

The Investment Channel of Monetary Policy: Disentangling Firm Heterogeneity*

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*The views expressed here do not necessarily reflect those of the Federal Reserve Bank of New York or the Federal Reserve System.

Motivation

- ▶ Widespread interest in the transmission of monetary policy to firm investment
- ▶ Particular focus on heterogeneity across firms

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- ▶ Particular focus on heterogeneity across firms
- ▶ Literature provides many results
 - ▶ Gertler & Gilchrist (1994): small firms more responsive to monetary policy
 - ▶ Ottonello & Winberry (2020): low-leverage firms more responsive
 - ▶ Cloyne et al (2023): young firms more responsive
 - ▶ Jeenas (2024): illiquid firms more responsive
 - ▶ ...

The conventional approach: panel local projection

Select **one** firm characteristic ex ante and include in interaction term:

$$\log k_{i,t+h} - \log k_{i,t-1} = \alpha_i^h + \beta^h x_{i,t-1} \times \epsilon_t^m + \xi^h \epsilon_t^m + \delta^h x_{i,t-1} + \text{controls} + \eta_{i,t}^h$$

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But:

- ▶ There might be heterogeneity unrelated to the chosen $x_{i,t-1}$
- ▶ There might be heterogeneity related to many additional $x_{i,t-1}$
- ▶ Heterogeneity could be nonlinear
- ▶ Heterogeneity could be unobservable

This paper

1. Directly estimate full distribution of firms' responsiveness of investment to monetary policy (RIMP)
 - ▶ Gaussian mixture regression to assign firm-time obs to finite number of RIMPs
 - ▶ Approach successfully used for HH consumption ([Lewis, Melcangi, Pilossoph, 2026](#))

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 - ▶ Gaussian mixture regression to assign firm-time obs to finite number of RIMPs
 - ▶ Approach successfully used for HH consumption (Lewis, Melcangi, Pilossoph, 2026)
2. Our approach
 - ▶ is ex ante agnostic about determinants of RIMP
 - ▶ allows a firm's RIMP to change over time
 - ▶ recovers latent and observable heterogeneity
 - ▶ can estimate ex post how much variation explained by a given observable
 - ▶ facilitates a horse race between competing drivers + nonlinearities

Our findings

1. Features of the RIMP distribution

- ▶ Most responses **small but non-zero**
- ▶ **Small share** of firm-time obs (5%) show strong responsiveness (1pp per 25bps)

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2. Drivers of the RIMP distribution

- ▶ Considerable variation **within firms**
- ▶ Candidate **characteristics from literature** play a role
- ▶ Also uncover **new drivers**
- ▶ Large share of variation **unexplained**

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3. Implications for structural models

- ▶ **New targets** for heterogeneous firm models
- ▶ RIMP distribution distinguishes models that one-covariate approach cannot

Empirical framework

- ▶ Follow [Ottonello and Winberry \(2020\)](#)
 - ▶ Same data: Compustat 1991Q2–2007Q4
 - ▶ Same left-hand-side: $\Delta \log$ book value tangible capital stock
 - ▶ Same right-hand-side: HF surprises (Δ front FFF, 1-hr window)
- ▶ Homogeneous specification

$$\Delta^h \log k_{i,t} = \alpha_i^h + \lambda^h \epsilon_t^m + \sum_{l=1}^4 \Gamma^{h'} Z_{t-l} + \eta_{i,t}^h$$

- ▶ Goal: heterogeneity in λ^h
- ▶ For now: $h = 0 \rightarrow$ generalize later
- ▶ No firm-level controls $\rightarrow$ project *ex-post*

Empirical framework (continued)

- ▶ Two preliminary steps:
 1. Absorb α_i
 2. Residualize w.r.t. aggregate controls $Z_t = [\Delta Y_t, U_t, \pi_t]'$
- ▶ Gaussian mixture linear regression model (GMLR):

$$\Delta \widetilde{\log k_{i,t+1}} = \sum_{g=1}^G d_{it,g} \lambda_g \widetilde{\epsilon_t^m} + \widetilde{\eta}_{i,t}$$

- ▶ $\widetilde{\cdot}$ denotes residualized variables
- ▶ $d_{it,g} = \mathbb{1}[it \in g]$
- ▶ $\widetilde{\eta}_{i,t} \sim \mathcal{N}(0, \sigma_g^2)$

GMLR clustering

Complete-data likelihood is:

$$L(\theta) = \prod_{j=1}^N \prod_{g=1}^G \left(\pi_g^G \right)^{d_{jg}} \phi \left(\widetilde{\Delta \log k_j}; \lambda_g \widetilde{\epsilon_t^m}, \sigma_g^2 \right)^{d_{jg}},$$

where:

- ▶ j is observation for firm i at time t
- ▶ π_g^G is unconditional probability of belonging to $g \in G$
- ▶ θ collects all parameters for $g = 1, \dots, G$
- ▶ $\phi(\cdot; \mu, \nu)$ normal pdf with mean μ and variance ν

d_{jg} latent: compute **expected log likelihood** over latent group membership

GMLR clustering (continued)

Expected log-likelihood is

$$l(\theta) \equiv E_D [L(\theta)] = \sum_{j=1}^N \sum_{g=1}^G \gamma_{jg} \left(\log \pi_g^G + \log \phi \left(\widetilde{\Delta \log k_j}; \lambda_g \widetilde{\epsilon_t^m}, \sigma_g^2 \right) \right),$$

where

$$\gamma_{jg} = \Pr \left(d_{jg} = 1 | \widetilde{\Delta \log k_j}, \widetilde{\epsilon_t^m} \right) = \frac{\pi_g^G \phi \left(\widetilde{\Delta \log k_j}; \lambda_g \widetilde{\epsilon_t^m}, \sigma_g^2 \right)}{\sum_{h=1}^G \pi_h^G \phi \left(\widetilde{\Delta \log k_j}; \lambda_h \widetilde{\epsilon_t^m}, \sigma_h^2 \right)}$$

is posterior probability (reflects econometrician's uncertainty)

Maximize $l(\theta)$ using **expectation-maximization (EM) algorithm**

Practical considerations

- ▶ Select $G = 4$ based on Bayesian Information Criterion
- ▶ Standard errors:
 - ▶ Fisher Information (accounts for estimation uncertainty)
 - ▶ Cluster by time (Almuzara and Sancibrian, 2024)
- ▶ Objects of interest:
 - ▶ Unconditional RIMP distribution: $\{\lambda_g, \pi_g\}_{g=1}^G$: consistent estimates
 - ▶ Posterior predicted RIMP distribution: $\hat{\lambda}_j = \sum_{g=1}^G \gamma_{j,g} \lambda_g$
- ▶ Focus mostly on $h = 0$ today, but also construct full IRFs for each g

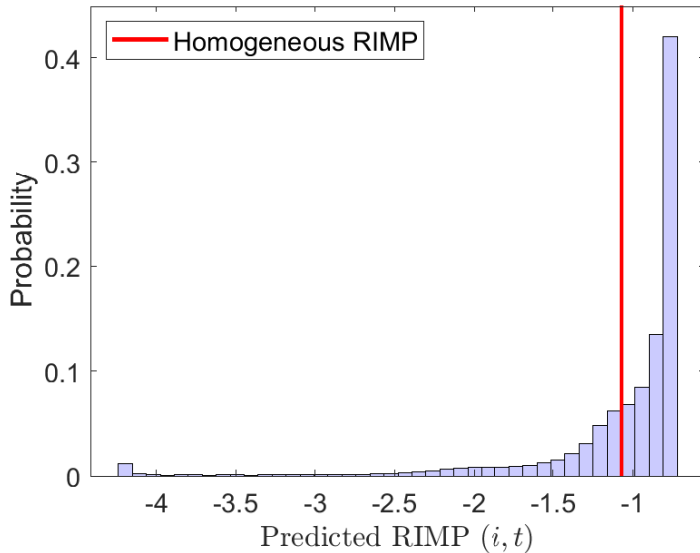
Results: the unconditional RIMP distribution

	group 1	group 2	group 3	group 4
RIMP (λ_g)	-4.22	-1.66	-0.90	-0.51
Standard Error	(1.81)	(0.35)	(0.09)	(0.04)
Probability of being in group (π_g)	0.05	0.19	0.45	0.32
Standard Error	(0.00)	(0.01)	(0.01)	(0.01)

- Magnitude: for group 4, FFR $\uparrow$ 1 pp $\Rightarrow \Delta \log k \downarrow$ by 0.5 pp

Pairwise significance

Results: the predicted RIMP distribution



Results: persistent vs. transitory heterogeneity

- ▶ 80% of overall variance in RIMP is **within** firm (based on variance decomposition)
- ▶ Transition matrix: high RIMP status transient; low RIMP status persistent

		modal RIMP in $t + 1$				
		λ_1	λ_2	λ_3	λ_4	
modal RIMP in t		-4.22	-1.66	-0.90	-0.51	Total
λ_1	-4.22	0.12	0.23	0.42	0.23	1.00
λ_2	-1.66	0.06	0.29	0.44	0.21	1.00
λ_3	-0.90	0.02	0.10	0.55	0.33	1.00
λ_4	-0.51	0.01	0.05	0.34	0.59	1.00
Total		0.03	0.10	0.44	0.43	1.00

Possible drivers of the RIMP

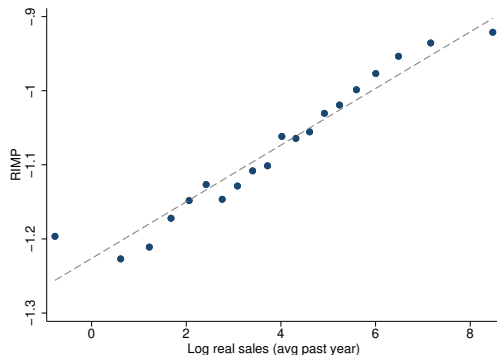
► “Traditional” characteristics → examine individually and jointly

1. Size: Small firms respond more [Gertler and Gilchrist \(1994\)](#)
2. Age: Young firms respond more [Cloyne, Ferreira, Froemel and Surico \(2023\)](#)
3. Default risk: Mixed results on leverage and distance to default [Ottonello and Winberry \(2020\)](#)
4. Cash ratio: Liquid firms respond more [Jeenas \(2023\)](#)
5. Debt maturity: Firms with more long-term debt respond less [Jungherr et al. \(2024\)](#)

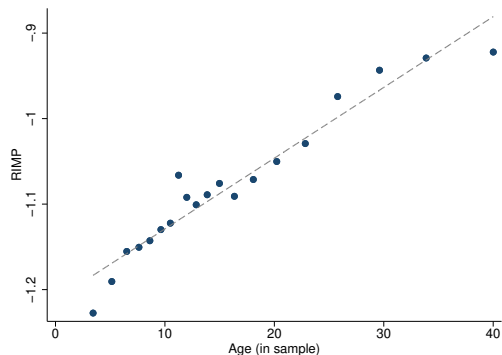
► “Novel” characteristics:

1. Perceived discount rates: larger wedge means more responsive [Gormsen and Huber \(2025\)](#)
2. CFO optimism: more optimistic firms respond less [Graham and Harvey \(2020\)](#)

Size and age



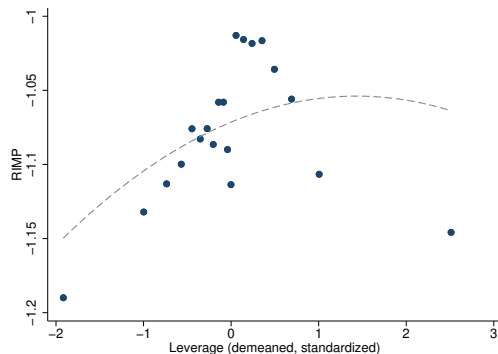
(a) RIMP and size



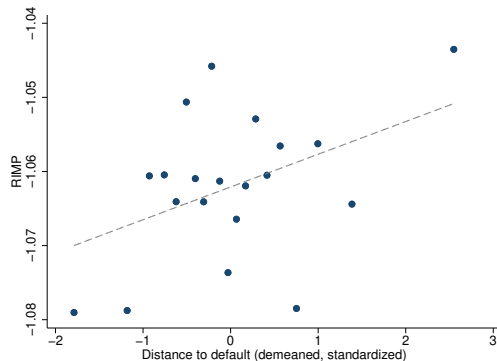
(b) RIMP and age

- ▶ Small firms respond **more**, as in [Gertler and Gilchrist \(1994\)](#)
- ▶ “Young” firms respond **more**, as in [Cloyne et al \(2023\)](#)

Default risk



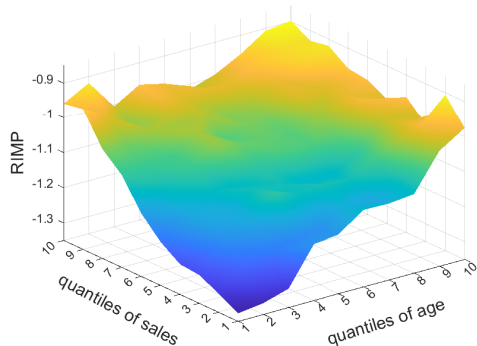
(a) RIMP and leverage



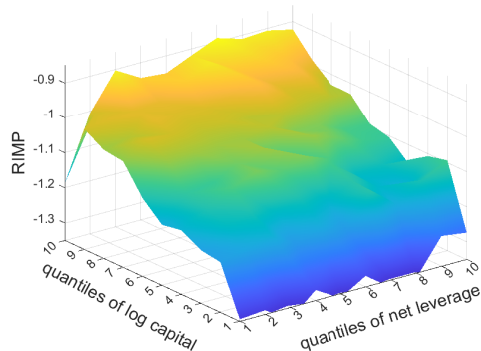
(b) RIMP and distance to default

- ▶ Low-leverage firms **more** responsive to monetary policy, as in OW (but **nonlinear!**)
- ▶ Distance to default ambiguous – different from OW

RIMP and multidimensional drivers



(a) RIMP by size and age



(b) RIMP by capital and net leverage ratio

- ▶ Small and young firms **more** responsive to monetary policy
- ▶ Small and less-leveraged firms **more** responsive to monetary policy

Joint analysis

	(1)	(2)	(3)
Leverage (demeaned, standardized)	-0.001 (0.003)	-0.002 (0.003)	0.002 (0.003)
Distance to default (demeaned, standardized)	0.004** (0.002)	0.005** (0.002)	0.000 (0.002)
Share of total debt that is long-term	0.096*** (0.006)	0.098*** (0.006)	0.035*** (0.008)
Cash ratio	-0.331*** (0.014)	-0.343*** (0.014)	-0.143*** (0.027)
Firm age	0.004*** (0.000)	0.004*** (0.000)	0.001** (0.001)
Log of real sales (avg past year)	0.022*** (0.001)	0.023*** (0.001)	0.016*** (0.005)
Adjusted R-squared	0.041	0.049	0.172
Time x Industry FE		✓	
Firm FE			✓

- ▶ Majority of RIMP variation **unexplained by observables**
- ▶ Nonlinearities matter, but do not substantially increase the fit

LASSO

Multinomial logit

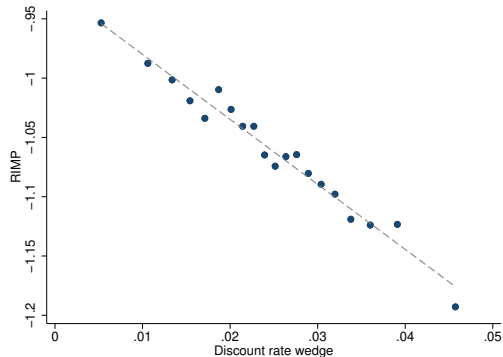
Implications of unobservable RIMP heterogeneity

- ▶ No clear benchmark for R^2
 - ▶ Unconditional investment behavior also hard to fit with firm observables
- ▶ Unobservable RIMP variation not critical for aggregate RIMP

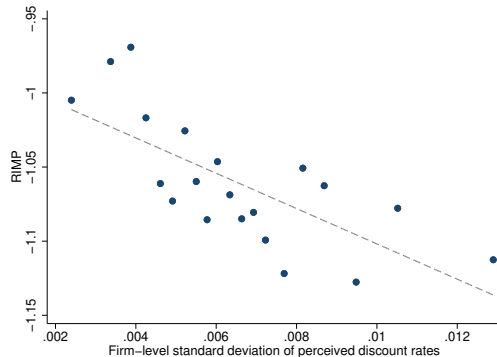
	Implied aggregate RIMP
Using all RIMP estimates	-0.908
Using RIMP estimates predicted by leverage only	-1.062
Using RIMP estimates predicted by size only	-0.895
Using RIMP estimates jointly predicted by observables	-0.896

- ▶ Motivates the focus on newer drivers, e.g. outside of Compustat information

Discount rate wedges and stickiness



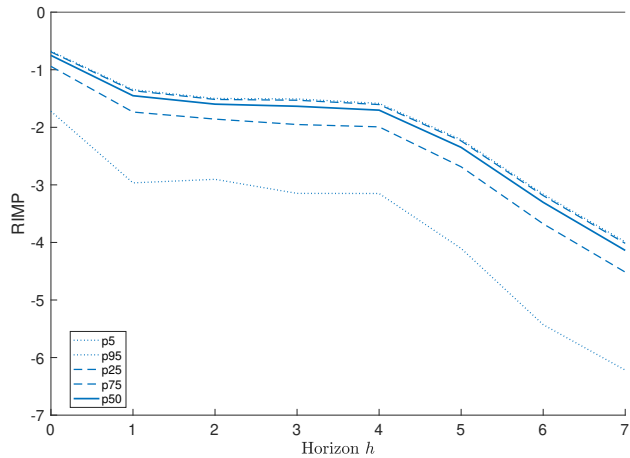
(a) RIMP and discount rate wedges



(b) RIMP and discount rate variation

- ▶ Firms with **larger wedge** between perceived discount rate and cost of capital (Gormsen and Huber, 2025) respond **more**
- ▶ Firms with **stickier discount rates** (Fukui, Gormsen, Huber, 2025) respond **less**

RIMP IRFs



RIMP IRFs - projections on firm characteristics

	Horizon		
	0	3	7
Leverage (demeaned, standardized)	0.003 (0.002)	0.004 (0.004)	0.006 (0.006)
Distance to default (demeaned, standardized)	0.000 (0.001)	0.001 (0.002)	0.000 (0.003)
Share of total debt that is long-term	0.020*** (0.006)	0.031*** (0.009)	0.052*** (0.015)
Cash ratio	-0.106*** (0.018)	-0.168*** (0.029)	-0.270*** (0.048)
Firm age	0.001*** (0.000)	0.002*** (0.001)	0.003*** (0.001)
Log of real sales (avg past year)	0.011*** (0.004)	0.017*** (0.006)	0.030*** (0.009)
Time $\times$ Industry FE			
Firm FE	✓	✓	✓
Adjusted R^2	0.187	0.187	0.157

Implications for structural models

Our empirical results as a new set of targets:

1. Shape of the RIMP distribution
2. Most of RIMP variation is within firms
3. RIMP and observable drivers, multidimensional correlations

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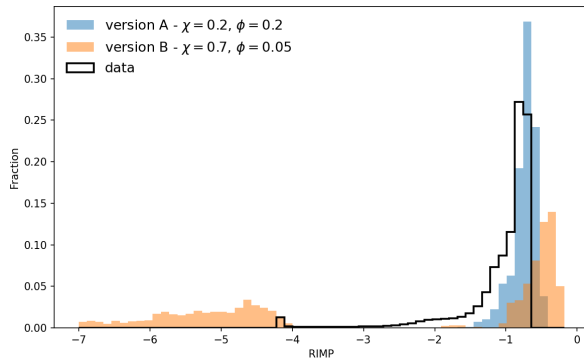
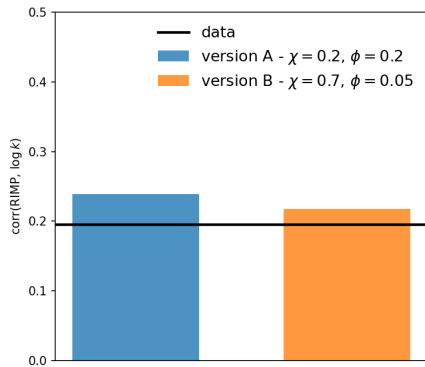
Our key argument is that (1) should be a model target:

- ▶ Show two model calibrations that match (3) but only one matches (1)
- ⇒ Full RIMP distribution is a critical target!

Model exercise

- ▶ Take **Winberry, Auclert, Rognlie, Straub (2026)** wars
 - ▶ Simplified **Khan and Thomas (2013)** model + NK block
 - ▶ Firm heterogeneity, capital adjustment costs, financial frictions
- ▶ Transitory, unexpected, monetary shock to the Taylor rule (SSJ perturbation)
- ▶ Compute the firm-time level GE RIMP at $h = 0$
- ▶ Two calibrations for adjustment costs (ϕ) and collateral parameters (χ):
 - A. $\phi = 0.20$, $\chi = 0.20$
 - B. $\phi = 0.05$, $\chi = 0.70$

RIMP moments as model targets



Conclusion

- ▶ We estimate distribution of firms' investment responses to monetary policy
- ▶ We uncover substantial heterogeneity:
 - ▶ Most responses are small
 - ▶ Few responses are large: up to 8x larger than smallest
 - ▶ Remains true at longer horizons
- ▶ We characterize RIMP heterogeneity:
 - ▶ Most variation is within firms
 - ▶ 'Old' and 'new' variables correlate with the RIMP
 - ▶ Majority of variation remains unexplained
- ▶ Full RIMP distribution is an important target for structural models

RIMP: pairwise significance

Test statistics and p-values for pairwise equality tests.

RIMP

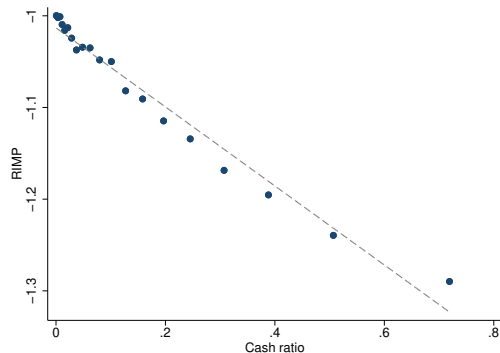
	−4.22	−1.66	−0.90	−0.51
−4.22	4.62 (0.03)			
−1.66	1.48 (0.22)	15.53 (0.00)		
−0.90	4.62 (0.09)	1.48 (0.12)	2.88 (0.00)	
−0.51	4.62 (0.06)	1.48 (0.01)	2.88 (0.03)	3.57 (0.00)

Different results to OW for D2D?

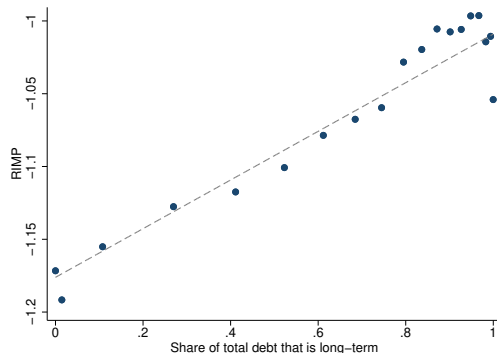
Possible reasons:

- ▶ OW effect is **nonlinear**:
 - ▶ To show this, we repeat OW's specification but interact with **quintiles** of D2D, and find nonlinearities.
- ▶ If D2D heterogeneity depends on other forms of heterogeneity, then OW suffers from **omitted variable bias** compared to GMLR.
- ▶ Bias can also arise from **higher-order relationships between** x_{t-1} and errors in both investment and RIMP prediction regressions.

Liquidity and debt maturity



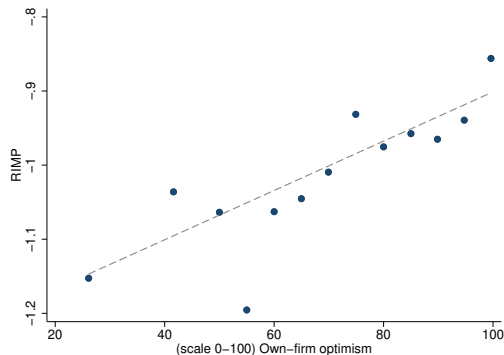
(a) RIMP and cash ratio



(b) RIMP and debt maturity

- ▶ Liquid firms respond **more** (contrasts Jeenas, 2023 for long horizons)
- ▶ Firms with more long-term debt respond **less** (Jungherr et al, 2024)

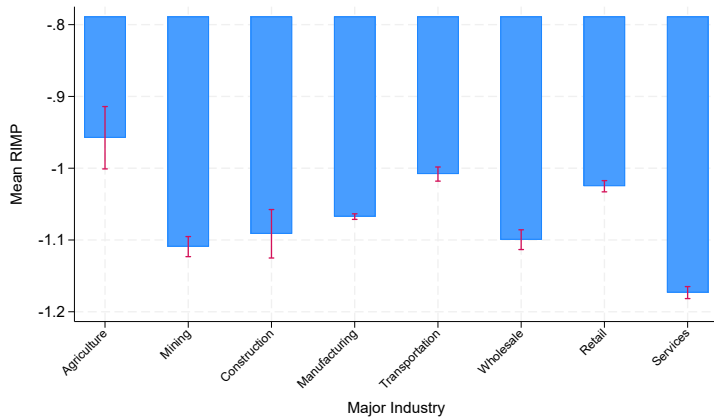
CFO optimism (CFO Business Outlook Survey)



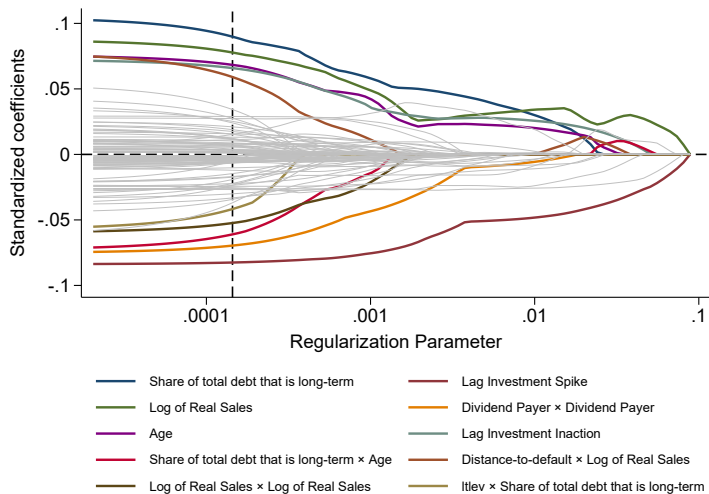
(a) RIMP and CFO optimism

► Firms with **more optimistic** CFOs respond **less** [Back](#)

RIMP by industry



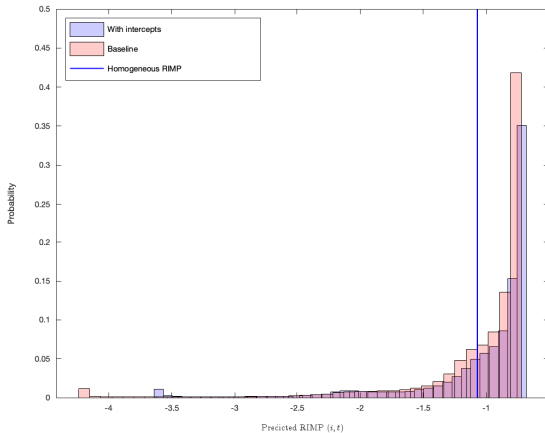
LASSO regression results



Predicting individual RIMPs

	Group 1 $\lambda_1 = -4.22$	Group 2 $\lambda_2 = -1.66$	Group 3 $\lambda_3 = -0.90$	Group 4 $\lambda_4 = -0.51$
Leverage (demeaned, standardized)	0.000 (0.001)	-0.000 (0.001)	0.000 (0.001)	-0.001 (0.001)
Distance to default (demeaned, standardized)	-0.000 (0.000)	-0.001* (0.001)	-0.001 (0.001)	0.002*** (0.001)
Share of total debt that is long-term	-0.014*** (0.001)	-0.032*** (0.002)	0.005*** (0.002)	0.042*** (0.002)
Cash ratio	0.038*** (0.002)	0.114*** (0.004)	0.027*** (0.004)	-0.178*** (0.005)
Firm age	-0.001*** (0.000)	-0.002*** (0.000)	0.000 (0.000)	0.002*** (0.000)
Log of real sales (avg past year)	-0.004*** (0.000)	-0.007*** (0.000)	0.002*** (0.000)	0.009*** (0.000)
Pseudo R^2	0.027	0.015	0.000	0.014

Allowing for group-specific intercepts α_g



► Correlation between the predicted RIMPs is 0.99

Winberry et al. (2025) wholesale producer problem

$$v(z, k, b) = \max_{n, k', b', d} d + \mathbb{E} \Lambda \left[(1 - \theta)v(z', k', b') + \theta v_{\text{exit}}(z', k', b') \right]$$

s.t.

$$d = pz k^\alpha n^\nu - wn - b - (k' - (1 - \delta)k) - \Phi(k, k') + \frac{b'}{1 + r}$$

$$d \geq 0$$

$$b' \leq \chi k'$$

$$v_{\text{exit}}(z, k, b) = zk^\alpha n^\nu - wn - b + (1 - \delta)k$$

Other model blocks:

- ▶ Household
- ▶ Retailers (Rotemberg adjustment cost) and final-good producer
- ▶ Monetary authority (Taylor rule as in OW)