Monetary Policy under Multiple Financing Constraints

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Motivation

- Credit channel: important mechanism through which monetary policy works
  - Policy rate changes influence tightness of financing constraints, credit, and investment (Bernanke and Gertler, 1989, 1995; Kiyotaki and Moore, 1997)
- Typical approach in the literature
  - Single financing constraint
  - Model linearity
- Research question:
  How and how much does the presence of multiple financing constraints–as documented empirically for U.S. non-financial firms (Lian and Ma, 2021)–affect the credit channel of monetary policy?

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1. Simple Theory:
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2. Empirics:
   - Strong evidence in favor of asymmetry and heterogeneity in individual responses

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1. Simple Theory:
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   - Rich heterogeneity in responses of constrained and unconstrained firms
2. Empirics:
   - Strong evidence in favor of asymmetry and heterogeneity in individual responses
3. Quantitative Theoretical Exploration (more preliminary):
   - Asymmetry in aggregate responses is quantitatively relevant
     (in a richer and calibrated version of the model, based on Ottonello and Winberry, 2020)

Related Literature

- **Asymmetry in Transmission of Monetary Policy**
  Tenreyro and Thwaites (2016); Barnichon et al. (2017); Angrist et al. (2018); Debortoli et al. (2020); Jordà et al. (2020); Barnichon et al. (2022)
- **Financial Frictions and Firm Heterogeneity**
  Jeenas (2019); Ottonello and Winberry (2020); Cloyne et al. (2023)
- **Anatomy of Financing Constraints**
  Greenwald (2019); Lian and Ma (2021); Ivashina et al. (2022); Drechsel (2023)

1. Theory

A Highly Parsimonious Model of Firm Investment

- Competitive firm that lives for two periods $t \in \{0, 1\}$
- Technology: Firm produces output good $y_t = F(k_t)$ using physical capital k_t
  - Adjusting k_1 over k_0 involves quasi-convex costs $H(|k_1 - k_0|)$
- Financing: $k_1 = \text{net worth}_0 + \text{debt}_1$:, with *multiple* $(J > 1)$ restrictions on debt that imply

$$k_1 \leq G_j(k_0; R), \text{ with } j \in \{1, 2, ..., J\},$$

where R is the gross interest rate and where the price of capital is normalized to 1

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! Key assumptions:

1. Multiple financing constraints can be binding
2. The constraints can feature different sensitivities to the interest rate

Financially Constrained Firm: Investment Response

Source of Asymmetry

Proposition 1. *If multiple financing constraints are binding, investment responds more aggressively to a marginal increase in the interest rate than to a marginal decrease. If a single constraint is binding, the response is instead symmetric.*

Financially Constrained Firm: Investment Response

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Proof. If the firm is financially constrained, then

$$\left| \lim_{h \to 0^+} \frac{\hat{k}_1 (k_0; R+h) - \hat{k}_1 (k_0; R)}{h} \right| = \max_{j \in B(k_0)} \left\{ \left| \frac{\partial}{\partial R} G_j (k_0; R) \right| \right\} , \tag{1}$$

and

$$\left| \lim_{h \to 0^-} \frac{\hat{k}_1 (k_0; R+h) - \hat{k}_1 (k_0; R)}{h} \right| = \min_{j \in B(k_0)} \left\{ \left| \frac{\partial}{\partial R} G_j (k_0; R) \right| \right\} , \tag{2}$$

where $\hat{k}_1 (\cdot; \cdot)$ is the constrained optimal investment and $B(\cdot)$ is the set of binding financing constraints.

Financially Constrained Firm: Investment Response

Strength of Asymmetry

Proposition 2. *If multiple financing constraints are binding, the larger the number of binding financing constraints, the stronger the asymmetry in the response of investment to a marginal change in the interest rate.*

Proof. Follows as corollary from Proposition 1.

→ Implies an intensive margin in the number of binding financing constraints

Financially Unconstrained Firm: Investment Response

Symmetry

Proposition 3. *If no financing constraint is binding, the response of investment to a marginal change in the interest rate is symmetric to the sign of the change.*

Proof. If the firm is financially unconstrained, then

$$\left|\frac{\partial}{\partial R}k_1\left(k_0;R\right)\right| = \frac{\frac{1}{R^2}\left[F'\left[k_1\left(k_0;R\right)\right]+\left(1-\delta\right)\right]}{H''\left[k_1\left(k_0;R\right)-k_0\right]-\frac{1}{R}F''\left[k_1\left(k_0;R\right)\right]}\ , \tag{3}$$

where unconstrained optimal investment $k_1\left(\cdot;\cdot\right) \leq \min_j\{G_j\left(\cdot,\cdot\right)\}$ is characterized by

$$1+H'\left[k_1\left(k_0;R\right)-k_0\right]=\frac{1}{R}\left[F'\left[k_1\left(k_0;R\right)\right]+\left(1-\delta\right)\right]\ . \tag{4}$$

Summary: Testable Implications

1. Asymmetry: investment of constrained firms responds more strongly, on average, to an increase in the interest rate than to a decrease of equal size
   (Note: constrained firms in data include firms with <u>one</u> and with <u>multiple</u> constraints!)

2. The higher the number of (potentially) binding financing constraints, the (weakly) stronger the asymmetry of the average investment response

3. Investment of unconstrained firms responds symmetrically to changes in the interest rate

2. Empirics

Data

- Firm-level balance sheet data
  - Compustat sample, U.S. nonfinancial firms, quarterly between 1995 and 2022
- Firm-level financial constraints: distance to default (D2D)
  - Merton (1974) model: firm's equity as call option on assets (strike price=debt)
  - CRSP (daily stock price data) combined with Compustat
  - Superior proxy for financing constraints → dominates usual proxies such as age, size, dividend payer status, etc... (Farre-Mensa and Ljungqvist, 2016)
- Monetary policy shocks from Miranda-Agrippino and Ricco (2021)
  - High-frequency changes in 2Y US Treasury yields around policy announcements
  - Abstract from new information from Fed regarding economy
  - Separate policy shocks in two types: "loosening" and "tightening" (similar average size between types and independence w.r.t. economic cycle)

Empirical Strategy

Regression equation at the firm level with double and triple interactions:

$$\begin{aligned}\Delta_9 LogK_{i,t+8} =& \beta_1 \text{MP Shock}_t + \beta_2(\text{MP Shock}_t * \mathbb{1}\text{Tight}_t) + \beta_3(\text{MP Shock}_t * \text{Constraint}_{i,t}) \\ &+ \beta_4(\text{MP Shock}_t * \mathbb{1}\text{Tight}_t * \text{Constraint}_{i,t}) + \mathbf{X}'\gamma + \epsilon_{i,t}\end{aligned}$$

where

- $\mathbb{1}\text{Tight}_t = 1$ if shock implies a monetary tightening, 0 otherwise
- $\text{Constraint}_{i,t}$ measures proximity to default
- Vector **X** includes uninteracted regressors, add. double interactions, controls, and FEs

Interpretation of interactions:

- $\beta_2 < 0$: MP effects are asymmetric, stronger for tightening
- $\beta_4 < 0$: MP asymmetry is stronger for financially constrained firms

Regression Output

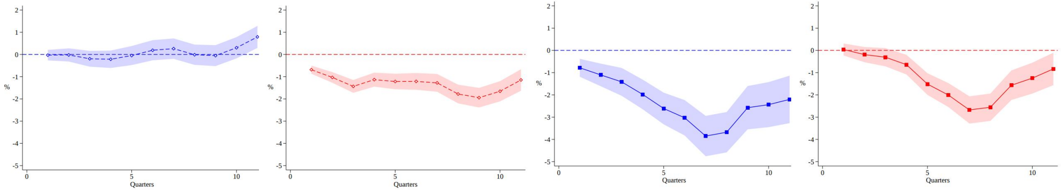
	Log(Capital)$_{t+8}$ − Log(Capital)$_{t-1}$			
	(1)	(2)	(3)	(4)
MP Shock	-1.221***			
	(0.140)			
MP Shock × Tightening	-1.933***			
	(0.298)			
MP Shock × Constraint	0.322***	0.273***	0.265***	0.228***
	(0.036)	(0.040)	(0.039)	(0.039)
MP Shock × Tightening × Constraint	-0.528***	-0.519***	-0.496***	-0.450***
	(0.061)	(0.067)	(0.066)	(0.066)
R-squared	0.341	0.377	0.374	0.388
N	242,653	245,261	242,653	242,653
Firm FE	✓	✓	✓	✓
Time FE		✓	✓	
Industry-Time FE				✓
Industry-Quarter FE	✓		✓	
p: β[MP Shock × Const.]+ β[MP Shock × Tight.× Const.]=0	.00001	.000002	.000004	.00001

- Financial constraints increase responsiveness to tightening shocks, while they decrease responsiveness to loosening shocks

Additional Output: Local Projections

Loosening Shocks

Tightening Shocks

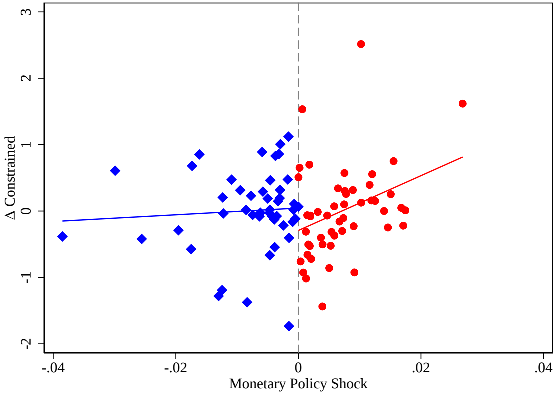


(c) Constrained Firms (d) Unconstrained Firms (a) Constrained Firms (b) Unconstrained Firms

- The average investment of financially constrained firms responds more aggressively to an increase in the interest rate than to a comparable decrease of equal size
- The average investment of financially unconstrained firms responds instead more symmetrically
- These responses start on impact and last approximately 12 quarters

Inspecting the Mechanism

Asymmetric Effect of MP Shock on Financing Constraints



- MP loosening → barely improves financially-constrained measure
- MP tightening → strongly worsens it

Further Inspecting the Mechanism

Importance of Multiple Financing Constraints

	$Log(Capital)_{t+8} - Log(Capital)_{t-1}$			
	(1)	(2)	(3)	(4)
	All Firms	Bottom Tercile # Constraints	Med Tercile # Constraints	Top Tercile # Constraints
MP Shock × Tightening × Constraints	-0.425***	-0.288**	-0.342***	-0.481***
	(0.076)	(0.145)	(0.113)	(0.140)
R-squared	0.334	0.363	0.344	0.294
N	172,634	37,420	73,216	61,998
Firm FE	✓	✓	✓	✓
Industry-Quarter FE	✓	✓	✓	✓
p: β [Shock*Const.]+ β [Shock*Const.*Tight.]=0	.0001	.0269	.4044	.0063

- The larger the number of relevant financing constraints, the stronger the asymmetry of the average investment response

Discussion: Robustness and Complementary Analysis

- Empirical findings are robust to:
  - using net leverage as a proxy for financial constraints
  - using alternative measures of MP shocks
- Further supportive evidence when looking at firms' borrowing: net debt flows respond most strongly to *tightening shocks* and in *financially constrained firms*
- Pending question: To what extent can multiple financing constraints quantitatively generate the observed asymmetry? Explore this next...

3. Quantitative Exploration

A Quantitative Model of Firm Investment under Multiple Financing Constraints (1/2)

- Time $t \in \{0, 1, 2, ...\}$ – No aggregate uncertainty
- A continuum of competitive firms
- Firms:
  - Produce an output good $y_t = (l_t)^\nu (k_t)^\alpha$ with $\nu + \alpha < 1$ using labor l_t and physical capital k_t
  - Incur in quadratic costs $(\varphi/2)(k_{t+1}/k_t - 1)^2 k_t$ when adjusting its capital stock (capital is pre-determined and depreciates at rate δ)
  - Can issue debt b_{t+1} at gross interest rate R_t but must respect an asset- and an earning-based financing constraint (details in next slide)
  - Exit stochastically at rate γ – Exiting firms replaced by newborns with initial capital stock $\bar{k}$
  - Distribute dividends only upon exiting
- Wage w_t exogenous & Price of capital normalized to 1

A Quantitative Model of Firm Investment under Multiple Financing Constraints (2/2)

- Asset-based constraint: $b_{t+1} \leq q_{t+1} k_{t+1}$, where collateral price q_t is given by

$$q_t = \theta_{1,t}\lambda_1 + \frac{1}{R_t}(1 - \theta_{1,t})q_{t+1}, \text{ with } \theta_{1,t} = \theta_{1,L}\left(\frac{K_t}{K_{ss}}\right)^{\theta_{1,S}}, \lambda_1, \theta_{1,L} \in [0,1], \theta_{1,S} \geq 0 \quad (5)$$

- Earnings-based constraint: $b_{t+1} \leq G_{t+1}(k_{t+1})$, with

$$G_t(k) = \lambda_2 \pi_t(k) + (1 - \theta_2)\left[-\delta k + \frac{1}{R_t} G_{t+1}(k)\right], \text{ with } \lambda_2, \theta_2 \in [0,1], \quad (6)$$

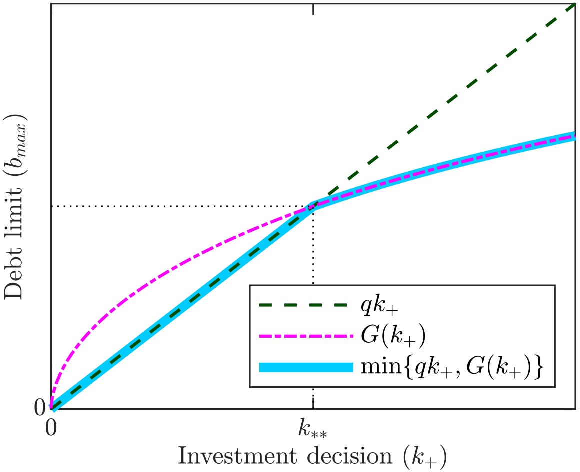
where operating profits net of investment expenditures are

$$\pi_t(k) \equiv \max_{l_t} \left\{ l_t^{\nu} k^{\alpha} - w_t l_t \right\} \quad (7)$$

- Effective financing constraint: $b_{t+1} \leq \min\{q_{t+1}k_{t+1}, G_{t+1}(k_{t+1})\}$

Effective Financing Constraint

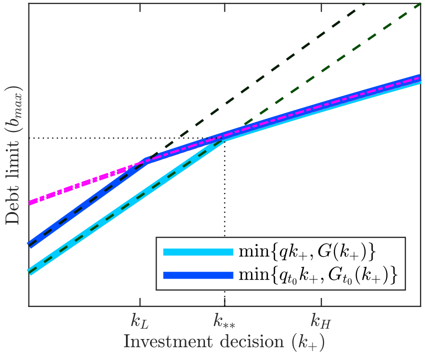
Steady State



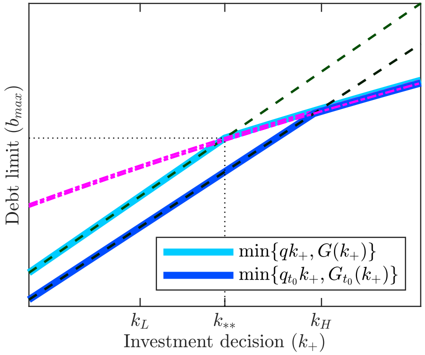
Sensitivity of Effective Financing Constraint to Interest Rate

Temporary Deviation from Steady State – Response on Impact

(a) Loosening



(b) Tightening



- With one underlying constraint → sensitivity is symmetric
- With two (or more) underlying constraints → sensitivity is asymmetric within $[k_L, k_H]$

Calibration

Parameter Values – Quarterly Frequency

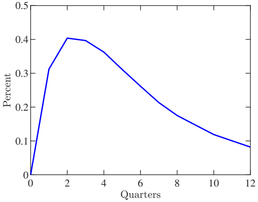
Description	Value	Target / Source
Coefficient of labor in production technology	$\nu = 0.64$	Labor share of output
Coefficient of capital in production technology	$\alpha = 0.21$	Returns to scale = 0.81
Depreciation Rate of capital	$\delta = 0.025$	Ottonello and Winberry (2020)
Adjustment cost of capital	$\varphi = 1$	Response of ratio investment-to-output
Gross interest rate	$R = 1.01$	Ottonello and Winberry (2020)
Wage	$w = 1$	Normalization
Exit rate of firms	$\gamma = 0.025$	= Target as Ottonello and Winberry (2020)
Initial capital stock of starting firms	$\bar{k} = 0.03$	= Target as Ottonello and Winberry (2020)
Share of pledgeable capital	$\lambda_1 = 0.75$	Share of asset-based constrained = 0.2
Duration of pledgeable capital	$\theta_{1,L} = 0.1$	Asset price sensitivity to long-run rates = 1
Sensitivity of duration to agg. capital stock	$\theta_{1,S} = 10$	Asset price sensitivity to short-run rates = 4
Share of pledgeable output	$\lambda_2 = 0.85$	Share of firms with debt = 0.80
Duration of pledgeable output	$\theta_2 = 0.15$	Average leverage = 0.33

Asymmetry at the Firm Level

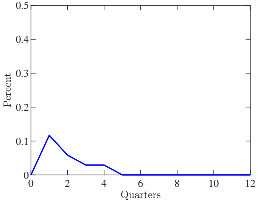
Response to $|\Delta\% R_t| = 0.25\%$ from steady state on impact with $\rho_R = 0.5$

Loosening:

(a) Unconstrained

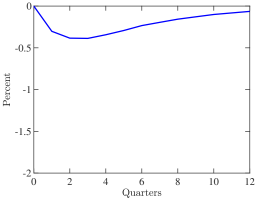


(b) Constrained

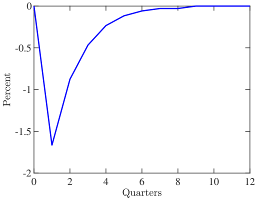


Tightening:

(c) Unconstrained



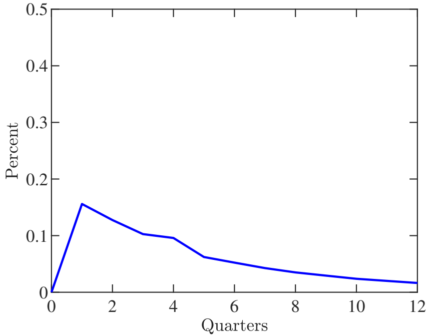
(d) Constrained



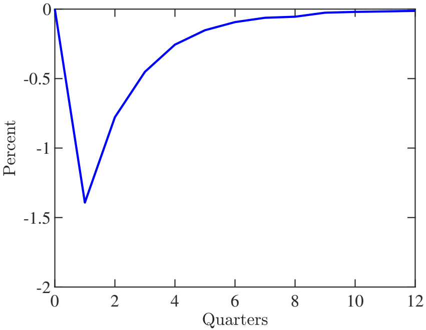
Asymmetry at the Aggregate Level

Response to $|\Delta\% R_t| = 0.25\%$ from steady state on impact with $\rho_R = 0.5$

(a) Loosening



(b) Tightening



Conclusion

- Firms face multiple financing constraints (Lian and Ma, 2021)
- This matters for the credit channel of monetary policy
- In particular, when firms face more than one potentially binding financing constraint:
  1. The average investment of financially constrained firms responds more aggressively to an increase in the interest rate than to a comparable decrease of equal size
  2. The larger the number of (potentially) binding financing constraints, the (weakly) stronger the asymmetry of the average investment response
  3. Aggregate investment tends to respond more aggressively to an increase in the interest rate than to a comparable decrease of equal size
- Empirical evidence in favor of results 1., 2. and 3.
- In quantitative exploration results are significant

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