points in the investment rate distribution. Similarly, red dots illustrate the impact of idiosyncratic profit volatility on cash holdings at various quantiles.

Abstrakt

Tento článek zkoumá, jak volatilita zisku ovlivnila rozhodování firem v posledních čtyřech desetiletích. Na základě údajů z Compustat zjišťujeme, že: (1) firmy s vysokou mírou investic snižují míru investic výrazněji než ostatní firmy, což znamená, že pro účinky nejistoty jsou důležitá rozsáhlá investiční rozhodnutí – zda investovat do nových projektů či nikoliv; (2) interakce mezi finančními a reálnými podmínkami firem zesiluje negativní dopad zvýšené nejistoty na míru investic. Vytváříme a kalibrujeme také model heterogenních firem, který zahrnuje reálné i finanční náklady. V tomto modelu vyšší náklady na přizpůsobení kapitálu zvyšují míru nečinnosti investic o 31 %, zatímco vyšší finanční náklady snižují míru nárůstu investic o 46 %. Zahrnutí nevratného kapitálu do kolaterálního omezení snižuje zadluženost firem, což vede ke zvýšení míry investiční nečinnosti, držby hotovosti a čistých dividend.

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