The Finance-Uncertainty Multiplier*

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Abstract

We show theoretically and empirically how real and financial frictions amplify the impact of uncertainty shocks on firms' investment, employment, debt (term structure of debt growth), and cash holding. We start by building a model with real and financial frictions, alongside uncertainty shocks, and show how adding financial frictions to the model roughly doubles the negative impact of uncertainty shocks on investment and hiring. The reason is higher uncertainty induces the standard negative real-options effects on the demand for capital and labor, but also leads firms to hoard cash and cut debt to hedge against future shocks, further reducing investment and hiring. We then test the model using a panel of US firms and a novel instrumentation strategy for uncertainty exploiting differential firm exposure to exchange rate and factor price volatility. We find that higher uncertainty reduces real investment and hiring, while also leading firms to increase cash holdings by cutting debt, dividends and stock-buy backs, and these effects are strongest in periods of higher financial frictions and for the most financially constrained firms. This highlights why in periods with greater financial frictions – like during the global-financial-crisis – uncertainty can be particularly damaging.

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1 Introduction

We study theoretically and empirically the impact of uncertainty shocks on firms' real and financial activity including investment, employment, debt, payout, and cash holding. We start by building a model with real and financial frictions, alongside uncertainty shocks, and show how adding financial frictions to the model almost doubles the negative impact of uncertainty shocks on investment and hiring. The reason is higher uncertainty induces the standard negative real-options effects on the demand for capital and labor, but also leads firms to hoard cash and cut debt to hedge against future shocks, further reducing investment and hiring. Furthermore, firms cut short-term debt more than long-term debt, causing a negative relation between uncertainty and the term structure of debt issuance.

We then test this model of real and financial frictions using a panel of US firms and a novel instrumentation strategy for uncertainty exploiting differential firm exposure to exchange rate, factor price and policy uncertainty. We find that higher uncertainty significantly reduces real investment and hiring, while also leading firms to take a more cautious financial position by increasing cash holdings and cutting debt, dividends and stock-buy backs. These findings highlight not only the importance of financial frictions for amplifying the impact of uncertainty shocks, but also how in periods with greater financial frictions – like during the global-financial-crisis – how uncertainty can be particularly damaging.

To understand the effects of uncertainty shocks on real activity and financial flows, we build a dynamic structural model including both real and financial frictions that amplify the impact of uncertainty shocks . It features a large cross section of firms where heterogeneity is driven by firm-specific productivity. Uncertainty is time-varying, so the model includes shocks to both the level of firms' productivity (the first moment) and its conditional volatility (the second moment). On the real side, investment incurs fixed cost and is partially irreversible (e.g. Cooper and Haltiwanger 2006) while employment is frictionless adjusted. On the financing side, building on the existing literature on capital structure models (e.g., Hennessy and Whited 2005), firms issue both short-term and long-term debt to finance investment, both of which are costly to issue. Long-term debt has a longer maturity than short-term debt and pays out a periodic coupon. The adjustment costs on short-term and long-term debt captures the cost of liquidity risk on short-term debt (e.g., Diamond 1991) and the agency costs (asset substitution) associated with long-term debt (e.g., Myers 1977, Barclay and Smith 1995, Hoven Stohs and Mauer 1996). In addition, both short-term and long-term debt are subject to collateral constraints which limit firms' debt capacity. Firms also issue external equity in addition to debt to finance investment. External equity is assumed to be costly to capture equity flotation cost and information cost on equity issuance. Firms make investment, long-term debt, and short-term debt issuance/cash saving decisions to maximize the market value of equity. In the model, firms face the trade-off between the liquidation and issuance cost and the tax benefit of short-term debt and long-term debt in presence of time-varying uncertainty. Additionally, firms also manage the trade-off between total debt, equity, and cash in financing capital investment.

The model highlights the endogenous interactions between uncertainty shocks, investment, short-term and long-term debt issuance, and cash saving decisions. Intuitively, when uncertainty is high, firms reduce capital investment and employment, a standard prediction implied by investment models with fixed cost and partial irreversibility on investment. Furthermore, when financial frictions exist firms also want to build up cash to hedge against future potential shocks. This provide an additional impetus to cut investment and equity payout to cut cash outflows. Firms also want to reduce debt to increase their flexibility to respond to shocks, so lower debt levels, particularly short-term debt which is the most restrictive.

As a broad motivation for the model Figure 1 shows the correlations of the quarterly VIX index which proxies for aggregate uncertainty and the aggregate real and financial variables. The top two panels show that times of high aggregate real investment rate and employment growth are negatively correlated with the low VIX. The middle two panels show that the total debt (sum of the short-term and long-term debt) growth and the term structure of the debt growth (short-term debt growth to long-term debt growth ratio) are negatively related with the VIX, implying firms cut the short-term debt more than the long-term debt when uncertainty shock is high. The bottom two panels show that cash holding is positively while dividend payout and equity repurchase are negatively related to the VIX.

We also test these predictions on a panel of US firms. One issue with estimating investment-uncertainty regressions is endogeneity, highlighted by theoretical and empirical evidence arguing for reverse causality from growth to uncertainty[1]. Our view is that both channels likely operate - uncertainty both reduces growth (an impact mechanism) and lower growth increases uncertainty (an amplification mechanism). Hence, the approach in this paper is to start by investigating the causal channel of uncertainty on growth, leaving the reverse causality amplification mechanism to explore in other papers.

To investigate the causal impact of uncertainty we develop an instrumentation strategy that exploits firm's differential exposure to energy and currency uncertainty (as measured by at-the-money forward call options for oil and 7 widely traded currencies) as well as policy uncertainty (proxied by the industry level exposure measure from Baker, Bloom and Davis (2016). This identification strategy works well delivering a first-stage F-statistic of between 20 to 40 and passing the Hansen over-identification test. Our second stage results reveal that higher uncertainty significantly reduces real activity (proxied by investment, hiring, input and sales growth), while also leading firms to take a more cautious financial position (by increasing cash holdings, and cutting debt, dividends and stock-buy backs). Furthermore, high uncertainty also cause firms to adjust the term structure of debt growth towards to the long-term debt, i.e., firms cut the long-term debt than the short-term debt facing high uncertainty shocks. These results are consistent with the model predictions.

Related literature Our paper relates to the investment literature that studies the impact of real frictions on investment dynamics (e.g., Doms and Dunne (1998), Davis and Haltiwanger

[1]See, for example, Van Nieuwerburgh and Veldkamp 2006; Bachman and Moscarini 2012; Pastor and Veronesi 2012, Orlik and Veldkamp 2015, Berger, Dew-Becker and Giglio 2016, and Fajgelbaum et al. 2016, for models and empirics on reverse causality with uncertainty and growth.

(1992), Caballero, Engel, and Haltiwanger (1995), Cooper and Haltiwanger (2006)). In particular, we are complementary to Abel and Eberly (1996) who show that costly reversibility is important to explain the real investment dynamics. We differ in that we show that time-vary uncertainty and financial frictions also play important roles in capturing firm-level real investment activity in addition to real frictions.

This paper also contributes to the growing literature that studies the impact of uncertainty shocks on firms real decisions and business cycle fluctuations. For example, Leahy and Whited (1996), Gusio and Parigi (1999) and Bloom, Bond, and Van Reenen (2007) all provide evidence suggesting that firm-level uncertainty shocks reduces firms' investment and labor hiring, while Ramey and Ramey (1995), Bloom (2009), Fernandez-Villaverde et al. (2011) provide evidence suggesting macro uncertainty shocks appear to drive business cycle fluctuations.[2]

Our empirical analysis also relates to the empirical corporate finance literature that studies the determinants of capital structure choice, e.g., Rajan and Zingalas (1995), Welch (2004), etc. We are complementary to these studies by showing that uncertainty shocks have significant impact on firms' financial flows. Our paper is closely related to Chen et. al. (2014) who also look at the impact of uncertainty shocks on firms' financing decisions. We differ in that empirically we use the instrumentation approach to study the causal effect of past uncertainty on the future changes of firms' financing flows and also build a structural model to interpret our results, while Chen et. al. (2014) focus on the contemporaneous relations between realized volatility and capital structure.

This paper also relates to the literature that examines the impact of financial frictions on corporate investment and financial flows. Hennessy and Whited (2005) study firms' leverage choice and investment decisions in the presence of financial distress costs and equity flotation costs. Bolton, Chen, and Wang (2013) study firms' investment, financing, and cash management decisions in a dynamic q-theoretic framework in which, external financing

[2] A more extensive literature review is contained in survey paper Bloom (2014).

conditions are stochastic. Rampini and Viswanathan (2013) examine the relationship between investment, capital structure, leasing and risk management and show that collateral is a key determinant of firms' capital structure. Our analysis is complementary to these studies in that we focus on the impact of uncertainty shocks on firms' capital structure choice, a dimension that is not studied in these papers.

On the macro side we have similarities to Alessandri and Mumtaz (2016) and Lhuissier and Tripier (2016) who show in VAR estimates a strong interaction effect of financial constraints on uncertainty. More generally Arellano, Bai and Kehoe (2012) and Christiano, Motto and Rostagno (2014) both focus on the macro impact of changes in micro-uncertainty through the lens of financial constraints via costs of default. The former does this via the financing costs needed by entrepreneurs to hire labor in advance, while the latter focuses on the capital accelerator channel of entrepreneurs requiring external finance for capital investment.

The papers closest to ours are: Gilchrist, Sim and Zakrajsek (2014) who examine the interaction between uncertainty and financial constraints, focusing on the importance of credit conditions in channeling the impact of uncertainty shocks; and Chen (2016) who investigates how firms manage their joint financing and investment when aggregate uncertainty is time-varying, noting positive interactions. We differ in that we study the impact of firms' uncertainty on the debt and the term-structure choice in addition to liquidity management, we empirically use the instrumentation approach to identify the causal effect of uncertainty on real and financial additivity, and focus on the multiplicative effect of financial constraints and uncertainty, particularly during recessions.

The rest of the paper is laid out as follows. In section 2 we write down the model. In section 3 we present the main quantitative results of the model. In section 4 we describe the international data that we use in the paper. In section 5 we present the empirical findings on uncertainty shocks and financial flows. Section 6 concludes.

2 Model

The model features a continuum of heterogeneous firms facing uncertainty shocks and financial frictions. Firms take on both short-term debt (or save in cash) and long-term debt and trade off the tax benefit of debt and liquidation cost. Firms choose optimal levels of physical capital investment, labor, and short-term debt (cash) and long-term debt each period to maximize the market value of equity.

2.1 Technology

Firms use physical capital (K_t) and labor (H_t) to produce a homogeneous good (Y_t). To save on notation, we omit firm index whenever possible. The production function is given by

$$Y_t = \widetilde{Z}_t K_t^{\alpha} H_t^{1-\alpha}, \tag{1}$$

in which $\widetilde{Z}_t$ is firms' productivity. The firm faces an isoelastic demand curve with elasticity (ε),

$$Q_t = X P_t^{-\varepsilon},$$

where X is a demand shifter. These can be combined into a revenue function $R(Z_t, X, K_t, H_t) = \widetilde{Z}_t^{1-1/\varepsilon} X^{1/\varepsilon} K_t^{\alpha(1-1/\varepsilon)} (H_t)^{(1-\alpha)(1-1/\varepsilon)}$. For analytical tractability we define $a = \alpha(1-1/\varepsilon)$ and $b = (1-\alpha)(1-1/\varepsilon)$, and substitute $Z_t^{1-a-b} = \widetilde{Z}_t^{1-1/\varepsilon} X^{1/\varepsilon}$. With these redefinitions we have

$$S(Z, K, H) = Z_t^{1-a-b} K_t^a H_t^b.$$

Wages are normalized to 1 denoted as $\bar{W}$. Given employment is flexible, we can obtain optimal labor.[3] Note that labor can be pre-optimized out even with financial frictions which will be discussed later.

[3] Pre-optimized labor is given by $\left(\frac{b}{\bar{W}} Z_t^{1-a-b} K_t^a\right)^{\frac{1}{1-b}}$.

Productivity is defined as a combination of a firm and aggregate productivity process, both following an AR(1) process

$$z_{t+1} = z_{t+1}^{f} + z_{t+1}^{m} \tag{2}$$

$$z_{t+1}^{f} = \bar{z}^{f}(1-\rho_z) + \rho_z z_t^{f} + \sigma_t^{f} \varepsilon_{t+1}^{zf} \tag{3}$$

$$z_{t+1}^{m} = \bar{z}^{m}(1-\rho_z) + \rho_z z_t^{m} + \sigma_t^{m} \varepsilon_{t+1}^{zm} \tag{4}$$

in which (dropping the firm and macro superscript for simplicity) $z_{t+1} = \log(Z_{t+1})$, ε_{t+1}^{z} is an i.i.d. standard normal shock (drawn independently across firms and at the macro level), and $\bar{z}$, ρ_z, and $\sigma_t^{\{f,m\}}$ are the mean, autocorrelation, and conditional volatility of the productivity processes.

The firm and macro stochastic volatility processes are both assumed for simplicity to follow the same two-point Markov chains

$$\sigma_t^{\{f,m\}} \in \left\{\sigma_L^{\{f,m\}}, \sigma_H^{\{f,m\}}\right\}, \text{where } \Pr\left(\sigma_{t+1}^{\{f,m\}} = \sigma_j^{\{f,m\}} | \sigma_t^{\{f,m\}} = \sigma_k^{\{f,m\}}\right) = \pi_{k,j}^{\sigma}, \tag{5}$$

where we assume that the firm and macro volatility processes are uncorrelated.

Physical capital accumulation is given by

$$K_{t+1} = (1-\delta)K_t + I_t, \tag{6}$$

where I_t represents investment and δ denotes the capital depreciation rate.

We assume that capital investment is costly reversible and entails nonconvex adjustment costs, denoted as G_t, which are given by:

$$G_t = I_t^{+} + \left(1 - c_k^{P}\right) I_t^{-} + b_k K_t \mathbf{1}_{\{I_t \neq 0\}} \tag{7}$$

in which $c_k^P, b_k > 0$ are constants. I_t^+ and I_t^- are positive and negative investment, respectively. The capital adjustment costs include planning and installation costs, learning to use the new equipment, or the fact that production is temporarily interrupted. The nonconvex costs $b_k K_t \mathbf{1}_{\{I_t \neq 0\}}$ capture the costs of adjusting capital that are independent of the size of the investment. The costly reversibility can arise because of resale losses due to transaction costs or the market for lemons phenomenon. The resale loss of capital is labelled c_k^P and is denominated as a fraction of the relative purchase price of capital.

2.2 Long-term and short-term debt and collateral constraint

Firms use equity as well as short-term (one period) debt and long-term (multi-period) debt to finance investment. At the beginning of time t, firms can issue an amount of short-term debt, denoted as B_t^S, which must be repaid at the beginning of period $t+1$. Following Hackbarth, Miao, and Morellec (2006) we model long-term debt with finite maturity via sinking funds provisions. We denote by B_t^L the book value of long-term debt that firms have outstanding at time t. Long-term corporate bonds pay a fixed coupon c in every period and a fraction θ is paid back each period (after payment of the coupon) with $0 < \theta < 1$. The average maturity of these long-term bonds then corresponds to $1/\theta$ periods. Denoting new long-term bond issuance by N_t, the amount of long-term corporate bonds evolves as

$$B_{t+1}^L = (1-\theta)\, B_t^L + N_t \tag{8}$$

The firm's ability to borrow is bounded by the limited enforceability as firms can default on their obligations. Following Hennessy and Whited (2005), we assume that the only asset available for liquidation is the physical capital K_t. In particular, we require that the respective liquidation values of capital is greater than or equal to the short and the long-term bonds, and that the sum of the short-term and long-term bonds cannot exceed the liquidation value of capital either. It follows that the collateral constraints are given by

$$
\begin{aligned}
B_{t+1}^S &\leq \varphi^S K_t. &\quad (9)\\
B_{t+1}^L &\leq \varphi^L K_t. &\quad (10)
\end{aligned}
$$

The parameters φ^S, φ^L are constants satisfying the constraints $0 < \varphi^S < \varphi^L < 1$, $0 < \varphi^S + \varphi^L \leq 1$ which affect the tightness of the collateral constraints, and therefore, the borrowing capacity of the firm. Due to the collateral constraints, the interest rate, denoted by r_f, is the risk-free rate which is assumed constant.

Firms can also save in cash when the short-term debt B_t^S takes on negative values. Firms also incur adjustment costs on debt, denoted by Φ_t when changing the amount of short-term debt and long-term debt outstanding,

$$
\Phi_t = b^S K_t \mathbf{1}_{\{\Delta B_t^S \neq 0 \text{ and } B_t^S > 0\}} + b^L K_t \mathbf{1}_{\{N_t \neq 0\}} \quad (11)
$$

where $\Delta B_t^S = B_t^S - B_{t-1}^S$, and $b^S, b^L > 0$. The debt adjustment costs capture the fact that adjusting capital structure is costly in terms of both managerial time and also issuance costs. For short-term debt, it captures the cost associated with liquidity risk, e.g., borrowers are forced into inefficient liquidation because refinancing is not available, thus prefer long-term contract (Diamond 1991). For long-term debt, it captures the agency costs associated with long-term debt (Myers 1977), e.g., the under-investment problem associated with debt overhang in the long-term debt contract. It also captures the information cost associated with long-term contract as borrowers with favorable inside information may avoid locking in their financing cost with long-term debt contracts. Lastly, cash is freely adjusted.

2.3 Costly external equity financing

Taxable corporate profits are equal to output less capital depreciation and interest expenses: $S_t - \bar{W}H_t - \delta K_t - r_f B_t^S \mathbf{1}_{\{B_t^S>0\}} - cB_t^L$. It follows that the firm's budget constraint can be written as

$$\begin{aligned} E_t &= (1-\tau)\left(S_t - \bar{W}H_t\right) + \tau\delta K_t + \tau r_f B_t^S \mathbf{1}_{\{B_t^S \geq 0\}} + \tau c B_t^L - I_t - G_t + B_{t+1}^S - (1+r_s)B_t^S \\ &\quad + N_t - (c+\theta)\, B_t^L - \Phi_t, \end{aligned} \tag{12}$$

in which τ is the corporate tax rate, $\tau\delta K_t$ is the depreciation tax shield, $\tau r_f B_t \mathbf{1}_{\{B_t^S>0\}}$ and $\tau c B_t^L$ are the interest tax shields where c is the coupon rate, and E_t is the firm's payout. When $B_t^S > 0$, short-term debt interest rate is $r_s = r_f$; when short-term debt is negative, cash saving rate is assumed to be $r_s = 0$.

When the sum of investment, capital, and debt adjustment costs exceeds the sum of after tax operating profits and debt financing, firms can take external funds by means of seasoned equity offerings. External equity O_t is given by

$$O_t = \max\left(-E_t, 0\right). \tag{13}$$

In practice, firms face external equity financing costs, which involve both direct and indirect costs. We do not explicitly model the sources of these costs. Rather, we attempt to capture the effect of the costs in a reduced-form fashion. The external equity costs are similarly to debt assumed to scale with firm size as measured by the capital stock:

$$\Psi\left(O_t\right) = \eta K_t \mathbf{1}_{\{O_t>0\}}. \tag{14}$$

Finally, firms do not incur costs when paying dividends or repurchasing shares. The effective cash flow D_t distributed to shareholders is given by[4]

$$D_t = E_t - \Psi_t. \tag{15}$$

2.4 Firm's problem

Firms solve the maximization problem by choosing capital investment, labor, short-term debt/cash and long-term debt optimally:

$$V_t = \max_{I_t, H_t, B^S_{t+1}, B^L_{t+1}} D_t + \beta \mathbb{E}_t V_{t+1}, \tag{16}$$

subject to firms' capital accumulation equation (Eq. 6), collateral constraints (Eq. 9 and 10), budget constraint (Eq. 12), and cash flow equation (Eq. 15).

3 Main results

This section presents the model solution and the main results. We first calibrate the model, then we simulate the model and study the quantitative implications of model for the relationship between uncertainty shocks and firms' real activity and financial flows.

3.1 Calibration

The model is solved at a monthly frequency. Because all the firm-level accounting variables in the data are only available at an annual frequency, we time-aggregate the simulated accounting data to make the model-implied moments comparable with those in the data.

Table 1 reports the parameter values used in the baseline calibration of the model. The model is calibrated using parameter values reported in previous studies, whenever possible, or by matching the selected moments in the data reported in Table 2. To evaluate the model

[4] In reality, firms tend to smooth dividends payout. We don't model dividend adjustment cost because that would introduce another state variable which would further complicate the problem.

fit, the table reports the target moments in both the data and the model. To generate the model's implied moments, we simulate $3,000$ firms for $1,000$ monthly periods. We drop the first 400 months to neutralize the impact of the initial condition. The remaining 600 months of simulated data are treated as those from the economy's stationary distribution. We then simulate 100 artificial samples and report the cross-sample average results as model moments.

[Insert Table 1 here]

[Insert Table 2 here]

We split the parameters into two groups. The first group includes those parameters which are based on the estimates in the previous literature including $\left\{\alpha, \varepsilon, \delta, \beta, c, \theta, \eta, \rho_z, \sigma_L^{\{f,m\}}, \sigma_H^{\{f,m\}}, \pi_{L,H}^{\sigma}, \pi_{H,H}^{\sigma}, \bar{z}\right\}$. We set the share of capital the production function at $1/3$, and the elasticity of demand ε to 4 which implies a markup of 33%, consistent with Hall (1988). The capital depreciation rate δ is set to be 1% per month. The discount factor β is set so that the real firms' discount rate $r_f = 4\%$ per annum, close the average of the real annual S&P index return in the data. This implies $\beta = 0.9967$ monthly. The rate of retirement of the long-term debt $\theta = 1/120$, implying the length of the long-term contract is 10 years, close to the empirical estimate in Guedes and Opler (1996). The monthly coupon rate c is set to 5% per year, implying that the average term premium is 1% per annum, close to the average in the U.S. We set the calibrate equity issuance cost parameters so that on average it costs 8% of the total level of issuance, consistent with the estimates in Altinkilic and Hansen (2000) and the estimates in Hennessy and Whited (2007). The fraction of equity issuance implied by the model is 23% close to the data at 17% estimated in Belo, Lin, and Yang (2016). We set the persistence of firms' micro and macro productivity as $\rho_z = 0.97$ following Khan and Thomas (2008). We set the baseline firm volatility as $\left\{\sigma_L^f, \sigma_L^m\right\} = \{0.10, 0.02\}$ and the high uncertainty state $\sigma_H^{\{f,m\}} = 2 * \sigma_L^{\{f,m\}}$, close to the level in Bloom (2009). We set transition probabilities of $\pi_{L,H}^{\sigma} = 1/36$, and $\pi_{H,H}^{\sigma} = 1 - 1/36$, consistent with one uncertainty shock every three years. The long-run average level of firm-specific and macro productivity, $\bar{z}^f$ and $\bar{z}^m$ are arbitrary scaling variables which we set to unity.

The second group contains the six parameters calibrated to match some moments in the data, including $\{c_k^P, b_k, b^S, b^L, \varphi^S, \varphi^L\}$. We calibrate the capital adjustment cost parameters to match several cross-sectional and time-series moments of firms' investment rates. Table 2 shows that this calibration of the model matches reasonably well the volatility of firm-level investment rate. The investment resale loss parameter c_k^P is set at 2.5% to match the inaction region in investment rate. Investment fixed cost parameter b_k is set at 0.01. The implied volatility of investment rate is 24%, close to the data moment at 23%. We calibrate the short-term and long-term debt adjustment cost parameters $b^S = b^L = 0.03\%$ and the tightness of the collateral constraint for short-term and long-term debt $\varphi^S = 0.3$ and $\varphi^L = 0.55$ to match the average level of financial leverage at 0.55 and the short-term debt to long-term ratio at 0.27 in the data. The model implied average leverage is 0.50 and the implied short-term debt to long-term ratio is 0.19, close to the data moment.

3.2 Uncertainty shocks, real and financing flows

In this subsection, we conduct the panel regression analysis using the artificial data obtained from the simulation of the model. For the real data we regress the rates of investment, employment growth, short-term debt and long-debt growth, the term structure of debt growth (the ratio of the short-term debt growth to the long-term debt growth), cash holding growth, and payout (dividend plus share repurchase) growth on one-year lagged stock return volatilities, alongside a full set of firm and year fixed-effects. To align simulated results with these real data results we aggregate monthly simulated data to annual values summing flow variables like sales over the year and taking year end values for stock variables like capital, and then use the same lag and fixed-effect structure in the regressions. Hence, we construct our simulated accounting data regressions to exactly mimic the process for the real data regressions.

Panel A in Table 3 presents the benchmark calibration result while panel E presents the data moments which will be discussed in detail in section 5. The model predicts a negative relation between past return volatility and investment rate, and employment growth in the univariate regressions. The model implied univariate regression slopes of investment and employment growth are -0.012 and -0.011, reasonably close to their respective data moments of -0.020 and -0.022 (noting that we did not calibrate our parameters to meet these moments). Turning to financial flows, the model also predicts a negative relation between past return volatility and short-term debt growth and a negative relation between past return volatility and the term structure of debt growth. The model implied slope coefficients on debt growth and the term structure of debt growth are -0.017 and -0.238, respectively, again reasonably close to the data moments of -0.045 and -0.103. Furthermore, cash holding growth and past return volatility are positively correlated; the model implied slope is 0.229, somewhat higher than the data at 0.078. Dividend payout growth is negatively correlated with past return volatility; the model implied moment is -0.109, smaller than the data slope at -0.257. So, overall these six qualitative predictions from the model fit the data.

[Insert Table 3 here]

3.3 Inspecting the mechanism

In this section we first study the impulse responses of the real and financial variables in the benchmark model and then compare them to a model without financial frictions.

To simulate the impulse response, we run our model for 400 periods and then in month zero kick every simulation level of uncertainty up to its high level, and then let the model to continue to run as before. Hence, we are simulating a one period increase in uncertainty on the ergodic distribution. We perform this analysis 100 times and take the average (to average across macro shocks) for the benchmark model and a model without financial adjustment costs, i.e., debt and equity issuance costs are zero. Figure 2 plots the impulse responses of the main real and financial variables. For the real variables we see upon impact capital and employment levels drop and slowly recover, while debt drops, particularly short-run debt, as does equity payout, so that cash holdings rise. We also see that compared to the benchmark, the simulation with no financial frictions has a smaller and less persistent impact on real variables. This highlights the role of financial frictions in multiplying the impact of uncertainty shocks on investment and hiring - if the future is uncertain and it is expensive to tap debt or equity funding, firms increase their cash holdings.

We also see that without financial frictions there is no impact of uncertainty on cash. The reason is that without financial frictions firms do not hold cash as it pays no interest and it has no liquidity value since debt and equity are perfectly liquid. Since firms do not hold cash the impact of uncertainty on other financial variables is muted (they observed impact is entirely driven by the financing requirements of investment and hiring).

Lastly figure 3 plots the impulse responses of output in the benchmark model and the model without financial frictions. Upon impact, output falls with similar magnitudes when volatility is high in both two cases. However, after the impact, the response of output in the model without financial frictions reverts to the stead state level immediately whereas the response of output in the benchmark model with financial frictions persists for more than 12 months before reverting to the long-run level. Taken together, financial frictions clearly amplify the impact of uncertainty shocks on real and financial variables.

Next we perform several comparative statics analyses to show the economic forces driving the overall good fit of the model. Panels B and C in Table 3 present the results. We consider two specifications:

- A model without real frictions (no partial irreversibility $c_k^P = 0$ and fixed cost is zero $b_k = 0$, and
- A model without financial frictions (no debt and equity issuance costs $b^S = b^L = \eta = 0$).

The results without real frictions are reported in panel B of Table 3. We see the responses of investment rate, employment and cash growth drop substantially relative to the benchmark. For example, the slope on investment drops from -0.012 in the benchmark to -0.002, employment growth from -0.011 to -0.009, and cash growth from 0.229 to 0.079. Furthermore, the term structure of debt growth loads positively, 0.010 compared to -0.238 in the benchmark and -0.103 in the data, which is counterfactual to the data. The slope on dividend growth does not change significantly (-0.109 in the benchmark compared to -0.108 in Panel A). Hence, real-frictions are needed to get reasonable real - and in this case financial - variable responses to uncertainty shocks.

When we shut down the financial frictions in panel C (i.e., both short-term and long-term debt and equity issuances are free), the slope coefficients on investment rate and employment growth drop by around half (from -0.012 in the benchmark to -0.007 for investment and from -0.011 to -0.007 for employment growth). This finding shows that financial frictions play an important role amplifying the effect of uncertainty shocks on real quantities. In addition, the coefficient on debt growth falls by more than two thirds from -0.017 to -0.005. The term structure of debt growth becomes unresponsive to the volatility shock, the slopes drops to zero, compared to -0.238 in the benchmark. Turning to cash, because all marginal sources of external financing are free now (debt up to the collateral constraints), firms do not save precautionarily, thus the equilibrium cash holding is zero. Similar to Panel C, dividend growth does not drop significantly, from -0.109 in the benchmark to -0.094. Taken together, these comparative analyses show that both real frictions and financial frictions amplify the impact of the uncertainty shocks and are jointly important for the model to capture the quantitative effect of uncertainty shocks on real and financial activity.

Lastly, we study the impact of uncertainty shock for real and financial activity in recessions. To simulate a recession in the model, we let the model run for 400 months, then induce an aggregate productivity shock in month 0 and then let firms productivity evolve again following the standard transition process. The productivity shock moves all firms down two productivity levels if possible - so firms at productivity level 5 (the highest level in our 5 point firm grid) move to 3, those at 4 to 2 and those at 3, 2 (or 1) move to 1. Panel D in Table 3 reports the result. Interestingly, the responses of both real and financial variables are much stronger than those in the benchmark calibration during the recession, because financial and real constraints become far more binding. For example, the slope coefficients on investment and employment growth are -0.031 and -0.030, respectively, about 50% bigger in absolute magnitude than the benchmark. The slope coefficients on financial variables including debt, term structure of debt growth, cash growth and payout are -0.043, -0.468, 0.438, and -0.243, respectively, about twice as big in magnitudes as those implied in the benchmark calibration. Hence, we in summary, we find that the triple interaction of real adjustment costs, financial adjustment costs and a recession leads to a dramatic amplification of the impact of uncertainty shocks on firms real and financial behavior.

3.4 General equilibrium type analysis

Currently the model is in a particular equilibrium setting, with a general equilibrium set-up requiring flexibility in four prices: wages, good prices, interest rates and the term-structure (long vs short rates). We are currently working on this extension, but adding these four state variables is complex so it not yet complete.

We should note, however, that in US data wages and inflation rate are acylical (King and Rebelo 1999) and so any well specified general equilibrium (GE) effects should be second order through the wage and good price channel. Interest rates do vary over the cycle, and in particular are negatively correlated with the VIX. Finally, the term structure also appears to be broadly acyclical (and, in particular, is uncorrelated with the VIX). Hence, our main pricing variable we need to consider in GE is interest-rates. As a short-cut to a full GE model we are also testing models assuming interest-rates drops ranging from 1% to 4% after uncertainty shocks (noting the zero-lower bound of a 4% drop). So far we find broad robustness of our results on the impact of uncertainty shocks, with the intuition being that higher uncertainty moves the Ss inaction bands outwards, making firms temporarily unresponsive to prices changes.

{Note: in the long sample of 1963 to 2014, term spread and the VIX have a correlation at 0.06, and this correlation is remain low except during the Financial Crisis period, in which the term spread and the VIX have a correlation is 0.25}.

4 Data and Instruments

We first describe the data and variable construction, then the identification strategy.

4.1 Data

Stock returns are from CRSP and annual accounting variables are from Compustat. The sample period is from January 1963 through December 2014. Financial, utilities and public sector firms are excluded (i.e., SIC between 6000 and 6999, 4900 and 4999, and above 9000). Compustat variables are at the annual frequency. Our main empirical tests involve regressions of changes in real and financial variables on changes in lagged uncertainty, where the lag is both to reduce concerns about endogeneity and because of natural time to build delays . Thus, our sample requires firms to have at least 3 consecutive non-missing data values. To ensure that the changes are indeed annual, we require a 12 month distance between fiscal-year end dates of accounting reports from one year to the next.

In measuring firm-level uncertainty we employ both realized annual uncertainty from CRSP stock returns and option-implied uncertainty from OptionMetrics. Uncertainty measured from stock-returns is the standard-deviation of returns over the accounting year (which typically spans about 252 days). OptionMetrics provides daily implied volatility data for underlying securities from January 1996 through December 2014, with our principal measure being the "at-the-money" "365-day" implied volatility. Additional information about OptionMetrics, Compustat, and CRSP data is provided in Appendix (B).

For all variables growth is defined following Davis and Haltiwanger (1992), where for any variable x_t this is $\Delta x_t = (x_t - x_{t-1})/(\frac{1}{2}x_t + \frac{1}{2}x_{t-1})$, which yields growth rates bounded between -2 and 2. The only exceptions are CRSP stock returns and capital formation. For the latter investment rate (implicitly the change in gross capital stock) is defined as $I_{i,t} = \frac{CAPEX_{i,t}}{K_{i,t-1}}$ where K is net property plant and equipment, and $CAPEX$ is capital expenditures. The changes and ratios of real and financial variables are then all winsorized at the 1 and 99 percentiles.

4.2 Identification Strategy

Our identification strategy exploits firms' differential exposure to energy, currency and policy exposure to generate exogenous changes in firm-level uncertainty. The idea is that some firms are very sensitive to, for example, oil prices (e.g. energy intensive manufacturing and mining firms) while others are not (e.g. retailers and business service firms), so that when oil-price volatility rises this shifts up firm-level volatility in the former group relative to the latter group. Likewise, some industries have different trading intensity with Europe versus Mexico (e.g. industrial machinery versus agricultural produce firms), so changes in bilateral exchange rate volatility generates differential moves in firm-level uncertainty. Finally, some industries - like defense, health care and construction - are more reliant on the Government, so when aggregate policy uncertainty rises (for example, because of elections or government shutdowns) firms in these industries experience greater increases in uncertainty.

This approach is conceptually similar to the classic Bartik (1991) identification strategy which exploits different regions exposure to different industry level shocks, and builds on the paper by Stone and Stein (2013).

The sensitivities to energy and currency prices are estimated at the industry as the factor loadings of a regression of a firm's stock return on energy and currency price changes. That is, for firm i in industry j , $sensitivity_i^c = \beta_j^c$ is estimated as follows

$$r_{i,t}^{risk\_adj} = \alpha_i + \sum_c \beta_j^c \cdot r_t^c + \epsilon_{i,t} \tag{17}$$

where $r_{i,t}^{risk\_adj}$ is the daily risk-adjusted return on firm i (explained below), r_t^c is the change in the price of commodity c, and α_i is firm i's fixed effect. The sensitivities are estimated using daily price data from the twenty years (Jan. 1985 to Dec. 2004) prior to the main two stage least squares (2SLS) estimation period. This estimation is run at the SIC 2-digit industry level to yield sufficient sample size to identify the crucial β_j^c coefficients.

The risk-adjusted return is estimated from the residuals obtained from firm-level regressions on the Carhart (1997) four-factor asset pricing model. In particular, we define the daily risk-adjusted return as the residuals obtained from the time series regression of each firm's excess return on the four factors over the full pre-estimation sample period (1985 to 2004):

$$r_{i,t}^{excess} = \alpha^c + \beta_{i,mkt} \cdot MKT_t + \beta_{i,HML} \cdot HML_t + \beta_{i,SMB} \cdot SMB_t + \beta_{i,UMD} \cdot UMD_t + \varepsilon_{i,t} \quad (18)$$

where $r_{i,t}^{excess}$ is firm i's daily CRSP stock return (including dividends and adjusted for delisting) in excess of the t-bill rate, MKT is the CRSP value-weighted index in excess of the risk free rate, HML is the book-to-market factor, SMB is the size factor, UMD is the momentum factor. These factor data are obtained from CRSP.

We adjust returns for risk to address concerns over whether the sensitivities to energy and currencies (β_j^c in equation 17) are largely capturing market-wide risks instead of exposure to energy and currency shocks. Nonetheless, we report that our main results are largely similar if we skip the risk-adjustment of returns and estimate the sensitivities to energy and currency prices using the raw CRSP returns directly in equation 17.

For energy we use the crude-oil price, and for exchange rates we select the 7 "major" currencies used by the Federal Board in constructing the nominal and real trade-weighted U.S. Dollar Index of Major Currencies.[5] For these eight market prices (the oil price and

[5] see `http://www.federalreserve.gov/pubs/bulletin/2005/winter05_index.pdf` . These include: the euro, Canadian dollar, Japanese yen, British pound, Swiss franc, Australian dollar, and Swedish krona. Each one of these trades widely in currency markets outside their respective home areas, and (along with

the seven exchange rate prices) we need not only their daily levels (for calculating the sensitivities β_j^c in equation 17) but also their annual implied volatilities $\sigma_{j,t}^c$ as a measure of their uncertainty. The composite of these two terms - $\mid \beta_j^c \mid \cdot \sigma_t^c$ - is then an industry-by-year instrument for uncertainty, where the first term is the absolute value of the sensitivity estimated in equation 17 at the industry level. Our instrumental variables estimation thus uses nine instruments - the oil price exposure term, the seven currencies exposure terms, and the policy-uncertainty exposure term (which is defined as industry average share of total revenue from Federal Government contracts times the policy uncertainty index, all of which comes from Baker, Bloom and Davis (2016)).

Finally, to control for any correlations between returns levels and volatilities of these 9 instrumental variables we also include as controls in the IV regressions the exposure times their returns. That is, in the regressions we also include $\beta_j^c \cdot r_t^c$ for the 7 currencies, the oil price and the EPU index (where for the EPU index the r_t^c is the level of government expenditure as a share of GDP).

5 Empirical findings

We start by examining how volatility relates to investment, then other real outcomes finally followed by financial variables.

5.1 Investment results

Table 4 examines how uncertainty influences future capital investment. Column 1 presents the univariate Ordinary Least Squares regression results of investment rate on lagged annual realized stock return volatility. We observe highly statistically significant coefficients on return volatility, showing that firms tend to invest more when their firm-specific uncertainty is low. Column 2 proxies uncertainty with implied volatility, which yields a larger coefficient,

the U.S. dollar) are referred to by the Board staff as major currencies.

although on a much smaller sample because of the limited availability of implied volatility data. While these results are consistent with the model these estimations suffer from endogeneity concerns - for example, changes in firms investment plans could change stock-prices, leading to a causal impact from investment on realized volatility.

We address these identification concerns by using our energy, currency and policy exposure instruments. Column 3 shows the univariate 2SLS results when we instrument lagged realized volatility. We see the point estimate of the coefficient on uncertainty is very near the OLS coefficient in column 1 (while remaining highly statistically significant), possibly because the upward bias from reverse causality roughly offsets the downward attenuation bias from measurement error in realized volatility as a proxy for firm-by-year uncertainty.[6]

A more rigorous test is run in columns 4 and 5, where we include a full set of controls based on the prior literature (e.g. Welch 2004). In particular, we include controls for Tobin's Q, sales and stock-returns to control for firm moment shocks, as well as book leverage, profitability (return on assets) and tangibility to control for financial conditions. Column 4 presents the OLS multivariate results while column 5 shows the 2SLS results. In both cases, rises in uncertainty remains a strong predictor of future reductions in capital investment even after controlling for lagged changes in Tobin's Q and changes in various measures of a firm's status (such as firm return on assets and sales). Interestingly, the point estimates for OLS in column 4 and IV in column 5 are similar in magnitude. Finally, in column (6) we include the IV for implied volatility and again find a significant negative impact of uncertainty on investment.

In terms of magnitudes these results imply that a two-standard deviation increase in realized volatility would reduce investment by between 4% to 6% (using the results from our preferred specifications in column (5) and (6)). This is moderate in comparison to firm-

[6] Of course there are several other factors changing between these columns, including the sample size (the IV sample is post 2007 onwards due to the lack of implied volatility data for oil and currency prices before 2006) and local average treatment effects (the instrumental variables estimation obtains identification from changes in macro energy, currency and policy risk).

level investment fluctuations (which have a standard deviation of 24.7%), but is large when considering that annual investment rates drop about 2% or 3% during recessions as show in figure (1).

[Insert Table 4 here]

5.1.1 First stage results

The instrumental investment results are only valid if the first-stage regressions have been predictive power and meet the exclusion restriction, which we jointly examine in table 5 which plots the first stage for the investment estimations. In columns (1) and (2) we report the first stages for the univariate and multivariate IV columns (3) and (5) from table 4. We see that, first, the F-statistics indicate a well identified first stage with values of 27 and 26. We also find reassuringly the Hansen overidentifying test does not reject the validity of our instruments with p-values of 0.494 and 0.354.

As another check of our identification strategy we would like to see our instruments are all positive and significant. Indeed, we see in columns (1) and (2) that any significant instrument in the first stage is positive. The negative coefficients are for insignificant instruments, which presumably arises because of the multicollinearity between the exchange rate instruments. To confirm this in columns (3) and (4) we re-run the first stage specifications but including only *each instrument one-by-one* and report in the cells for each instrument the results from this regressions. So, for example, the values 0.278 and 12.51 at the top of column (3) are the point-estimate and t-statistic for a first stage like column (1) except when the only instrument was exposure to oil volatility (using the same sample). We now see that every instrument is positive and strongly significant, suggesting the reason that some instruments in columns (1) and (2) were not significant is due to multicollinearity.

[Inset Table 5 here]

5.2 Employment, intangible capital and sales

Table 6 examines the predictive implications of uncertainty on other important *real* outcomes. Panel A examines employment changes, Panel B changes in the investment in intangible capital (as measured by expenditure on sales, general and administration and R&D, extending the approach of Eisfeldt and Papanikolaou (2013)) and Panel C changes in sales. In each panel we present the same 6 columns of regression results as we did for investment. The specifications in each column follow the regression specifications described in the investment rate Table 4. Moreover, to preserve space we only report the point coefficient estimates on lagged changes in uncertainty (the results include the exact same set on control variables as for investment).

The three panels show that realized and implied volatility is negatively related to real future outcomes in employment, investment in intangible capital, and sales. These results are largely confirmed in specifications 3 and 6 where we instrument realized and implied volatility by volatility exposure to commodity markets. In particular, the negative coefficient estimates are quite pronounced and 5% statistically significant for both intangible capital and sales, and weakly (10% or 15%) significant for employment. Moreover, as with investment these regressions show a strong first-stage with F-statistics above 20 in all specifications except for the implied volatility where smaller sample sizes cut the F-statistics to around 8 to 10.

[Insert Table 6 here]

Hence, in summary this confirms the robustness of the causal impact of uncertainty shocks on real firm activity across other inputs (employment and intangible capital investment) and output (sales) - even in the presence of extensive first-moment and financial conditions controls - plus an extensive instrumentation strategy for uncertainty.

5.3 Financial variables

Table 7 examines how firm uncertainty affects future total debt and the debt maturity structure. Panel A shows that increases in uncertainty reduce the willingness of firm's to increases their overall debt. The correlations are strong and significant in both the OLS and instrumental variable regressions. Panels B examines how uncertainty affects corporate payout. Consistent with a precautionary saving motive rises in a firm's uncertainty associates with a large reduction in equity payouts. Panel C examines the firms cash holding policies, and finds weaker evidence for an impact of uncertainty leading firms to accumulate cash reserves, again as part of the an increase in cautionary behavior. Finally, in Panel D we regresses changes in the ratio of short to long term debt. Uncertainty has a strong negative sign in the basic OLS regressions in columns (1) and (2), indicating that firm's short-term debt ratio is lower when uncertainty is higher. While the IV results show a similar result in terms of the point-estimate they have large standard-errors so are not statistically significant.

[Insert Table 7 here]

5.4 Instrument and credit supply robustness

In table 8 we investigate the main multivariate investment results dropping each instrument one-by-one in columns (2) to (10) (compared to the baseline results in column (1)). As we see across the columns the results are impressively robust - the F-test and is 20 or above in all specifications and the Hansen over-identifying test does not reject at the 5% level in any specification.[7] Hence, our results are not driven by one particular instrument, but instead are driven by the combined identification of energy, exchange rate and policy uncertainty driving firm-level uncertainty fluctuations. This suggests this identification strategy will be broadly useful for a wide-range of models of the causal impact of uncertainty on firm behavior.

[7] In the final column the Hansen test is significant at the 10% level, which given this table runs 10 tests across the instruments, is within the distribution of the random sampling.

In Appendix table A2 we investigate the robustness of the results to including firm-level controls for financial constraints. One concern could be that uncertainty reduces financial supply - for example, banks are unwilling to lend in periods of high uncertainty - which causes the results we observe. So to try to address this we include a variety of different controls for firms financial conditions and show our results are robust to this. In particular for both the realized and implied volatility we include controls for the firms: CAPM-beta (defined as the covariance of the firms daily returns with the market returns in that year) in columns 2 and 2A, the firms Kaplan and Zingales (1997) and Whited and Wu (2006) financial conditions measures in columns 3 and 3A, the firms credit rating (a full set of dummies including an indicator for no rating) in columns 4 and 4A, and all these measures combined in columns 5 and 5A. In summary, as we can see from table (Table:2SLSRobustness) including these financial supply variables does not notably change our results. So while these are not perfect controls for financial conditions, the robustness of our results to their inclusion suggests that financial supply conditions are unlikely to be the main driver of our results.

5.5 The finance-uncertainty multiplier

Finally, table 9 shows the results from running a series of finance-uncertainty interactions on the data during the 2008-2010 period of the financial crisis. In panel A we measure firms financial constraints by their S&P credit rating in 2005[8]. Following Duchin et al. (2010) firms with positive debt and no S&P credit rating are defined as constrained, while those with either no-debt or a credit rating are defined as unconstrained. We then interact this measure of financial constraints with uncertainty in our preferred specification for uncertainty, which uses realized volatility with a full set of controls and instrumental variables (e.g. the column (5) specification in tables 4 and 6).

In the top panel of table 9 we see that the interaction of financial constraints (proxied by the S&P credit rating) with uncertainty is significantly negative for investment, intangible

[8]2005 is chosen as the year before our regression data starts, since we examine 2008-2010, with the explanatory variables lagged one year (2007-2009) and require another lag to generate the first diferences.

capital investment and sales (although insignificant for employment). This suggests that for financially constrained firms uncertainty has a significantly more negative effect of tangible and intangible investments, and hence also on sales. In the middle and bottom panels we proxy financial constraints using the 2005 level of firm size measured by employment and assets, and again find a similar result - smaller firms (who are typically more financially constrained) are significantly more responsive to increased uncertainty in terms of cutting investment and sales. Hence, overall this provides important evidence for an interactive effect of financial constraints and uncertainty in deterring firms investment activities during the 2008-2010 period of the financial crisis.

To show this graphically figure 4 plots investment rates for financially constrained and unconstrained firms from 2003 to 2013. We normalize the investment rates of both groups of firms to their respective values of investment rates in 2006. Financial constraints are defined as a firm having short or long-term debt but no public bond rating (see, e.g., Faulkender and Petersen 2006 and Duchin, Ozbas and Sensoy 2010). Volatility is the annual realized stock return volatility. It is clear that constrained and unconstrained firms' investment rates track each other closely until the Great Recession and the spike in uncertainty, at which point the constrained firms' investment drop substantially more than unconstrained firms. As uncertainty recedes post 2012 the gaps start to recede again as the investment rates begin to converge.

6 Conclusion

This paper studies the impact of uncertainty shocks on firms' real and financial activity both theoretically and empirically. We build a dynamic capital structure model which highlights the interactions between the time-varying uncertainty and the external financial frictions and the real frictions. The model generates the links between uncertainty shocks and real and financial activity observed in the data. We show that both real and financial frictions significantly amplify the impact of uncertainty shocks on firms's real and financing decisions. Empirically, we test the model and show that uncertainty shocks cause firms to reduce investment and employment on real side and furthermore, reduce their total debt and the term structure of debt, while increase the cash holding and cut dividend payout on financial side. Taken together, our theoretical and empirical analyses show that real and financial frictions are quantitatively crucial to amplify the impact of uncertainty shocks on firms' activity.

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A Numerical algorithm

To solve the model numerically, we use the value function iteration procedure to solve the firm's maximization problem. We specify three grids of 22 points for capital, long-term debt, and short-term debt/cash, respectively, with upper bounds $\bar{k}$, $\bar{n}$ and $\bar{b}$ that are large enough to be nonbinding. The grids for capital, short-term debt and long-term debt are constructed recursively, following McGrattan (1999), that is, $k_i = k_{i-1} + c_{k1} \exp(c_{k2}(i-2))$, where $i = 1,...,n$ is the index of grids points and c_{k1} and c_{k2} are two constants chosen to provide the desired number of grid points and two upper bounds $\bar{k}, \bar{n}$ and $\bar{b}$, given three pre-specified lower bounds $\underline{k}$, $\underline{n}$, and $\underline{b}$. The advantage of this recursive construction is that more grid points are assigned around $\underline{k}$, $\underline{n}$ and $\underline{\text{b}}$, where the value function has most of its curvature.

We use Tauchen (1986) method augmented with two state Markov process of time-varying conditional volatility to discretize the processes of aggregate and idiosyncratic productivities z^m and z^f. We use 5 grid points for both of the z^m and z^f processes. In all cases, the results are robust to finer grids as well. Once the discrete state space is available, the conditional expectation can be carried out simply as a matrix multiplication. Linear interpolation is used extensively to obtain optimal investment, short-term debt/cash and long-term debt that do not lie directly on the grid points. Finally, we use a simple discrete global search routine in maximizing the firm's problem.

B Data appendix

The Compustat accounting data, CRSP stock-returns, option metrics, and instrumental variable data are detailed here. We also provide a table of descriptive statistics in Table A1.

B.1 Company financial reports and realized stock return volatility

We draw financial information for US publicly held companies from Compustat. Our sample period begins in 1963 and ends in 2014. We use fiscal-year annual company data from balance sheet, income statements, and cash flow statements. Financial, utilities, and public sector firms are excluded from the sample. In particular, we exclude firms with historical SIC codes in the range of 6000 to 6999, 4900 to 4999, and above 9000.[9] When Compustat reports more than one annual data for the same company in a given fiscal year (e.g., when a company changes its fiscal-year end month) we drop the first chronologically dated observations and keep only the last data for that fiscal year.

Our main empirical tests involve changes in real and financial variables from one fiscal year to the next. To ensure that the changes are indeed annual, we require a 12 month distance between fiscal-year end dates of accounting reports from one year to the next. For all variables we measure change as the growth rate defined in Davis and Haltiwanger (1992), where for any variable x_t this is $\Delta x_t = (x_t - x_{t-1})/(\frac{1}{2}x_t + \frac{1}{2}x_{t-1})$, which for positive values of x_t and x_{t-1} yields growth rates bounded between -2 and 2. The only exceptions are CRSP stock returns and capital formation. For the latter investment rate (implicitly the change in gross capital stock) is defined as $I_{i,t} = \frac{CAPEX_{i,t}}{K_{i,t-1}}$ where K is net property plant and equipment, and $CAPEX$ is capital expenditures. We bound investment rate above at 1 and below at -0.10. For all other variables, the changes of real and financial variables (in

[9] In particular, we do not use the present or "header" SIC code of a company (which is time invariant and only representative of the company's industry at the time of Compustat data download), but rather classify companies each year based on their historical industry SICH variable (i.e., standard industrial classification -historical, from Compustat). Moreover, when SICH is missing for a given year we either replace it with the closest backward-looking non-missing value (when available) or the company's first non-missing SICH value in the time-series. Moreover, when SICH is not available in any year for a company, we employ its current (header) SIC code.

levels or in ratios) are winsorized at the 1 and 99 percentiles. Moreover, whenever both x_t and x_{t-1} are zero we set the corresponding growth rate equal to zero (which avoids losing information to undefined values and because in fact the growth rate is zero in this case).

The set of dependent variables is as follows. We define total debt as $Total\ Debt = DLC + DLTT$, where DLC and $DLTT$ are short-term and long-term debt from Compustat, respectively. The ratio of short to long term debt is $short/long\ term = DLC/DLTT$. Corporate payout is defined as $Payout = DV + PRSTKC$, where DV is cash dividends and $PRSTKC$ is purchase of common and preferred stock from Compustat. Cash holdings is the level of cash and short-term investments (CHE) from Compustat. Aside from investment rate, we explore the following real outcomes from Compustat. Employment is EMP, Intangible Capital is $SG\&A + R\&D$ (sales, general and administration plus research and development), and Sales is simply $SALES$.

In our regression analysis we control for the lagged growth rate in variables known to influence capital structure and investment decisions. That is, our independent variables are measured in growth rates from year $t-2$ to $t-1$. Given that our dependent variables are measured as growth rates from year $t-1$ to t, our analysis implicitly requires firms to have at least 3 years of contiguous non-missing annual data. However, our main tests include firm-fixed effects, and thus singletons are ruled out from our regression specifications[10]. Thus, for a firm to appear in our regression analysis it must have at least 4 years of contiguous non-missing annual data.

Our main set of controls includes the following variables. We measure $Stock\ Return$ as a firm's compounded fiscal-year return, using CRSP daily returns (including dividends, RET) within the corresponding 12-month fiscal-year period. $Tangibility_t = PPEGT/AT$, where $PPEGT$ is gross property, plant, and equipment and AT is total assets. We control for the $book\ leverage = (DLC + DLTT)/(DLC + DLTT + CEQ)$, where CEQ is Compustat common book equity. Tobin's Q is computed as in Duchin, Ozbaz, and

[10] We employ the reghdfe package and run all regressions in Stata version 13.

Sensoy (2010) and Kaplan and Zingales (1997). Specifically, $Q_{i,t} = (market\ value\ of assets)$ $/(0.9 *\ book\ assets + 0.1 *\ market\ value\ of assets)$) , where market value of assets is ($AT + ME + CEQ - TXDB$), ME is CRSP market value of equity (i.e. stock price times shares outstanding), book assets is AT, and $TXDB$ is deferred taxes. We handle outliers in Tobin's Q by bounding Q above at 10. Return on assets, $ROA_t = EBIT/AT$, where $EBIT$ is earnings before interest and tax. We further control for firm size, defined as $SALE$.

As for our main variable of interest, we measure firm-level uncertainty as the annual volatility of the firm's realized stock return. Specifically, we estimate it as the 12-month fiscal-year standard deviation of daily CRSP returns. We annualize this standard deviation by multiplying by the square root of 252 (average trading days in a year). This makes the standard deviation comparable to the annual volatility implied by call options, described below.

B.2 Implied volatility

Although our main measure of firm-level uncertainty is realized annual stock return volatility, we further proxy for uncertainty by using OptionMetrics' 365-day implied volatility of at-the-money-forward call options. We describe this alternative measure in this subsection.

OptionMetrics provides daily implied volatility from January 1996 onward for securities with exchange-traded equity options. Each security has a corresponding series of call and put options which differ in their expiration dates and strike prices. For each of these options, OptionMetrics imputes an implied volatility for each trading day using the average of the end-of-day best bid and offer price quotes. Given an option price, duration, and strike price, along with interest rates, underlying stock price, and dividends, the Black-Scholes formula is used to back out implied volatility. This is an annualized measure representing the standard deviation of the expected change in the stock price. Note that this is not a directional measure, but rather an expectation of absolute stock price movements regardless of their direction.

One of the advantages of using implied volatilities is that they can be measured across a variety of time horizons using options with different expiration dates. In particular, OptionMetrics calculates implied volatilities for durations ranging from 30 to 730 days. We can use these implied volatility horizons to measure uncertainty over different forward-looking periods, yet to be consistent with the annual Compustat data used throughout, our main tests focus only on 365-day implied volatility. However, our main results are largely similar if we employ 91-day implied volatility.

While implied volatility data is available for a variety of strike prices, we restrict our analysis to at-the-money-forward options; i.e., options for which the strike price is equal to the forward price of the underlying stock at the given expiration date. The forward (or expected future) price is calculated from the current stock price, the stock's dividend payout rate, and the interest rate yield curve. We further restrict our analysis to call options. Note that a call option and a put option on a given underlying asset with the same strike price and expiration date have the same implied volatilities; the difference in their prices comes from the fact that interest rates and dividends affect the value of call and put options in opposite directions.

Therefore, our principal proxy for uncertainty is 365-day implied volatility of at-the-money-forward call options.

B.3 Currency exchange rates and implied volatility

We use bilateral exchange rate data from the Federal Reserve Board. Although there is a large number of bilateral currencies available, we restrict our attention to the exchange rates between the U.S. dollar and the 7 "major" currencies used by the Board in constructing the nominal and real trade-weighted U.S. dollar Index of Major Currencies[11].These include the euro, Canadian dollar, Japanese yen, British pound, Swiss franc, Australian dollar, and Swedish krona. Each one of these trades widely in currency markets outside their

[11] See: http://www.federalreserve.gov/pubs/bulletin/2005/winter05_index.pdf .

respective home areas, and (along with the U.S. dollar) are referred to by the Board staff as major currencies. These daily currency spot prices are used in the daily regression described in equation 17 .

In addition to the daily currency prices, our instrumental variables approach further requires measures of forward-looking implied volatility for each of the 7 currencies. For these we use daily data on three-month implied exchange rate volatilities for each bilateral rate, from Bloomberg. Specifically, we extract these data using the VOLC function available at Bloomberg terminals.

Moreover, to construct our year t annual industry-by-year instrument for exchange rate uncertainty, $\mid \beta_j^c \mid \cdot \sigma_t^c$, at every fiscal-year month-end date of a company we average the daily implied currency volatility over the previous 252 observations (which corresponds to the average number of trading days in the 365-day period) . This average implied currency exchange rate volatility, σ_t^c, serves as our source of time-variation in the composite term, $\mid \beta_j^c \mid \cdot \sigma_t^c$, of instrument for uncertainty.

B.4 Energy prices and implied volatility

We employ shocks to oil price as a general proxy for energy prices. We collect oil price and implied volatility data from Bloomberg. In particular, Bloomberg provides price and 30-day implied volatility data for one-month crude oil futures. Specifically, we use data on the New York Mercantile Exchange Division's light, sweet crude oil futures contract (Bloomberg CL1). This contract is the world's most liquid, largest-volume futures contract on a physical commodity. The contract size is 1,000 U.S. barrels and delivery occurs in Cushing, Oklahoma. Oil futures implied volatility data is available starting in 3Q 2005.

As with exchange rates above, we construct our annual industry-by-year instrument for oil by averaging the daily implied volatility data for oil over the corresponding 252-day backward-looking window for each fiscal-year month-end date of a company.

B.5 Timing alignment of firm-level volatility and instruments

As discussed above, our main empirical analysis examines changes in both independent and dependent variables x_t , as defined by $\Delta x_t = (x_t - x_{t-1})/(\frac{1}{2}x_t + \frac{1}{2}x_{t-1})$. This also applies to our instruments for energy prices, exchange rates, and policy uncertainty, $\mid \beta_j^c \mid \cdot\sigma_t^c$. Moreover, this growth definition is likewise applicable to our main uncertainty measure of firm $j's$ realized annual volatility , $vol_{j,t}$. Therefore, recalling that our regressions are predictive from year $t-1$ to year t , our first-stage 2SLS regressions involve a regression of $\Delta vol_{j,t-1} = (vol_{j,t-1} - vol_{j,t-2})/(\frac{1}{2}vol_{j,t-1} + \frac{1}{2}vol_{j,t-2})$ on $\Delta IV_{t-1}^c = (IV_{t-1}^c - IV_{t-2}^c)/(\frac{1}{2}IV_{t-1}^c + \frac{1}{2}, IV_{t-2}^c)$, where $IV_{t-1}^c = \mid \beta_j^c \mid \cdot\sigma_{t-1}^c$ is the corresponding instrument for commodity c uncertainty in year $t-1$.

Lastly, taking into account that oil futures implied volatility data starts in 3Q 2005, our main 2SLS regression sample containing the full set of 9 instruments (oil, 7 exchange rates, and policy) effectively starts in fiscal year 2007 and ends in fiscal year 2014. The 2SLS robustness test results are report in Table 8.

Table A1:
Descriptive Statistics

	Obs.	Mean	S. Dev	P1	P10	P50	P90	P99
Dependent Variables								
Investment Rate	154295	0.295	0.247	0.006	0.065	0.218	0.660	1.000
Employment	146942	0.036	0.239	-0.811	-0.187	0.024	0.283	0.911
Intangible Capital Investment	142503	0.090	0.231	-0.689	-0.149	0.086	0.339	0.877
Sales	155709	0.093	0.303	-1.063	-0.181	0.087	0.378	1.283
Debt Total	153224	0.054	0.685	-2.00	-0.530	0.00	0.787	2.00
Short/Long Term	123366	0.017	0.968	-2.00	-1.412	0.031	1.354	2.00
Payout	155000	0.067	0.910	-2.00	-1.124	0.00	1.482	2.00
Cash Holdings	154263	0.048	0.713	-1.806	-0.847	0.045	0.961	1.862
Independent Variables								
Realized Volatility	153001	0.007	0.326	-0.788	-0.385	-0.008	0.415	1.010
Implied Volatility	27094	-0.014	0.291	-0.677	-0.385	-0.028	0.370	0.769
Tobin's Q	147285	-0.021	0.263	-0.842	-0.343	-0.007	0.271	0.730
Book Leverage	136553	0.001	0.716	-2.00	-0.656	-0.017	0.710	2.00
Stock Return	155000	0.167	0.644	-0.810	-0.478	0.054	0.865	3.166
Return on Assets	154309	-0.008	2.370	-11.54	-1.191	0.001	1.088	12.36
Tangibility	153641	0.029	0.244	-0.867	-0.186	0.022	0.266	0.919
Instruments								
Oil Vol Exposure	24030	-0.061	0.319	-0.601	-0.526	-0.092	0.533	0.680
Cad Vol Exposure	50433	0.018	0.216	-0.451	-0.301	0.041	0.250	0.490
Euro Vol Exposure	49941	-0.012	0.249	-0.398	-0.276	-0.084	0.292	0.708
Jpy Vol Exposure	60372	0.018	0.229	-0.377	-0.242	-0.042	0.375	0.517
Aud Vol Exposure	60136	0.031	0.279	-0.487	-0.331	0.032	0.460	0.596
Sek Vol Exposure	50433	-0.010	0.221	-0.408	-0.290	-0.060	0.228	0.609
Gbp Vol Exposure	59785	0.022	0.238	-0.377	-0.247	-0.061	0.402	0.693
Policy Vol Exposure	88920	0.002	0.045	-0.076	-0.058	0.00	0.072	0.127

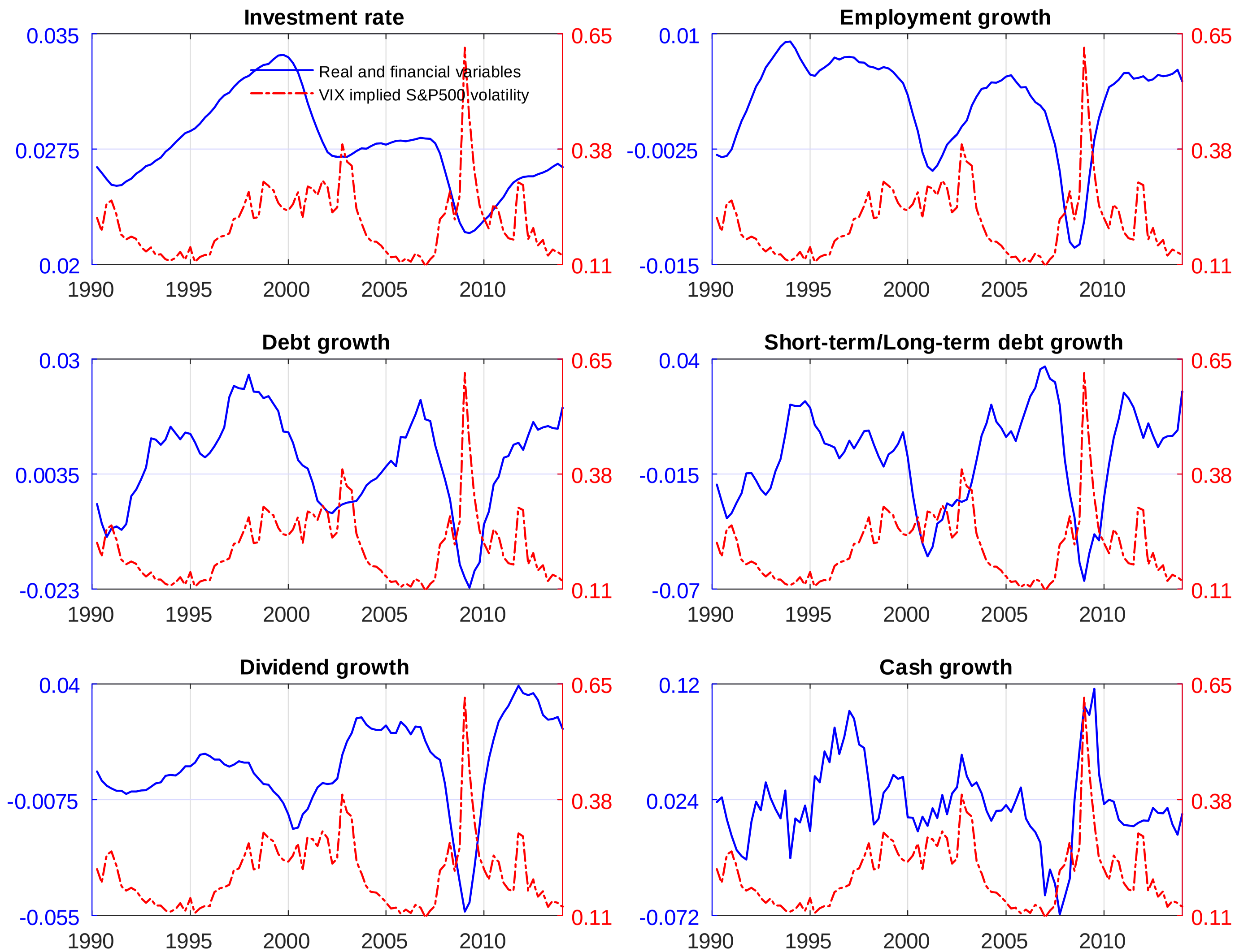
This table presents summary statistics for all the main variables used in the empirical analysis. Except for investment rate, all variables are in growth rates. S. Dev is the standard deviation. P1, P10, P50, P90 and P99 stand for the 1, 10, 50, 90 and 99 percentiles, respectively. See sections 4 and 5 for the details on the construction of variables and data.

Table A2:
2SLS Robustness Tests

Volatility Instrumented	(1) Realized	(2) Realized	(3) Realized	(4) Realized	(5) Realized	(1A) Implied	(2A) Implied	(3A) Implied	(4A) Implied	(5A) Implied
Real Variables										
Investment Rate	-0.062**	-0.067**	-0.068**	-0.060*	-0.070**	-0.098*	-0.100*	-0.089†	-0.094†	-0.085†
Employment	-0.070†	-0.071†	-0.048	-0.069†	-0.049	-0.151*	-0.152*	-0.154*	-0.146*	-0.145*
Intangible Capital Investment	-0.076**	-0.080**	-0.065*	-0.073*	-0.068*	-0.210***	-0.212***	-0.228***	-0.208***	-0.226***
Sales	-0.135**	-0.139**	-0.103**	-0.134**	-0.112**	-0.173**	-0.166**	-0.173**	-0.167**	-0.156*
Financial Variables										
Debt Total	-0.496***	-0.508***	-0.507***	-0.490***	-0.521***	-0.621**	-0.606**	-0.662***	-0.600**	-0.600**
Payout	-0.533**	-0.548**	-0.442*	-0.534**	-0.473**	-1.382***	-1.346***	-1.137**	-1.375***	-1.034**
Cash Holdings	0.195	0.215	0.256*	0.197	0.280*	0.406	0.398	0.423	0.409	0.432
Short/Long Term	0.220	0.243	0.230	0.213	0.244	-0.029	-0.019	-0.046	-0.052	-0.051
Main Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Covariance w/ Market		Yes			Yes		Yes			Yes
Financial Constraint Indexes			Yes		Yes			Yes		Yes
Credit Ratings				Yes	Yes				Yes	Yes
Investment Rate Stats										
Observations	17,310	17,310	16,233	17,310	16,233	10,590	10,590	10,123	10,590	10,123
F-test of 1st stage	25.59	25.65	26	25.43	25.59	7.939	8.518	7.829	7.866	8.784
Hansen J Chi-sq P-val	0.354	0.402	0.715	0.407	0.794	0.200	0.202	0.308	0.278	0.372

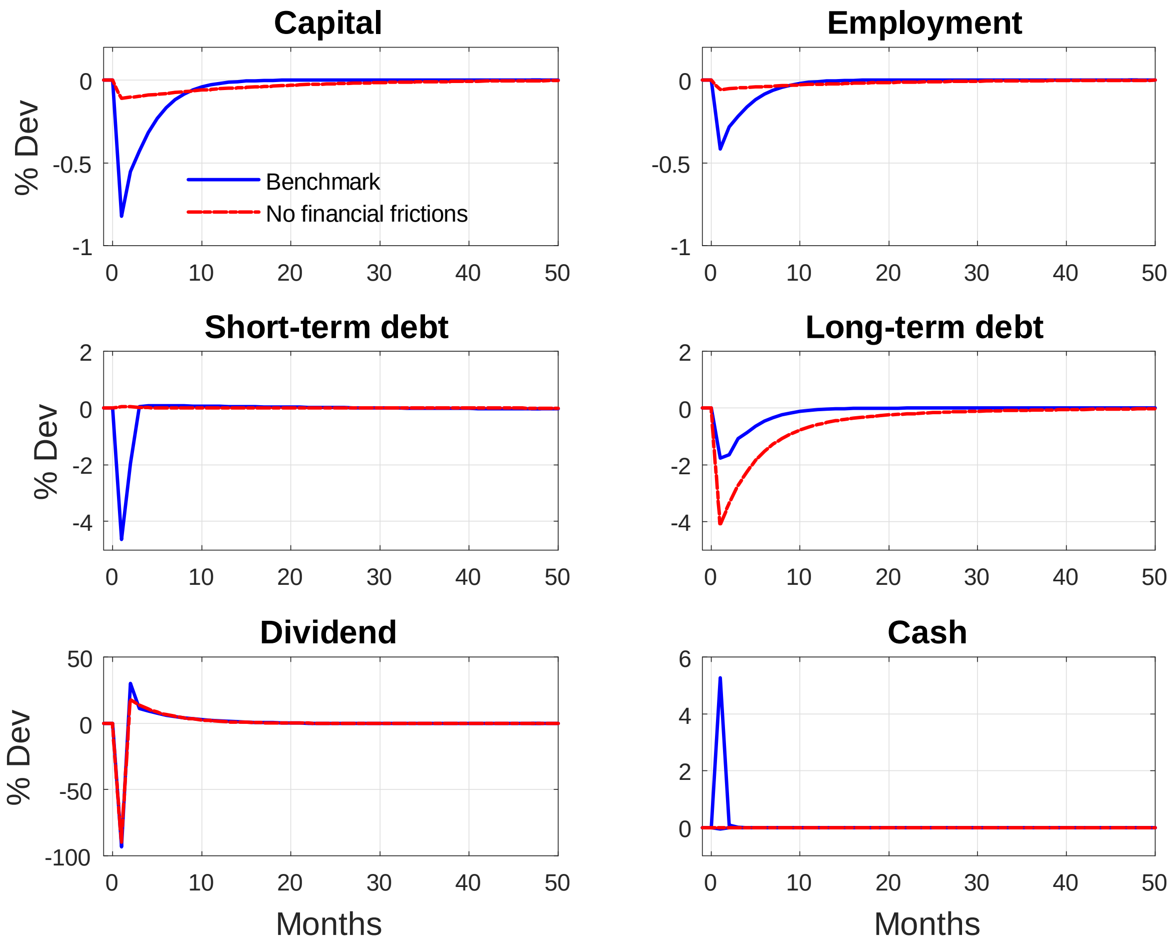
This table presents the 2SLS results of the various robustness tests for all the real and financial variables. Statistical significance: *** p<0.01, ** p<0.05, * p<0.1, † p<0.15. See sections 4 and 5 for the details on the construction of variables and data.

Figure 1: **Uncertainty shocks and aggregate real and financial flows**



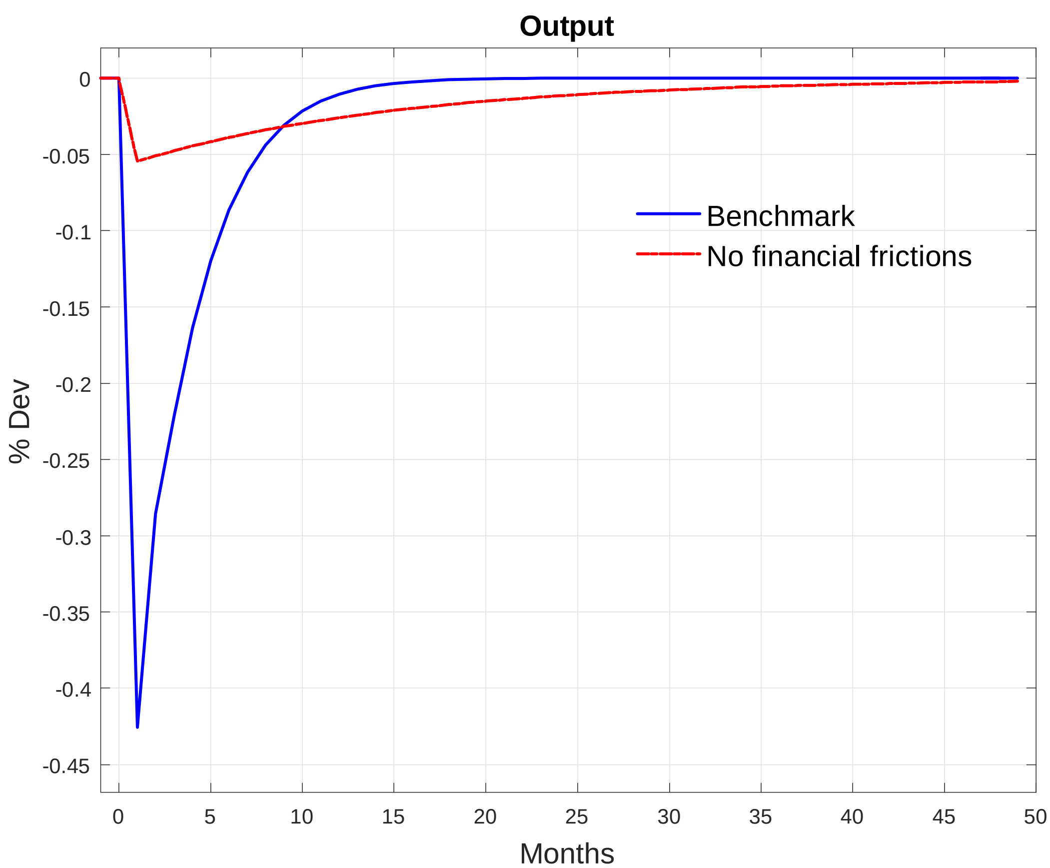
This figure plots the aggregate stock market volatility and the selected real and financial variables. Stock market volatility is the quarterly average of the monthly VIX. We construct quarterly series of the aggregate investment rate following Bachmann et al. (2011) using quarterly investment and capital data from the national account and fixed asset tables, available from the Bureau of Economic Analysis (BEA). Employment is the quarterly average of seasonally adjusted total private employment from BLS with the ID of CES0500000025. Short-term debt, long-term debt, and cash are from the NIPA Integrated Macroeconomic Accounts Table S.5.q nonfinancial corporate business. Short-term debt is the sum of open market paper (line 123) and short-term loans (line 127). Long-term debt is the sum of bonds (line 125) and mortgages (line 130). Cash is the sum of currency and transferable deposits (line 97) and time and savings deposits (line 98). Dividend is the quarterly average of the aggregate real dividend from the stock market data on Robert Shiller's webpage http://www.econ.yale.edu/~shiller/data.htm. We scale the nominal short-term and long-term debt and cash by the quarterly consumer price index from NIPA table 1.1.4 (line 1) to get the real variables. The growth rates of all the real and financial variables are the moving average with a window of 5 quarters ahead.

Figure 2: **Impulse responses of real and financial flows**



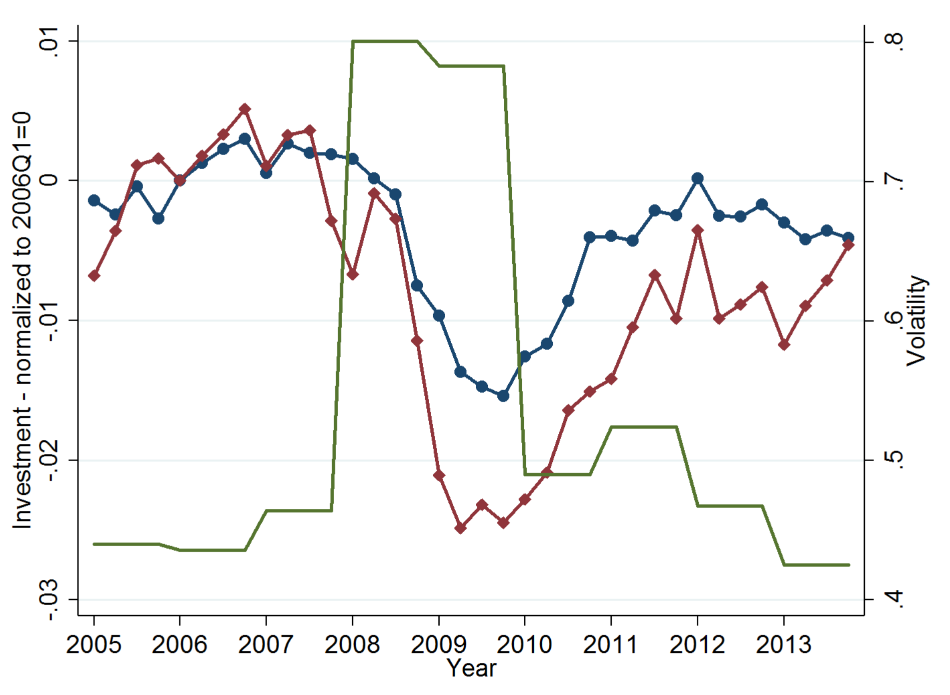
This figure plots the impulse responses of the real and financial variables from the low volatility state to high volatility state while fixing the level of productivity at the long-run average level. There are two model specifications: i) the benchmark model (solid line) and ii) a model without financial frictions (no debt costs $b^S = b^L = \eta = 0$, dash line).

Figure 3: **Impulse response of output**



This figure plots the impulse responses of output from the low volatility state to high volatility state while fixing the level of productivity at the long-run average level. There are two model specifications: i) the benchmark model (solid line) and ii) a model without financial frictions (no debt and equity issuance costs $b^S = b^L = \eta = 0$, dash line).

Figure 4: **Investment rates of constrained and unconstrained firms**



This figure plots the average quarterly investment rates of the constrained (the red line) and unconstrained firms (the blue line) normalized to their respective values of the first quarter of 2006. Financial constraints are defined as a firm having short or long term debt but no bond rating (see Faulkender and Petersen 2006 and Duchin, Ozbas and Sensoy 2010). Volatility is the annual realized stock return volatility (the green line).

Table 1:

Parameter values under benchmark calibration

Description	Notation	Value	Justification
Predetermined parameters			
Subjective discount factor	β	0.996	Long-run average for U.S. firm-level discount rate at 4% annually
Share on capital	α	0.33	Capital share in output is one-third, labor share is two-thirds
Markup	ε	4	33% markup (Hall 1988)
Wage	$\bar{w}$	1	Wage rate normalized to 1
Rate of depreciation for capital	δ	0.01	Capital depreciation rate assumed 1% per month (˜10% annually)
Linear equity issuance cost	η	0.08	Linear equity issuance cost (Hennessy and Whited 2005)
Coupon rate of long-term debt	c	0.05/12	Coupon rate of long-term debt (term premium on Corp.+ T. Bills)
Maturity of long-term debt	$1/\theta$	120	Avg. maturity of long-term debt as 10 years (Guedes-Opler 1996)
Monthly conditional vol. of idio. productivity	σ_L	0.10	Baseline uncertainty (Bloom 2009)
Monthly conditional vol. in high idio. uncertainty state	σ_H	0.20	Uncertainty shocks 2 times baseline uncertainty (Bloom 2009)
Monthly transition prob. from low to high uncertainty	$\pi_{L,H}$	0.0278	Uncertainty shocks expected every 3 years (Bloom 2009)
Monthly transition prob. of staying in high uncertainty	$\pi_{H,H}$	0.9722	Probability of high uncertainty state remaining at the high state
Persistence of logged idio. productivity	ρ_z	0.97	Persistence of logged idiosyncratic productivity (Belo et al 2014).
Average of logged idio. productivity	$\bar{z}$	-3	Scalor; average long-term debt is 0.5
Calibrated parameters			
Fixed cost of investment	b_k	0.01	Fixed cost of investment
Partial irreversibility parameter on investment	c_k^P	0.025	Investment resale loss
Adj. cost parameters in short-term debt	b^S	0.3%	Adj. cost parameters in short-term debt
Adj. cost parameters in long-term debt	b^L	0.3%	Adj. cost parameters in long-term debt
Tightness of collateral constraint for short-term debt	ϕ^S	0.30	Tightness of collateral constraint short-term debt
Tightness of collateral constraint for long-term debt	ϕ^L	0.55	Tightness of collateral constraint long-term debt (match S/L ratio)

This table presents the predetermined and the calibrated parameter values of the benchmark model.

Table 2:
Unconditional moments under the benchmark calibration

Moments	Data	Model
Std. dev. of investment rate	0.25	0.19
Std. dev. of net hiring rate	0.23	0.24
Mean of financial leverage	0.56	0.55
Average fraction of the firms holding cash	0.50	0.49
Short term to long term debt ratio	0.27	0.23
Average fraction of the firms issuing equity	0.17	0.16

This table presents the selected moments in the data and implied by the model under the benchmark calibration. The reported statistics in the model are averages from 100 samples of simulated data, each with 3000 firms and 600 monthly observations (50 years). We report the cross-simulation averaged annual moments.

Table 3:
Coefficient on lagged changes in volatility for real and financial variables.

	Real		**Financial**			
	I/K	dEmp	dDebt	ST/LT	dCash	dDiv
A: Benchmark model						
Volatility	-0.012	-0.011	-0.017	-0.238	0.229	-0.109
B: No real frictions						
Volatility	-0.002	-0.009	-0.015	0.010	0.079	-0.108
C: No financial frictions						
Volatility	-0.007	-0.008	-0.005	0.000	na	-0.094
D: Recessions						
Volatility	-0.031	-0.030	-0.043	-0.468	0.438	-0.243
E: Data						
Volatility	-0.029	-0.028	-0.054	-0.056	0.022	-0.133

This table reports the model regression results of real and financial variables on lagged stock return volatility. The reported statistics in the model are averages from 100 samples of simulated data, each with 3000 firms and 600 monthly observations. We report the cross-simulation averaged annual moments. I/K is the investment rate, dEmp is the employment growth, dDebt is the total debt growth, ST/LT is the short-term debt to long-term debt growth, dCash is the cash growth rate, and dDiv the dividend growth in the model and cash dividend plus repurchase growth in the data.

Table 4:
Investment rate

Investment rate	(1) OLS Realized	(2) OLS Implied	(3) IV Realized	(4) OLS Realized	(5) IV Realized	(6) IV Implied
Volatility	-0.029***	-0.060***	-0.056*	-0.023***	-0.062**	-0.098*
	(-13.694)	(-11.192)	(-1.905)	(-4.322)	(-1.968)	(-1.699)
Book Leverage				-0.011***	-0.012***	-0.009***
				(-4.869)	(-4.935)	(-2.791)
Stock Return				0.031***	0.031***	0.021**
				(7.647)	(6.720)	(2.162)
Sales				0.041***	0.040***	0.028**
				(5.208)	(4.899)	(2.229)
Return on Assets				-0.000	-0.000	-0.001
				(-0.540)	(-0.624)	(-1.291)
Tangibility				-0.104***	-0.103***	-0.082***
				(-11.530)	(-10.796)	(-6.146)
Tobin's Q				0.024**	0.018*	0.014
				(2.427)	(1.655)	(0.920)
1st moment controls	No	No	No	Yes	Yes	Yes
Firm & Time FEs	Yes	Yes	Yes	Yes	Yes	Yes
Observations	148,729	26,215	21,153	19,434	17,310	10,590
F-test of 1st stage			29.18		25.59	7.939
Hansen J P-val			0.249		0.354	0.200

This table presents OLS and 2SLS regression results for investment rate on lagged changes in firm-level volatility and firm-level controls. Investment defined as I_t/K_{t-1} (Capex/Lagged Capital). Sample period is annual from 1963 to 2014. Specifications 1,2, and 4 are OLS regressions, while 4, 5, and 6 are 2SLS regressions. The latter instrument lagged changes in realized volatility by lagged changes in volatility exposure to energy and currency markets (measures by at-the-money implied volatility of oil and 7 widely traded currencies) and economic policy uncertainty from Baker, Bloom, and Davis (2016) . We measure firm-level uncertainty in two ways: realized and implied volatility. Realized volatility is the annual volatility of the firm's stock return, estimated as the 12-month fiscal-year standard deviation of daily CRSP returns. We annualize this standard deviation by multiplying by the square root of 252 (average trading days in a year). Implied volatility is proxied by using OptionMetrics' 365-day implied volatility of at-the-money-forward call options. In all regressions specifications we include both firm and time fixed effects, where time dummies are defined at the fiscal-semester basis. Standard errors are clustered at the firm level. All regressors are in changes from fiscal year $t-2$ to $t-1$. In addition to our main set of controls (book leverage, stock return, sales, return on assets, tangibility, and Tobin's Q) our main multivariate regressions include sensitivity to oil and currency prices as controls (i.e., 1st moment controls). Data availability on implied volatility of oil and currencies restrict the start of the 2SLS sample to fiscal year 2007. Statistical significance: *** p<0.01, ** p<0.05, * p<0.1, † p<0.15. See sections 4 and 5 for the details on the construction of variables and data.

Table 5:
Investment rate - 2SLS 1st Stage Results

Specification: Realized vol	Univariate	Multivariate	Univariate	Multivariate
Set-up	All instruments together		Instruments individually	
change vol exposure Oil	0.182***	0.194***	0.278***	0.295***
t-stat	(6.010)	(5.880)	(12.510)	(11.720)
change vol exposure Cad	-0.074	-0.080	0.313***	0.298***
t-stat	(-1.080)	(-1.100)	(7.680)	(6.740)
change vol exposure Euro	-0.071	-0.067	0.359***	0.381***
t-stat	(-1.180)	(-1.030)	(12.870)	(12.560)
change vol exposure Jpy	0.182***	0.202***	0.421***	0.444***
t-stat	(3.530)	(3.630)	(13.070)	(12.250)
change vol exposure Aud	-0.021	-0.018	0.357***	0.361***
t-stat	(-0.340)	(-0.260)	(11.190)	(10.230)
change vol exposure Sek	0.245***	0.240***	0.455***	0.449***
t-stat	(3.180)	(2.770)	(13.520)	(12.020)
change vol exposure Chf	0.073	0.083*	0.373***	0.394***
t-stat	(1.420)	(1.500)	(13.490)	(12.830)
change vol exposure Gbp	0.139**	0.143**	0.444***	0.462***
t-stat	(2.220)	(2.010)	(13.640)	(12.610)
change vol exposure Policy	0.510***	0.466**	0.351***	0.340***
t-stat	(3.110)	(2.620)	(5.370)	(4.820)
Observations	21,153	17,310		
F-test	27.7	25.59		
Hansen J Chi-sq(8) P-val	0.4944	0.3538		

This table presents the first stage results of the univariate and multivariate 2SLS regression of investment rate on lagged change in realized volatility and main set of controls. Columns 1 and 2 instrument lagged changes in volatility with the benchmark set of 9 instruments (i.e., lagged changes in sensitivity to volatility of oil, 7 widely traded currencies, and economic policy uncertainty). Columns 3 and 4 instrument lagged change in volatility using only one the 9 instruments at a time. When instrumenting firm-level volatility with sensitivities to oil and/or currencies we include the price sensitivity to that corresponding commodity as control. Realized volatility is the annual volatility of the firm's stock return, estimated as the 12-month fiscal-year standard deviation of daily CRSP returns. We annualize this standard deviation by multiplying by the square root of 252 (average trading days in a year). Statistical significance: *** p<0.01, ** p<0.05, * p<0.1, † p<0.15. See sections 4 and 5 for the details on the construction of variables and data.

Table 6:
Additional Real Quantities

	(1) OLS Realized	(2) OLS Implied	(3) IV Realized	(4) OLS Realized	(5) IV Realized	(6) IV Implied
A: Employment						
Volatility	-0.028***	-0.078***	-0.056	-0.019***	-0.070†	-0.151*
	(-11.186)	(-12.172)	(-1.417)	(-2.802)	(-1.535)	(-1.832)
Observations	148,790	26,215	21,152	19,435	17,311	10,590
F-test of 1st stage			29.18		25.60	7.939
Hansen J Chi-sq(8) P-val			0.171		0.357	0.0565
B: Intangible Capital Investment						
Volatility	-0.043***	-0.077***	-0.083**	-0.035***	-0.076**	-0.210***
	(-17.472)	(-12.593)	(-2.316)	(-5.813)	(-1.966)	(-3.022)
Observations	148,729	26,215	21,153	19,434	17,310	10,590
F-test of 1st stage			29.18		25.59	7.939
Hansen J Chi-sq(8) P-val			0.249		0.354	0.200
C: Sales						
Volatility	-0.025***	-0.079***	-0.154***	-0.028***	-0.135**	-0.173**
	(-8.071)	(-9.277)	(-3.120)	(-3.173)	(-2.473)	(-2.049)
Observations	151,187	26,392	21,164	19,459	17,318	10,592
F-test of 1st stage			29.19		25.37	7.931
Hansen J Chi-sq(8) P-val			0.00154		0.0146	0.409

This table reports regression results of changes in employment (Panel A), changes in intangible capital investment (SG&A+R&D) (Panel B), and changes in Sales (Panel C), where growth rates defined as $(x_t - x_{t-1})/(0.5 * x_t + 0.5 * x_{t-1})$. Specifications 1 through 6 follow the same setup of the investment rate specifications described in Table 4. To preserve space we do not report the coefficients and t-statistics on controls. The sample period is annual from 1963 to 2014. Specifications 1,2, and 4 are OLS regressions, while 4, 5, and 6 are 2SLS regressions. The latter instrument lagged changes in realized volatility by lagged changes in volatility exposure to energy and currency markets (measures by at-the-money implied volatility of oil and 7 widely traded currencies) and economic policy uncertainty from Baker, Bloom, and Davis (2016) . We measure firm-level uncertainty in two ways: realized and implied volatility. Realized volatility is the annual volatility of the firm's stock return, estimated as the 12-month fiscal-year standard deviation of daily CRSP returns. We annualize this standard deviation by multiplying by the square root of 252 (average trading days in a year). Implied volatility is proxied by using OptionMetrics' 365-day implied volatility of at-the-money-forward call options. In all regressions specifications we include both firm and time fixed effects, where time dummies are defined at the fiscal-semester basis. Standard errors are clustered at the firm level. All regressors are in changes from fiscal year $t-2$ to $t-1$. In addition to our main set of controls (book leverage, stock return, sales, return on assets, tangibility, and Tobin's Q) our main multivariate regressions include sensitivity to oil and currency prices as controls (i.e., 1st moment controls). Data availability on implied volatility of oil and currencies restrict the start of the 2SLS sample to fiscal year 2007. Statistical significance: *** p<0.01, ** p<0.05, * p<0.1, † p<0.15. See sections 4 and 5 for the details on the construction of variables and data.

Table 7:
Financial Outcomes

	(1) OLS Realized	(2) OLS Implied	(3) IV Realized	(4) OLS Realized	(5) IV Realized	(6) IV Implied
A: Total Debt						
Volatility	-0.054***	-0.061***	-0.219*	-0.068***	-0.496***	-0.621**
	(-7.762)	(-2.915)	(-1.737)	(-3.259)	(-3.588)	(-2.465)
Observations	149,724	26,217	21,034	19,426	17,289	10,575
F-test of 1st stage			28.79		25.36	7.949
Hansen J Chi-sq(8) P-val			0.445		0.347	0.336
B: Payout						
Uncertainty (volatility)	-0.133***	-0.285***	-0.916***	-0.211***	-0.533**	-1.382***
	(-14.272)	(-9.053)	(-4.429)	(-7.055)	(-2.281)	(-3.011)
Observations	151,465	26,397	21,164	19,461	17,318	10,592
F-test of 1st stage			29.19		25.37	7.931
Hansen J Chi-sq(8) P-val			0.148		0.166	0.00487
C: Cash holding						
Volatility	0.022***	-0.004	0.107	0.042**	0.195	0.406
	(2.877)	(-0.192)	(0.853)	(1.994)	(1.298)	(1.271)
Observations	150,752	26,322	21,108	19,402	17,264	10,560
F-test of 1st stage			29		24.89	7.674
Hansen J Chi-sq(8) P-val			0.216		0.0902	0.00456
D: Short term/Long term						
Volatility	-0.056***	-0.078**	0.196	-0.053	0.220	-0.029
	(-5.021)	(-2.003)	(0.879)	(-1.437)	(0.877)	(-0.054)
Observations	120,233	20,253	14,740	16,376	14,595	9,439
F-test of 1st stage			26.52		24.85	7.869
Hansen J Chi-sq(8) P-val			0.0881		0.0265	0.816

This table reports regression results of changes in total debt (Panel A), changes in firm payout (sum of cash dividend and share repurchase; Panel B) and changes in cash holdings (Panel C), where growth rates are defined as $(x_t - x_{t-1})/(0.5 * x_t + 0.5 * x_{t-1})$, and changes in the ratio of short- to long- term debt (Panel D). Specifications 1 through 6 follow the same setup of the investment rate specifications described in Table 4. To preserve space we do not report the coefficients and t-statistics on controls. The sample period is annual from 1963 to 2014. Specifications 1,2, and 4 are OLS regressions, while 4, 5, and 6 are 2SLS regressions. The latter instrument lagged changes in realized volatility by lagged changes in volatility exposure to energy and currency markets (measures by at-the-money implied volatility of oil and 7 widely traded currencies) and economic policy uncertainty from Baker, Bloom, and Davis (2016) . We measure firm-level uncertainty in two ways: realized and implied volatility. Realized volatility is the annual volatility of the firm's stock return, estimated as the 12-month fiscal-year standard deviation of daily CRSP returns. We annualize this standard deviation by multiplying by the square root of 252 (average trading days in a year). Implied volatility is proxied by using OptionMetrics' 365-day implied volatility of at-the-money-forward call options. In all regressions specifications we include both firm and time fixed effects, where time dummies are defined at the fiscal-semester basis. Standard errors are clustered at the firm level. All regressors are in changes from fiscal year $t-2$ to $t-1$. In addition to our main set of controls our main multivariate regressions include sensitivity to oil and currency prices as controls (i.e., 1st moment controls). The 2SLS sample is 2007-2014. Statistical significance: *** p<0.01, ** p<0.05, * p<0.1, † p<0.15. See sections 4 and 5 for the details on the construction of variables and data.

Table 8:
2SLS Sensitivity to Individual Instruments

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
IV Dropped	None	Oil	Cad	Euro	Jpy	Aud	Sek	Chf	Gbp	Policy
Real Variables										
Investment Rate	-0.062**	-0.077**	-0.065**	-0.064**	-0.057*	-0.061*	-0.071**	-0.060*	-0.059*	-0.063**
Employment	-0.070†	-0.103**	-0.068†	-0.074†	-0.063	-0.070†	-0.072†	-0.071†	-0.077*	-0.042
Intangible Capital Investment	-0.076**	-0.084*	-0.079**	-0.077**	-0.063†	-0.074*	-0.083**	-0.078**	-0.077**	-0.103**
Sales	-0.135**	-0.159***	-0.135**	-0.137**	-0.126**	-0.134**	-0.114**	-0.141**	-0.142**	-0.179***
Financial Variables										
Debt Total	-0.496***	-0.493***	-0.513***	-0.498***	-0.485***	-0.491***	-0.477***	-0.504***	-0.500***	-0.461***
Payout	-0.533**	-0.781***	-0.531**	-0.531**	-0.489**	-0.535**	-0.512**	-0.521**	-0.581**	-0.488**
Cash Holdings	0.195	0.204	0.210	0.201	0.217	0.189	0.211	0.179	0.175	0.272*
Short/Long Term	0.220	0.267	0.216	0.221	0.210	0.217	0.199	0.165	0.279	0.199
Investment Stats										
Observations	17,310	17,615	17,310	17,310	17,310	17,310	17,310	17,310	17,310	19,081
F-test of 1st stage	25.59	24.38	28.45	28.71	27.54	28.83	28.09	28.50	27.80	29.46
Hansen J Chi-sq P-val	0.354	0.373	0.469	0.346	0.288	0.383	0.573	0.328	0.301	0.0739

This table presents 2SLS regression results using all main controls but dropping individual instruments one at a time from the benchmark set of 9 instrumental variables (IVs). Results in (1) are the benchmark 2SLS multivariate results (on realized volatility) presented in column (5) in Tables 4, 6, and 7. The sample is annual from 2007 to 2014. The statistics under "Investment Stats" correspond to the 1st stage results of the multivariate 2SLS regression of investment rate on lagged change in volatility and main set of controls. 1st Stage statistics for other real and financial estimations are largely comparable to their benchmark specifications with the full set of instruments. In all regressions specifications we include both firm and time fixed effects, where time dummies are defined at the fiscal-semester basis. Standard errors are clustered at the firm level. Statistical significance: *** $p<0.01$, ** $p<0.05$, * $p<0.1$, † $p<0.15$. See sections 4 and 5 for the details on the construction of variables and data.

Table 9:
Volatility Impact on Financially Constrained and Unconstrained Firms

	2SLS with Main Controls			
2008-2010	Investment Rate	Employment	Intangible Capital Investment	Sales
A: S&P Credit Ratings				
Volatility	-0.025	-0.106**	-0.071†	-0.119†
	(-0.628)	(-2.368)	(-1.517)	(-1.441)
Volatility*Financial Constraint	-0.198***	0.034	-0.154**	-0.340***
	(-2.886)	(0.462)	(-2.264)	(-2.801)
Observations	2,857	2,829	2,602	2,857
F-test of 1st stage	14.26	13.42	13.28	14.26
Hansen J Chi-sq P-val	0.653	0.150	0.0729	0.0393
B: Employment				
Volatility	-0.089**	-0.107**	-0.108**	-0.230**
	(-2.030)	(-2.070)	(-2.075)	(-2.465)
Volatility*Financial Constraint	-0.111***	-0.001	-0.064*	-0.192***
	(-3.207)	(-0.022)	(-1.717)	(-2.814)
Observations	2,857	2,829	2,602	2,602
F-test of 1st stage	14.26	13.42	13.28	13.28
Hansen J Chi-sq P-val	0.807	0.123	0.0934	0.0386
C: Assets				
Volatility	-0.059	-0.083†	-0.104**	-0.113
	(-1.353)	(-1.631)	(-2.125)	(-1.251)
Volatility*Financial Constraint	-0.105**	0.042	-0.100**	-0.074
	(-2.541)	(0.893)	(-2.221)	(-0.886)
Observations	2,081	2,062	1,919	2,081
F-test of 1st stage	18.31	17.91	18.72	18.31
Hansen J Chi-sq P-val	0.627	0.517	0.369	0.0889

This table presents multivariate 2SLS estimates from panel regressions explaining investment rate, changes in employment, changes in intangible capital investment, and changes in sales for financially constrained and unconstrained firms, during the financial crisis of 2008. Sample period is for fiscal years 2008 to 2010. In addition to instrumenting changes in firm-level annual realized volatility, we instrument the interaction of this volatility with a dummy that proxies for whether a firm was ex-ante financially constrained or not in fiscal year 2005. We define this dummy in terms of credit ratings and firm size. For bond ratings, we use S&P rating on long-term debt, and consider a firm to have been ex-ante financially constrained if it had positive debt and no bond rating in 2005 and unconstrained otherwise (which includes firms with zero debt and no debt rating). In terms of size, a firm is considered to have been financially constrained if it was a small firm and unconstrained if a big firm in 2005, were small are firms in tercile 1 and big are firms in tercile 3 with respect to 2005 sample size percentiles (where size is measured by employees and total assets). Firms in the median tercile are ignored. In all regressions specifications we include both firm and time fixed effects, where time dummies are defined at the fiscal-semester basis. Standard errors are clustered at the firm level. All regressors are in changes from fiscal year $t-2$ to $t-1$. In addition to our main set of controls we further include sensitivity to oil and currency prices (i.e., 1st moment controls) as controls. Statistical significance: *** p<0.01, ** p<0.05, * p<0.1, † p<0.15. See sections 4 and 5 for the details on the construction of variables and data.