Uncertainty, Financial Frictions, and Irreversible Investment

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Empirical Observations

- Economic uncertainty is time-varying and countercyclical.
  Campbell et al. (2001); Storesletten et al. (2004); Eisfeldt & Rampini (2006); Bloom (2009); Bloom et al. (2011)
- Credit spreads on corporate bonds are countercyclical.
  Gertler & Lown (1999); Gilchrist, Yankov & Zakrajšek (2009)
- Credit spreads predict economic activity.
  Philippon (2009); Gilchrist & Zakrajšek (2012); Faust et al. (2012); Bleaney et al. (2012)

Motivation

- Existing literature:
  - Investment-uncertainty nexus motivated by irreversibility.
    Bernanke (1983); Abel & Eberly (1994,1996); Caballero & Bertola (1994); Caballero & Pindyck (1996); Bloom (2009); Bloom et al. (2011)
- We examine the interaction between uncertainty and investment in the context of imperfect financial markets and irreversibility.
- We also analyze macroeconomic implications of fluctuations in capital liquidity.
  Shleifer & Vishny (1992); Eisfeldt (2004); Manso (2008)

Uncertainty, Financial Frictions & Investment

- Standard debt contract:
  - Payoff from holding a risky bond is a concave function of the (stochastic) project return.
- Mean-preserving spread in the distribution of shocks:
  - Perfect financial markets:
    - expected defaults $\uparrow \Rightarrow$ credit spreads $\uparrow \Rightarrow$ no impact on I
  - Imperfect financial markets:
    - expected defaults $\uparrow \Rightarrow$ credit spreads $\uparrow \Rightarrow$ cost of capital $\uparrow \Rightarrow I \downarrow$

Our Paper

- Provides new empirical evidence on the link between uncertainty, business investment, and credit spreads.
- Develops a quantitative GE model that replicates key empirical relationships in the data:
  - Embeds a costly reversible investment framework in a GE model with frictions in both the debt and equity markets.
  - Generalizes previous GE frameworks.
    Kiyotaki & Moore (1997); BGG (1999); Jermann & Quadrini (2009)
  - Allows for heterogeneity across firms in the economy.
    Chugh (2010); Arellano, Bai & Kehoe (2010); Kahn & Thomas (2010); Midrigan & Xu (2010); Christiano et al. (2013)

Key Results

- The impact of uncertainty shocks on business investment occurs primarily through changes in credit spreads.
- Model implications in response to uncertainty shock:
  - Financial frictions magnify the impact of uncertainty shocks relative to a model with irreversible investment only.
  - Negative comovement between credit spreads and investment.
  - Positive comovement between net worth and investment.
- Model also implies substantial economic fluctuations in response to capital liquidity shocks.

A New Uncertainty Proxy

- There is no objective measure of uncertainty.
- Informational and/or contractual frictions can generate countercyclical dispersion of economic returns.

  Eisfeldt & Rampini (2006); Jurado et al. (2013)
- Use information from the stock market to infer fluctuations in uncertainty:
  - **Cross Section**: 11,303 U.S. nonfinancial corporations
  - **Time Series**: July 1, 1963 to September 30, 2012
- Use a standard asset pricing framework to purge our uncertainty proxy of forecastable variation.

THREE-STEP ESTIMATION PROCEDURE

- Standard (linear) factor model of asset returns:

$$(R_{it_d} - r^f_{t_d}) = \alpha_i + \boldsymbol{\beta}_i' \mathbf{f}_{t_d} + u_{it_d}$$

  - **Risk factors**: market excess return, SMB, HML, MOM

- Idiosyncratic uncertainty:

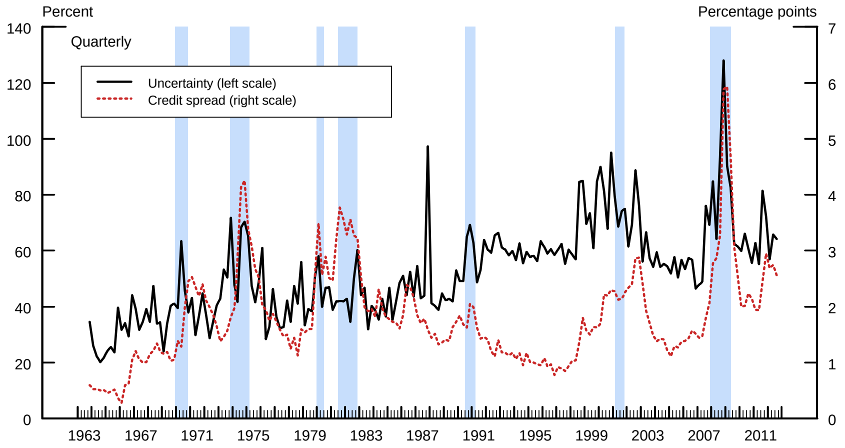
$$\sigma_{it} = \sqrt{\frac{1}{D_t} \sum_{d=1}^{D_t} (\hat{u}_{it_d} - \bar{u}_{it})^2}; \quad \bar{u}_{it} = \frac{1}{D_t} \sum_{d=1}^{D_t} \hat{u}_{it_d}$$

- Dynamic volatility model:

$$\log \sigma_{it} = \gamma_i + \delta_i t + \rho \log \sigma_{i,t-1} + \nu_t + \epsilon_{it}$$

  - Benchmark uncertainty estimate: $\hat{\nu}_t, t = 1, \ldots, T$.

UNCERTAINTY & CREDIT SPREADS



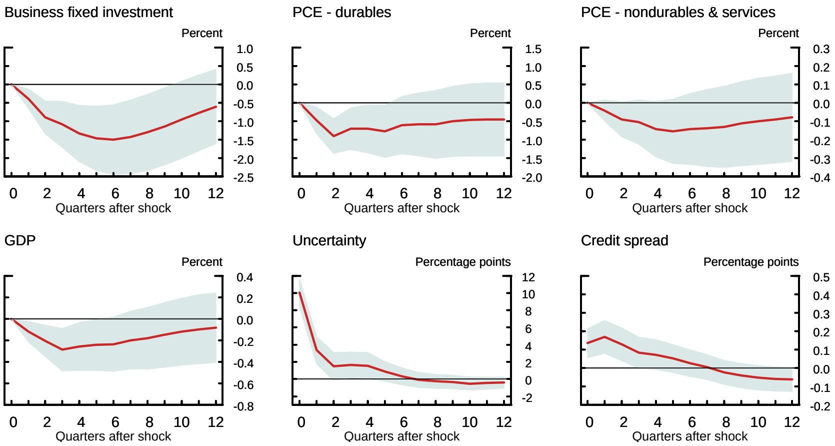
NOTE: Credit spread is the (nonfinancial) 10-year BBB-Treasury spread.

SVAR Analysis

- 8-variable VAR(4) system:
  - i_t = log of real business fixed investment
  - c_t^D = log of real PCE on durable goods
  - c_t^N = log of real PCE on nondurable goods & services
  - y_t = log of real GDP
  - p_t = log of the GDP price deflator
  - $\hat{v}_t$ = economic uncertainty
  - s_t = 10-year BBB-Treasury corporate bond spread
  - m_t = effective (nominal) federal funds rate
- Implications of two types of shocks:
  - Uncertainty: orthogonalized innovations in $\hat{v}_t$
  - Financial: orthogonalized innovations in s_t
- **Identification Scheme I**: $(i_t, c_t^D, c_t^N, y_t, p_t, \hat{v}_t, s_t, m_t)$
- **Identification Scheme II**: $(i_t, c_t^D, c_t^N, y_t, p_t, s_t, \hat{v}_t, m_t)$

IMPLICATIONS OF AN UNCERTAINTY SHOCK

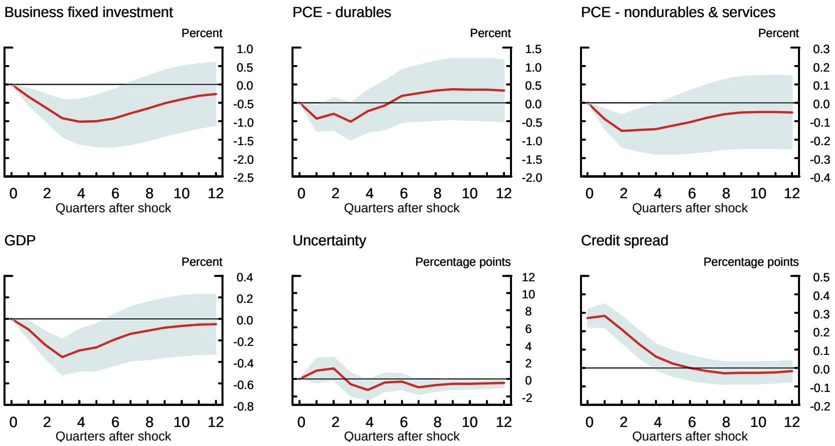
Identification scheme I



NOTE: The shaded bands represent the 95-percent confidence intervals.

Implications of a Financial Shock

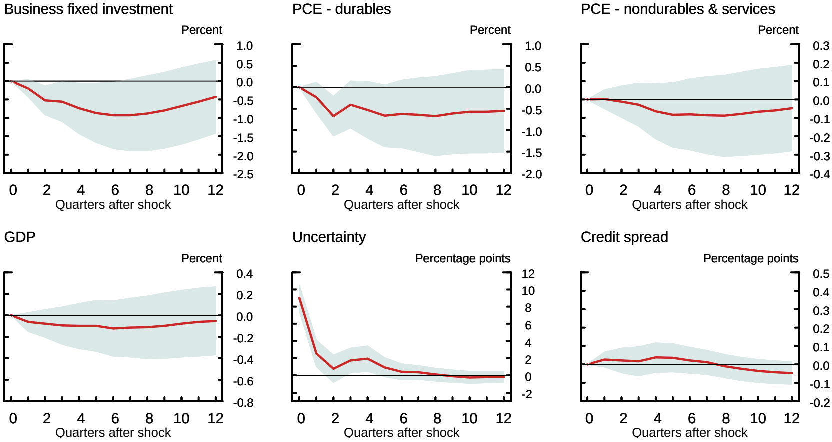
Identification scheme I



NOTE: The shaded bands represent the 95-percent confidence intervals.

Implications of an Uncertainty Shock

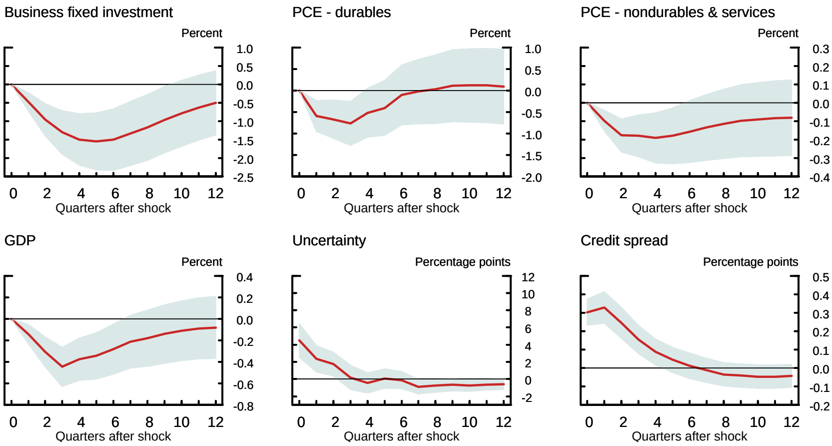
Identification scheme II



NOTE: The shaded bands represent the 95-percent confidence intervals.

Implications of a Financial Shock

Identification scheme II



NOTE: The shaded bands represent the 95-percent confidence intervals.

Firm-Level Panel Analysis

- Examine the link between uncertainty, credit spreads, and business investment using a firm-level panel dataset.
- CRSP/Compustat panel of U.S. nonfinancial firms matched with prices of outstanding corporate bonds traded in the secondary market.
- Lehman/Warga & Merrill Lynch issue-level data:
  - **Sample period**: Jan1973–Sep2012 (month-end)
  - 1,164 U.S. nonfinancial issuers
  - 6,725 senior unsecured, fixed-coupon issues
  - 385,062 bond/month observations
  - **Information**: price, issue date, maturity, coupon, issue size, etc.

SummaryStatistics

UNCERTAINTY & CREDIT SPREADS

- Credit-spread regression:

$$\log s_{it}[k] = \beta_1 \log \sigma_{it} + \beta_2 R^E_{it} + \beta_3 [\Pi/A]_{it} + \beta_4 \log[D/E]_{i,t-1} + \boldsymbol{\theta}' \mathbf{X}_{it}[k] + \epsilon_{it}[k]$$

  - $s_{it}[k]$ = credit spread on bond k (issued by firm i)
  - $[D/E]_{it}$ = debt-to-equity ratio
  - R^E_{it} = realized return on equity
  - $[\Pi/A]_{it}$ = OIBDA-to-assets ratio
  - $\mathbf{X}_{it}[k]$ = bond-specific control variables (par value, coupon, duration, age, callable indicator)

UNCERTAINTY & CREDIT SPREADS

Explanatory Variable	(1)	(2)	(3)	(4)
$\log \sigma_{it}$	0.730	0.459	0.484	0.216
	(0.041)	(0.046)	(0.049)	(0.021)
R^E_{it}	-0.095	-0.112	-0.109	-0.053
	(0.026)	(0.025)	(0.024)	(0.009)
$[\Pi/A]_{it}$	-4.100	-1.835	-1.500	-1.318
	(0.698)	(0.502)	(0.475)	(0.385)
$\log[D/E]_{i,t-1}$	0.212	0.056	0.049	0.078
	(0.024)	(0.013)	(0.013)	(0.011)
Adjusted R^2	0.474	0.641	0.648	0.797
p-value: credit rating effects	-	0.000	0.000	0.000
p-value: industry effects	-	-	0.000	0.000
p-value: time effects	-	-	-	0.000

NOTE: Robust standard errors in parentheses.

UNCERTAINTY, CREDIT SPREADS & INVESTMENT

- Investment regression:

$$\log[I/K]_{it} = \beta_1 \log \sigma_{it} + \beta_2 \log s_{it} + \theta \log Z_{it} + \eta_i + \lambda_t + \epsilon_{it}$$

- Investment fundamentals (Z):
  - $[Y/K]_{it}$ = sales-to-capital ratio
  - $[\Pi/K]_{it}$ = operating-income-to-capital ratio
  - Q_{it} = Tobin's Q
  - $[I/K]_{i,t-1}$ = lagged investment rate

UNCERTAINTY, CREDIT SPREADS & INVESTMENT

Static specification

Explanatory Variable	(1)	(2)	(3)	(4)	(5)	(6)
$\log \sigma_{it}$	-0.169	-0.081	-0.157	-0.036	0.022	-0.062
	(0.036)	(0.034)	(0.034)	(0.035)	(0.033)	(0.034)
$\log s_{it}$	-	-	-	-0.206	-0.172	-0.152
				(0.021)	(0.021)	(0.021)
$\log[Y/K]_{it}$	0.558	-	-	0.535	-	-
	(0.046)			(0.045)		
$\log[\Pi/K]_{it}$	-	1.166	-	-	1.075	-
		(0.086)			(0.088)	
$\log Q_{i,t-1}$	-	-	0.715	-	-	0.645
			(0.040)			(0.041)
R^2 (within)	0.325	0.307	0.297	0.349	0.323	0.310

NOTE: Robust standard errors in parentheses.

Uncertainty, Credit Spreads & Investment

Dynamic specification

Explanatory Variable	(1)	(2)	(3)	(4)	(5)	(6)
$\log \sigma_{it}$	-0.272	-0.179	-0.199	-0.123	-0.078	-0.106
	(0.062)	(0.059)	(0.060)	(0.057)	(0.054)	(0.057)
$\log s_{it}$	-	-	-	-0.101	-0.068	-0.080
				(0.031)	(0.031)	(0.032)
$\log[I/K]_{i,t-1}$	0.568	0.576	0.538	0.565	0.567	0.535
	(0.028)	(0.023)	(0.029)	(0.027)	(0.023)	(0.023)
$\log[Y/K]_{it}$	0.446	-	-	0.452	-	-
	(0.056)			(0.053)		
$\log[\Pi/K]_{it}$	-	0.918	-	-	0.908	-
		(0.144)			(0.135)	
$\log Q_{i,t-1}$	-	-	0.548	-	-	0.507
			(0.045)			(0.042)

NOTE: Robust standard errors in parentheses.

Summary of Empirical Evidence

- Three stylized facts:
  - Fluctuations in uncertainty can have a large effect on aggregate investment.
  - The impact of uncertainty on business investment occurs largely through changes in credit spreads.
  - Financial shocks have a strong effect on aggregate investment, irrespective of the level of uncertainty.
- **Implications**: Financial frictions are an important part of the transmission mechanism through which fluctuations in uncertainty are propagated to the real economy.

Agents & Technological Environment

- **Representative household**: consumes, works, and saves by investing in stocks and corporate bonds.
- **Heterogeneous firms**: use DRS technology to produce final-good output and accumulate capital.
  - Production subject to persistent aggregate and idiosyncratic technology shocks.
  - Volatility of idiosyncratic technology shocks is time varying.
  - Nonconvex capital adjustment costs:
    - fixed costs
    - costly reversibility $\Rightarrow$ purchase price of capital $>$ sale price of capital
  - Liquidation value of capital follows a stochastic process $\Rightarrow$ capital liquidity shocks.

REPRESENTATIVE HOUSEHOLD

- The household earns a competitive real market wage w by working h hours and saves by purchasing bonds and equity shares of firms in the economy.
- Household preferences:

$$u(c,h) = \frac{c^{1-\theta} - 1}{1-\theta} - \zeta \frac{h^{1+\vartheta}}{1+\vartheta};$$

Production Technology

- Decreasing returns-to-scale and fixed costs of production:

$$y = (az)^{(1-\alpha)\chi}(k^{\alpha}h^{1-\alpha})^{\chi} - F_o k$$

  - $a =$ aggregate technology shock
  - $z =$ idiosyncratic technology shock
  - $\chi =$ degree of DRS in production
  - $F_o =$ fixed operation costs

- Profits are linear in a and z:

$$\begin{aligned} \pi(a,z,w,k) &= \max_h \left\{(az)^{(1-\alpha)\chi}(k^{\alpha}h^{1-\alpha})^{\chi} - F_o k - wh\right\} \\ &= az\psi(w)k^{\gamma} - F_o k \end{aligned}$$

TECHNOLOGY SHOCKS

- Aggregate technology shock:

$$\log a' = \rho_a \log a + \log \epsilon_a'; \quad \epsilon_a' \sim N(-0.5\omega_a^2, \omega_a^2)$$

- Idiosyncratic technology shock: N-state Markov chain process with time-varying volatility

$$\log \sigma_z' = (1-\rho_\sigma) \log \tilde{\sigma}_z + \rho_\sigma \log \sigma_z + \epsilon_\sigma'; \quad \epsilon_\sigma' \sim N(-0.5\omega_\sigma^2, \omega_\sigma^2)$$

  - Fluctuations in σ_z do not affect the conditional expectation of z'.
  - An increase in σ_z represent a mean-preserving spread of z'.

Capital Accumulation

- Nonconvex capital adjustment:

$$p(k', k) = F_k k \times \mathbf{1}[k' \neq (1-\delta)k] + \big(p^+ \times \mathbf{1}[k' \geq (1-\delta)k] + p^- \times \mathbf{1}[k' \leq (1-\delta)k]\big)\big(k' - (1-\delta)k\big)$$

  - F_k = fixed investment adjustment costs
  - p^+ = purchase price of capital
  - p^- = liquidation price of capital
  - $p^-/p^+ < 1 \Rightarrow$ capital specificity

- Liquidation price of capital p^-:

$$\log p^{-\prime} = (1-\rho_{p^-}) \log \tilde{p}^- + \rho_{p^-} \log p^- + \epsilon'_{p^-}$$

  - $\log \epsilon'_{p^-} \sim N(-0.5\omega_\kappa^2, \omega_\kappa^2)$ = capital liquidity shock

Financial Distortions

- Moral hazard and limited liability in credit markets.
- Issuance costs in equity markets.
- Implications:
  - Full set of capital structure choices (i.e., debt vs. equity vs. internal funds)
  - Strategic default and debt renegotiation (i.e., Chapter 11 bankruptcy)

Net Worth

- Realized net worth next period equals the sum of net profits and the market value of undepreciated capital less the face value of debt:

$$n' = a'z'\psi(w(\mathbf{s}'))k'^{\gamma} - F_o k' + p^{-\prime}(1-\delta)k' - b'.$$

  - The value of capital follows a stochastic process and entails a discount in the amount of $1 - p^{-\prime}/p^{+}$.

- Net liquid asset position:

$$x'(\sigma_z) \equiv a'z'(\sigma_z)\psi(w')k'^{\gamma} - F_o k' - b' = n'(\sigma_z) - p^{-\prime}(1-\delta)k'$$

- Value of the firm: $v = v_i(k, x; \mathbf{s})$

Endogenous Default

- Limited liability: lower bound on net worth $\bar{n}$
- Default level of idiosyncratic technology, conditional on the next period's aggregate state $\mathbf{s}'$ and individual state (k', b'):

$$z^D(k', b'; \mathbf{s}') \equiv \frac{\bar{n} + b' + F_k k' - p^{-\prime}(1-\delta)k'}{a'\psi(w')k'^{\gamma}}$$

- Set of default states:

$$\mathcal{D} = \left\{ j \mid j \in \{1, \ldots, N\} \text{ and } z_j'(\sigma_z) \leq z^D(k', b'; \mathbf{s}') \right\}$$

- Firm defaults if and only if $z_j'(\sigma_z) \in \mathcal{D}$

Debt Renegotiation

- With limited liability, renegotiated debt equals the amount consistent with the lower bound of the net worth $\bar{n}$:

$$b^R \leq \bar{b}(k', z'(\sigma_z); \mathbf{s}') \equiv a' z^D(\sigma_z)\psi(w')k'^{\gamma} - F_o k' + p^{-\prime}(1-\delta)k'$$

- No bargaining power for firm implies the maximum recovery in equilibrium:

$$b^R = \bar{b}(k', z'(\sigma_z); \mathbf{s}')$$

  - Subject to bankruptcy costs: $\xi(1-\delta)k'; \quad 0 < \xi < 1$

BOND FINANCING

- Recovery rate in the case of default:

$$\mathcal{R}(k', b', z'(\sigma_z); \mathbf{s}') = \frac{\bar{b}(k', z'(\sigma_z), \mathbf{s}')}{b'} - \xi(1-\delta)\frac{k'}{b'}$$

- Bond price:

$$q_i(k', b'; \mathbf{s}') = \mathbb{E}\left\{ m(\mathbf{s}, \mathbf{s}') \left[1 + \sum_{j \in \mathcal{D}} p_{i,j} \left[\mathcal{R}(k', b', z'_j(\sigma_z); \mathbf{s}') - 1 \right] \right] \middle| \, \mathbf{s} \right\}$$

Equity Financing

- Letting e represent equity issuance, then dividends satisfy:

$$d \equiv az_i\psi(w)k^{\gamma} - F_o k - p(k', k) - b + q_i(k', b'; \mathbf{s}')b' + e$$

- Frictions in equity market:
  - Dividend constraint:

$$d \geq \bar{d} \geq 0$$

  - Equity dilution costs:

$$\bar{\varphi}(e) \equiv e + \varphi \max\{e, 0\}; \quad 0 < \varphi < 1$$

Firm Value Maximization Problem

Discrete choice problem:

$$v_i(k, x; \mathbf{s}) = \max\left\{v_i^+(k, x; \mathbf{s}), v_i^-(k, x; \mathbf{s})\right\},$$

where

$$v_i^+(k, x; \mathbf{s}) = \min_{\phi, \lambda^+} \max_{d^+, e^+, k^+, b^+} \Bigg\{ d^+ + \phi(d^+ - \underline{d}) - \bar{\varphi}(e^+) + \lambda^+[k^+ - (1-\delta)k] + \eta \mathbb{E}\left[m(\mathbf{s}, \mathbf{s}') \sum_{j=1}^{N} p_{i,j} \max\left\{v_j(k^+, x^+(\sigma_z); \mathbf{s}'), v_j(k^+, x^{R+}(\sigma_z); \mathbf{s}')\right\} \,\Big|\, \mathbf{s} \right]$$

$$v_i^-(k, x; \mathbf{s}) = \min_{\phi, \lambda^-} \max_{d^-, e^-, k^-, b^-} \Bigg\{ d^- + \phi(d^- - \underline{d}) - \bar{\varphi}(e^-) - \lambda^-[k^- - (1-\delta)k] + \eta \mathbb{E}\left[m(\mathbf{s}, \mathbf{s}') \sum_{j=1}^{N} p_{i,j} \max\left\{v_j(k^-, x^-(\sigma_z); \mathbf{s}'), v_j(k^-, x^{R-}(\sigma_z); \mathbf{s}')\right\} \,\Big|\, \mathbf{s} \right]$$

OPTIMAL CAPITAL STRUCTURE

FOC: equity issuance:

$$1 + \phi = 1 + \varphi \times \mathbf{1}[e > 0]$$

FOC: debt issuance:

$$\begin{aligned} q_i(k', b'; \mathbf{s}) + q_{i,b}(k', b'; \mathbf{s})b' &= \eta \mathbb{E}\left[m(\mathbf{s}, \mathbf{s}') \sum_{j \in \mathcal{D}^c} p_{i,j} \left(\frac{1 + \phi'}{1 + \phi} \right) \Big| \, \mathbf{s} \right] \\ &= \eta \mathbb{E}\left[m(\mathbf{s}, \mathbf{s}') \sum_{j \in \mathcal{D}^c} p_{i,j} \left(\frac{1 + \varphi \times \mathbf{1}(e' > 0)}{1 + \varphi \times \mathbf{1}(e > 0)} \right) \Big| \, \mathbf{s} \right] \end{aligned}$$

Optimal Capacity Choice

Capital expansion problem

$$
\begin{aligned}
Q_i^{+}(k, x; \mathbf{s}) = \eta \mathbb{E}\Bigg[& m(\mathbf{s}, \mathbf{s}') \sum_{j=1}^{N} p_{i,j} \left(\frac{1+\phi_j'}{1+\phi_i} \right) \\
& \times \left[\pi_{j,k}(k^{+}; s') + (1-\delta) Q_j'(k^{+}, x'(\sigma_z); \mathbf{s}') \right] \Bigg| \; \mathbf{s} \Bigg] \\
& + q_{i,k}(k^{+}, b^{+}; \mathbf{s}) b^{+} \\
& - \eta \mathbb{E}\left[m(\mathbf{s}, \mathbf{s}') \sum_{j \in \mathcal{D}} p_{i,j} \left(\frac{1+\phi_j'}{1+\phi_i} \right) \left[\pi_{j,k}(k^{+}; s') + (1-\delta) p^{-\prime} \right] \Bigg| \; \mathbf{s} \right]
\end{aligned}
$$

Optimal Capacity Choice

Capital contraction problem

$$
\begin{aligned}
Q_i^-(k,x;\mathbf{s}) = \eta\mathbb{E}\Bigg[& m(\mathbf{s},\mathbf{s}') \sum_{j=1}^{N} p_{i,j} \left(\frac{1+\phi_j'}{1+\phi_i}\right) \\
& \times \left[\pi_{j,k}(k^-;s') + (1-\delta)Q_j'(k^-,x'(\sigma_z);\mathbf{s}')\right] \Bigg| \mathbf{s} \Bigg] \\
& + q_{i,k}(k^-,b^-;\mathbf{s})b^- \\
& - \eta\mathbb{E}\left[m(\mathbf{s},\mathbf{s}') \sum_{j\in\mathcal{D}} p_{i,j} \left(\frac{1+\phi_j'}{1+\phi_i}\right) \left[\pi_{j,k}(k^-;s') + (1-\delta)p^{-\prime}\right] \Bigg| \mathbf{s} \right]
\end{aligned}
$$

TOBIN'S Q

- Tobin's Q:

$$
\begin{aligned}
Q_i(k, x; \mathbf{s}) &= \min\left\{p^+, \max\left\{p^-, p^+ - \frac{\lambda_i^+(k, x; \mathbf{s})}{1 + \phi_i(k, x; \mathbf{s})}\right\}\right\} \\
&= \min\left\{p^+, \max\left\{p^-, p^- + \frac{\lambda_i^-(k, x; \mathbf{s})}{1 + \phi_i(k, x; \mathbf{s})}\right\}\right\}
\end{aligned}
$$

  - With partial irreversibility, Q is still monotonic and nonincreasing in k, but truncated from above by p^+ and below by p^-.
  - With fixed investment adjustment costs, Q is no longer monotonic.

Optimal Investment Policy

- Generalized (S, s) policy:

$$k_i'(k, x; \mathbf{s}) = \min\left\{k_i^-(k, x; \mathbf{s}), \max\{k_i^+(k, x; \mathbf{s}), (1-\delta)k\}\right\}$$

- (S, s) capital targets: $k_i^-(k, x; \mathbf{s})$, $k_i^+(k, x; \mathbf{s})$ are functions of the firm's overall financial condition (k, x).

▸ Ss-Policy-1 ▸ Ss-Policy-2

HOUSEHOLDS

Household maximization problem:

$$W(\mathbf{s}) = \max_{b',s',c,h} \left\{ u(c,h) + \beta \mathbb{E}[W(\mathbf{s}') | \, \mathbf{s}] \right\}$$

subject to a budget constraint,

$$c + \int \left(qb' + p_S s' \right) \mu(dz,dk,dx) = wh + \int \left[\tilde{R}^b + (d + \tilde{p}_S)s \right] \mu(dz,dk,dx) + \int F_o k \mu(dz,dk,dx).$$

where

$$\tilde{R}^b \equiv \left[1 + \mathbf{1}(z \in \mathcal{D}(k,b,z)) \times [\mathcal{R}(k,b,z(\sigma_z)) - 1] \right] b$$

Dynamic Efficiency Conditions

- Consistency between firm and household problems.
- Ex-dividend value of equity:

$$p_S(k,x,z;\mathbf{s}) = \mathbb{E}\left[\beta\frac{u'(c',h')}{u(c,h)}\left[d' - \bar{\varphi}(e') + p_S'(k',x',z';\mathbf{s}')\right]\Big|\, z,\mathbf{s}\right]$$

- Price of bond:

$$q(k',b',z;\mathbf{s}) =$$
$$\mathbb{E}\left[\beta\frac{u'(c',h')}{u(c,h)}\left[1 + \mathbf{1}[z' \in \mathcal{D}'(k',b';\mathbf{s}')] \times \left[\mathcal{R}'(k',b',z';\mathbf{s}') - 1\right]\right]\Big|\, z,\mathbf{s}\right]$$

MARKET CLEARING

- Market-clearing conditions:

$$
\begin{aligned}
\text{Stock market:} \quad & s' = s = 1 \\
\text{Labor market:} \quad & h^s(\mathbf{s}) = \int h^d(z, k; \mathbf{s})\mu(dz, dk, dx) \\
\text{Goods market:} \quad & c(\mathbf{s}) = \int y(z, k, h; \mathbf{s})\mu(dz, dk, dx) \\
& \quad - \int p(k'(k, x, z; \mathbf{s}), k)\mu(dz, dk, dx)
\end{aligned}
$$

- Bond market clears by Warlas' law.

LAW OF MOTION FOR μ

- μ is the join distribution of $z \in Z$, $k \in K$, and $x \in X$:

$$\mu'(Z, K, X, \mathbf{s}') = \int \mathbf{1}[z_j \in Z] \times \mathbf{1}[k'_i \in K] \times \mathbf{1}[x'_j(k'_i, \min\{b'_i, b^R\}, \mathbf{s}) \in X] \times p_{i,j}\mu(dz, dk, dx, \mathbf{s})G(\mathbf{s}, d\mathbf{s}')$$

- Solution method for GE models with heterogeneous agents: Krusell & Smith (1998)
  - Agents use only a finite number of momments of μ to forecast equilibrium prices.

MODEL CALIBRATION

- Idiosyncratic productivity process:

$$\begin{aligned} \log Y_{it} &= \theta \log K_{i,t-1} + \eta_i + \lambda_{st} + u_{it} \\ u_{it} &= \rho_z u_{i,t-1} + \epsilon_{it} \end{aligned}$$

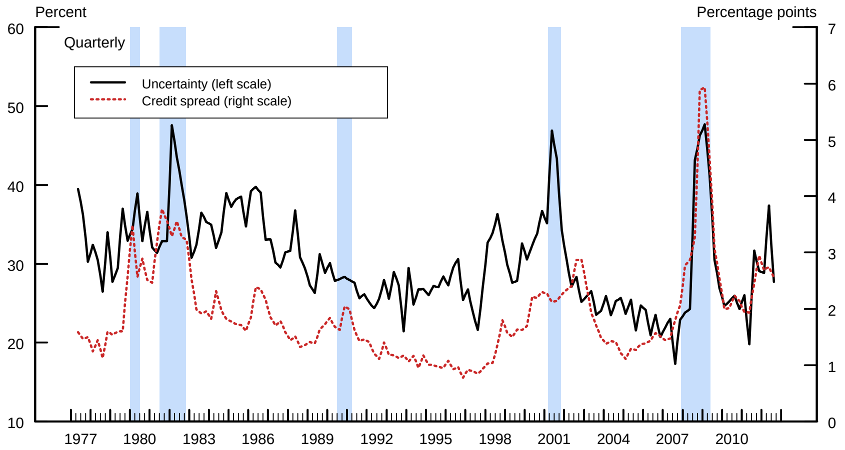
  - $\alpha = 0.3$ and $\hat{\theta} = 0.65 \Rightarrow$ DRS parameter $\chi = 0.85$

- Idiosyncratic uncertainty process:

$$\log \left[\sqrt{\frac{\pi}{2}} |\hat{\epsilon}_{it}| \right] = \gamma_i + +\sigma_t + \zeta_{it}$$

  - Estimate: $\hat{\sigma}_t = \mu + \rho_\sigma \hat{\sigma}_{t-1} + e_t$
  - Calibration: $\tilde{\sigma} = 0.15$; $\rho_\sigma = 0.90$; $\omega_\sigma = 0.04$

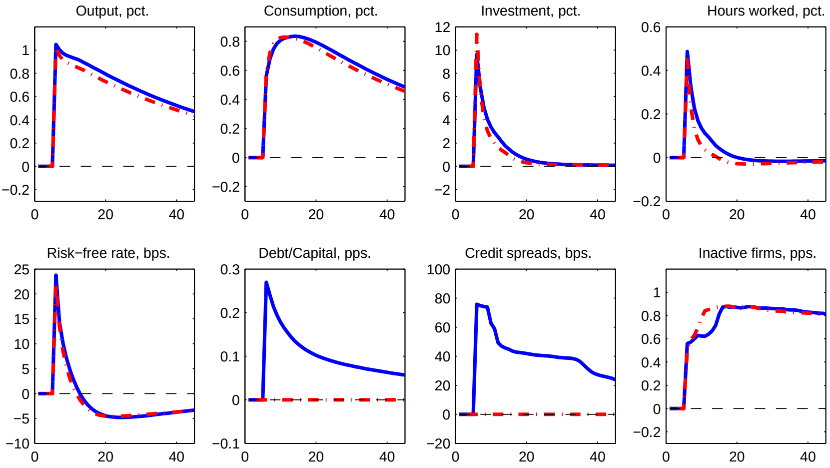
UNCERTAINTY BASED ON PROFITABILITY SHOCKS



CALIBRATION (CONT.)

- Resale price of capital: $\tilde{p}^- = 0.5$; $\rho_{p^-} = 0.98$; $\omega_\kappa = 0.015$
- Purchase price of capital: $p^+ = 1$
- Bankruptcy costs: $\xi = 0.10$
- Equity flotation cost: $\varphi = 0.12$
- Survival probability: $\eta = 0.946$
- Quasi-fixed operating cost: $F_o = 0.05$
- Fixed costs of capital adjustment: $F_k = 0.01$
- Depreciation rate: $\delta = 0.045$
- Time discount factor: $\beta = 0.989$

IMPACT OF AN AGGREGATE TECHNOLOGY SHOCK



NOTE: Model w/ financial frictions. Model w/o financial frictions.

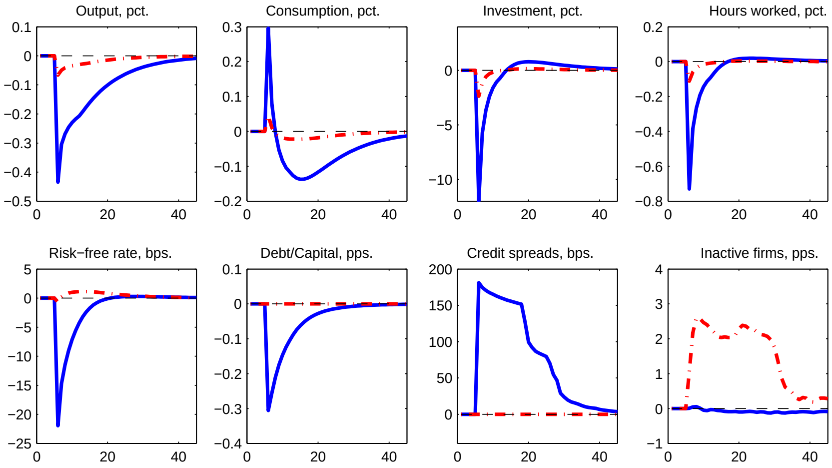
CONDITIONAL BUSINESS CYCLE MOMENTS

Aggregate technology shocks only

	Relative Volatility			
Model Specification	STD(I)	STD(C)	STD(H)	STD(Y)
With financial frictions	2.60	0.95	0.12	2.47
Without financial frictions	2.90	0.98	0.12	2.32
Memo: Data	2.79	0.43	0.60	1.12
	Comovements			
Model Specification	Corr(I, Y)	Corr(C, Y)	Corr(H, Y)	Corr(C, I)
With financial frictions	0.63	0.99	0.46	0.54
Without financial frictions	0.53	0.99	0.22	0.53
Memo: Data	0.63	0.56	0.65	0.43

NOTE: All variables are expressed in deviations from their respective steady-state values.

IMPACT OF AN UNCERTAINTY SHOCK



NOTE: Model w/ financial frictions. Model w/o financial frictions.

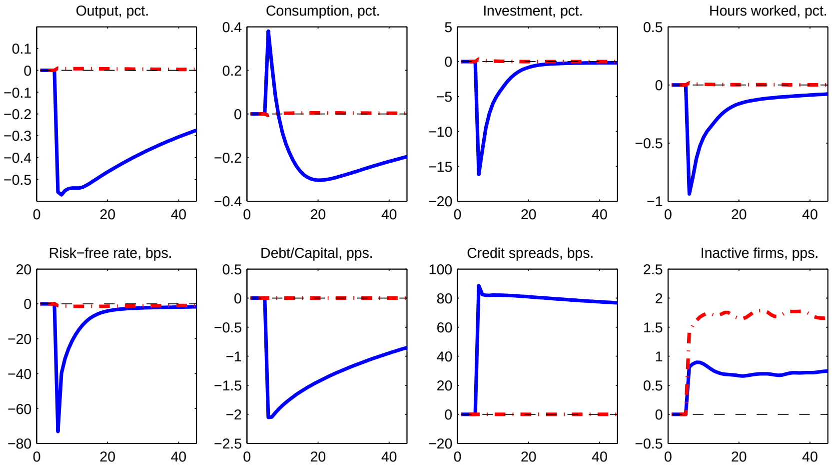
CONDITIONAL BUSINESS CYCLE MOMENTS

Uncertainty shocks only

	Relative Volatility			
Model Specification	STD(I)	STD(C)	STD(H)	STD(Y)
With financial frictions	13.5	0.63	0.88	0.23
Without financial frictions	14.6	0.63	0.71	0.10
Memo: Data	2.79	0.43	0.60	1.12
	Comovements			
Model Specification	Corr(I, Y)	Corr(C, Y)	Corr(H, Y)	Corr(C, I)
With financial frictions	0.65	0.49	0.78	-0.33
Without financial frictions	0.76	0.71	0.78	0.10
Memo: Data	0.63	0.56	0.65	0.43

NOTE: All variables are expressed in deviations from their respective steady-state values.

IMPACT OF A CAPITAL LIQUIDITY SHOCK



NOTE: Model w/ financial frictions. Model w/o financial frictions.

Conditional Business Cycle Moments

Capital Liquidity shocks only

	Relative Volatility			
Model Specification	STD(I)	STD(C)	STD(H)	STD(Y)
With financial frictions	6.71	0.60	0.55	1.11
Without financial frictions	14.3	0.63	0.69	0.09
Memo: Data	2.79	0.42	0.60	1.12
	Comovements			
Model Specification	Corr(I,Y)	Corr(C,Y)	Corr(H,Y)	Corr(C,I)
With financial frictions	0.61	0.88	0.86	0.16
Without financial frictions	0.78	0.73	0.78	0.14
Memo: Data	0.63	0.56	0.65	0.43

NOTE: All variables are expressed in deviations from their respective steady-state values.

Cyclical Properties of Credit Spreads

	Conditional on the Type of Shock			
Selected Correlations	Technology	Uncertainty	Liquidity	Data
Corr(S, Y)	0.927	-0.811	-0.938	-0.457
Corr(S, I)	0.626	-0.515	-0.577	-0.531
Corr(S, C)	0.916	-0.368	-0.816	-0.498
Corr(S, NW)	-0.813	0.802	-0.703	-0.297
Corr(STD(S), Y)	0.933	-0.832	-0.950	-0.245

CreditSpreads

NOTE: All variables are expressed in deviations from their respective steady-state values.

Concluding Remarks

- Financial market frictions have an important effect on the investment-uncertainty nexus.
- The presence of financial market frictions significantly amplifies the response of investment and output to both uncertainty and liquidity shocks.
- An important extension of our framework would involve endogenizing the price of capital.

Summary Statistics

Selected bond characteristics

Bond Characteristic	Mean	StdDev	Min	Median	Max
# of bonds per firm/month	2.99	3.69	1.00	2.00	76.0
Mkt. value of issue (millions, $2005)	339.9	338.9	1.22	249.2	5,628
Maturity at issue (years)	12.8	9.2	1.0	10.0	50.0
Term to maturity (years)	11.1	8.5	1.0	8.0	30.0
Duration (years)	6.49	3.28	0.91	6.03	18.0
Credit rating (S&P)	-	-	D	BBB1	AAA
Coupon rate (pct.)	7.06	2.14	0.60	6.88	17.5
Nominal effective yield (pct.)	7.23	2.98	0.22	6.92	30.0
Credit spread (bps.)	202	223	5	128	2,000

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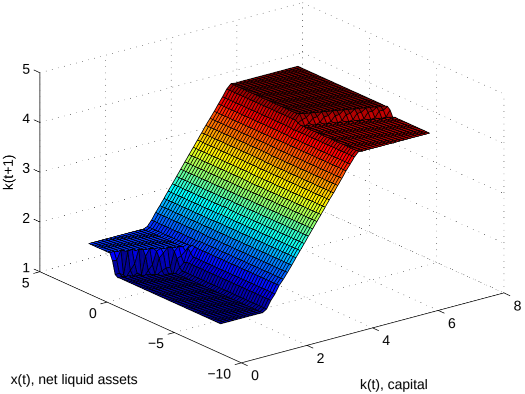
(S, s) Investment Policy Function

Partial irreversibility only



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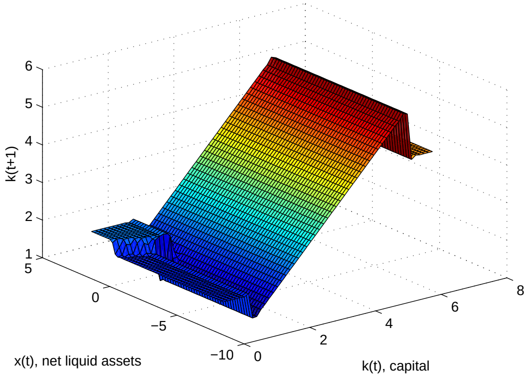
(S, s) Investment Policy Function

Partial irreversibility and fixed adjustment costs



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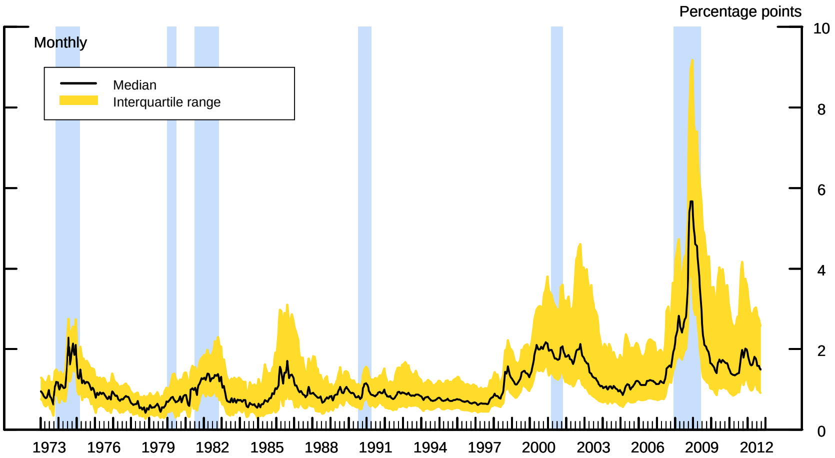
Corporate Bond Credit Spreads



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