Incomplete Information and Investment Inaction

4th Workshop on Firm Heterogeneity and Macroeconomics (Bonn): December 12, 2025

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*The views in this paper are solely the authors' responsibility and should not reflect the views of the Federal Reserve Bank of Kansas City or the Board of Governors of the Federal Reserve System.

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- How does incomplete information affect capital when investments are irreversible?

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- Several lines of active research trying to resolve this tension, e.g. production networks (Winberry and vom Lehn 2025)

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3. **Empirical Analysis:**
    - Test predictions using Japanese administrative data
    - Firms with worse information behave as predicted by model

Theory

Firms' Problem

- Atomistic firms face simple investment problem
- Produce using capital K and stochastic productivity A by

$$F(A,K) = A^{1-\alpha}K^{\alpha}$$

- Log productivity a follows a random walk:

$$da = \sigma_a dW^a$$

- Investment I is irreversible. Conditional on investing, profits are

$$\pi = A^{1-\alpha}K^{\alpha} - \psi I$$

- The law of motion for capital is

$$dK = I - \delta K dt$$

Firms' Behavior: Investment Inaction Region

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- Effect of incomplete information? *It determines the inaction region*

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$$\Omega(t) = \{a(j-\tau), s(j) : j \leq t\}$$

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- Relevant state variables: log capital k and *nowcast* $\hat{a} \equiv \mathbb{E}[a|\Omega]$
- $\hat{a}$ follows a random walk with the same properties as a

Nowcast Behavior

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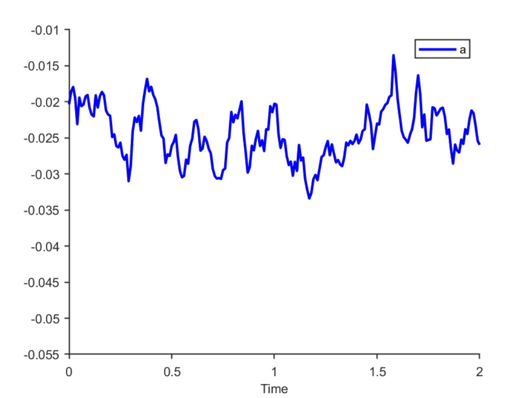
- Firm maximizes *expected value function* $\hat{V}(e^{\hat{x}}) = \mathbb{E}[V(e^x)|e^{\hat{x}}]$
- We show that the optimum is characterized by usual value-matching and super contact conditions, except applied to $\hat{V}$:

$$\hat{V}'(e^{\hat{b}}) = \psi \qquad \lim_{e^{\hat{x}} \to \infty} \hat{V}'(e^{\hat{x}}) = 0$$

$$\hat{V}''(e^{\hat{b}}) = 0 \qquad \lim_{e^{\hat{x}} \to \infty} \hat{V}''(e^{\hat{x}}) = 0$$

Exact Expression Normalized HJB

Example of a Typical Firm's Behavior



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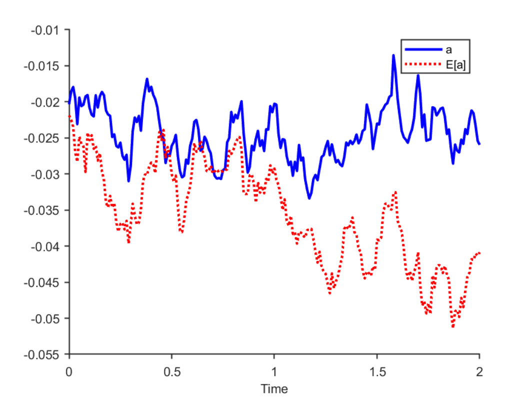

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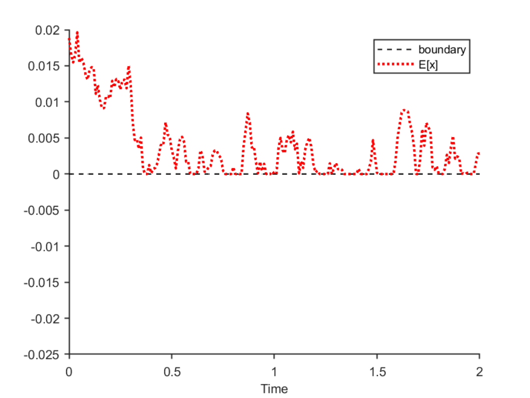

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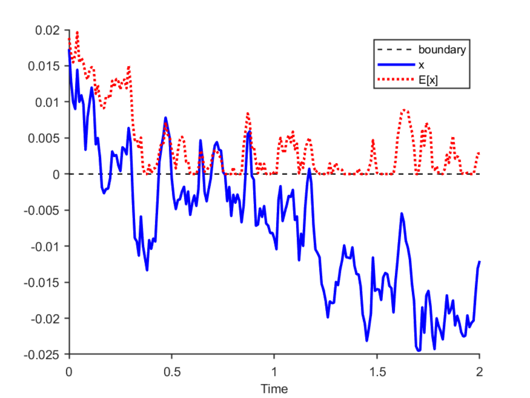

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- Actual norm. capital x follows $x = k - a = \hat{x} + \hat{a} - a$

Micro-Level Implications 1: Reduced Inaction

1. Information friction **increases** the incentive to invest

$$\hat{b} = \underbrace{b^{FI}}_{\text{Full Info.}} + \frac{\alpha^2}{2(1-\alpha)} \underbrace{\frac{\tau \sigma_a^2 \sigma_n^2}{\sigma_a^2 + \sigma_n^2}}_{Var[u]}$$

- Greater noise ($\sigma_n \uparrow$) or delay ($\tau \uparrow$) raise boundary $\hat{b}$
- Contrasts with traditional uncertainty channel: $\sigma_a \uparrow \implies b^{FI} \downarrow$
- Why? An Oi-Hartman-Abel effect:
  - MPK is convex in log productivity. Firms: risk-loving on normalized capital x
  - Friction acts as a mean preserving spread on x

▸ Boundary Properties ▸ Partial Irreversibility

Micro-Level Implications 2: Attenuated Shocks

2. Information friction **reduces** elasticity of forecasts to productivity shocks

$$\frac{d}{da_{t-h}}\mathbb{E}[a_t|\Omega_t] = \begin{cases} \gamma & 0 \leq h < \tau \\ 1 & h \geq \tau \end{cases}$$

where

$$\gamma \equiv \frac{\sigma_a^2}{\sigma_a^2 + \sigma_n^2} < 1$$

Testable predictions for later: worse information associated with

- **Lower inaction rate**, conditional on firm size
- **Lower sensitivity of investment to productivity shocks**

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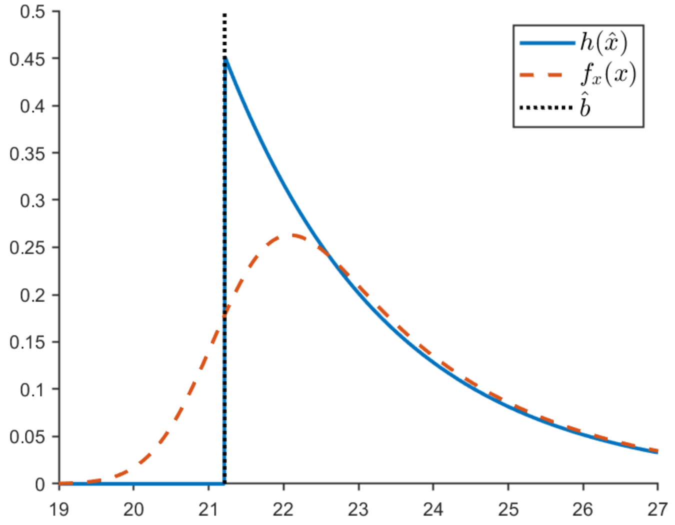
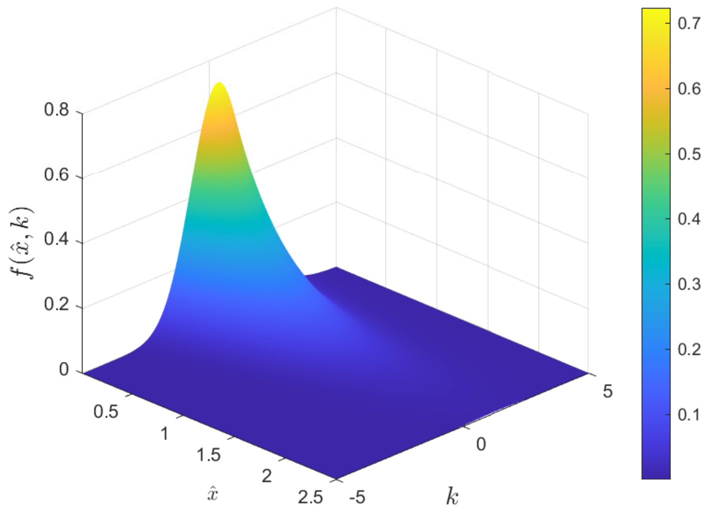
- Actual $x = \hat{x} + u$ is more dispersed

Stationary Distributions: Expected & Actual Normalized Capital



Stationary Distribution: Capital & Expected Norm. Capital



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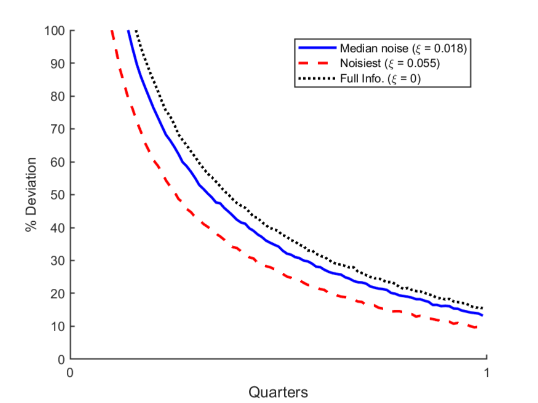
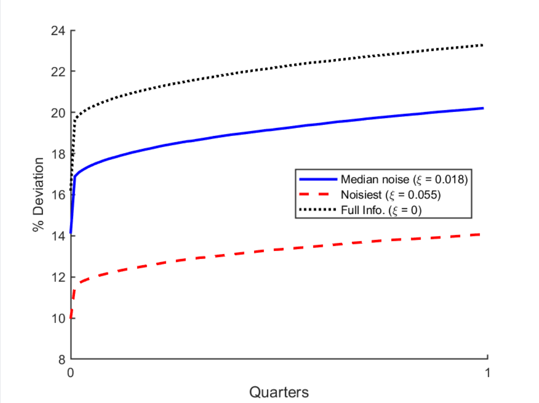
2. Information friction **increases** capital misallocation
    - Greater noise ($\sigma_n \uparrow$) or delay ($\tau \uparrow$) increase nowcast error variance $Var[u]$
3. Information friction **attenuates** aggregate responses to productivity shocks:

$$\widehat{IRF}_k(t) = \gamma \widehat{IRF}_k^{FI}(t) \qquad \gamma = \frac{\sigma_a^2}{\sigma_a^2 + \sigma_n^2}$$

Info. Friction Attenuates Aggregate Response to Shocks



Investment



Output

Validation with Firm-level Data

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  - All large firms and representative sample of small and medium-sized firms

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  - Industry-time, region-time, size-time fixed effects

Heterogeneity in Attenuation Coefficients

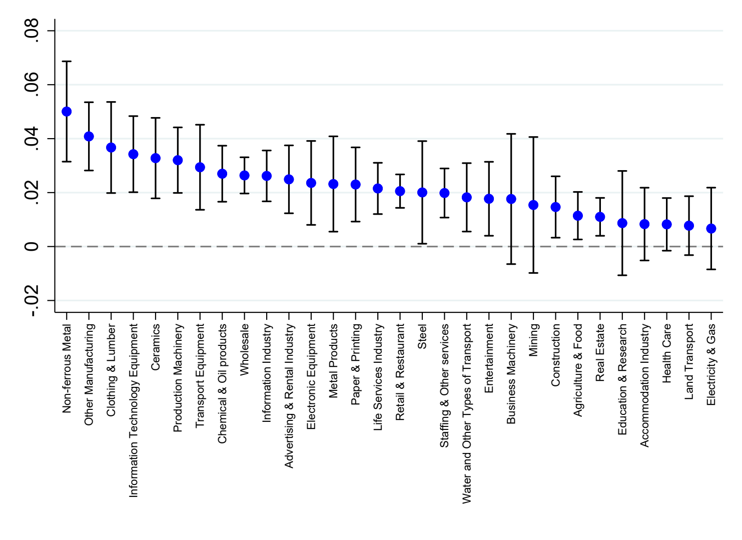
- Information friction: forecast error response to productivity shocks
- Estimate industry-specific attenuation coefficient ξ_s:

$$e_{it+1} = \xi_s w_{it} + \Gamma z_{it} + \gamma_{st} + \gamma_{rt} + \gamma_{gt} + \epsilon_{it+1}$$

  - $e_{it+1} = y_{it+1} - \widehat{y_{it+1}}$ is the sales forecast error
  - $w_{it} = a_{it} - a_{it-1}$ is the measured (labor) productivity shock
  - z_{it}: firm-level controls
  - Industry-time, region-time, size-time fixed effects

- Positive $\xi_s \implies$ forecast *underreaction*

Attenuation Coefficients across Industries



Empirical Exercise 1: Information Frictions & Inv. Inaction

- Do we observe more investment inaction for firms in industries with more severe information frictions?

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  - ζ_s: industry-level controls
  - γ_t: time fixed effects
  - Standardize ξ_s

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  - z_{it}: firm-level controls
  - ζ_s: industry-level controls
  - γ_t: time fixed effects
  - Standardize ξ_s
- We calibrate & simulate our model (& match ξ_s distrib.) for comparison.

Calibration

Empirical Exercise 1: Information Frictions & Inv. Inaction

	inaction = 1							
	Data						Model	
ξ_s	**-0.076****	**-0.079*****	**-0.054****	**-0.069****	**-0.039***	**-0.051****	-0.013	-0.011
	(0.028)	(0.026)	(0.025)	(0.026)	(0.020)	(0.021)	(——)	(——)
$a_{i,t}$	0.039	0.059*	0.104***	0.113***	0.091**	0.099***	-0.206	-0.298
	(0.034)	(0.031)	(0.038)	(0.033)	(0.033)	(0.032)	(——)	(——)
$k_{i,t-1}$		-0.050***	-0.049***	-0.044***	-0.041***	-0.039***		-0.458
		(0.009)	(0.009)	(0.007)	(0.008)	(0.007)		(——)
$m_{i,t}$			-0.026	-0.045***	-0.015	-0.030**		
			(0.021)	(0.016)	(0.019)	(0.014)		
cap share$_s$				-0.549*		-0.366		
				(0.314)		(0.304)		
growth vol$_s$					1.016***	0.870***		
					(0.279)	(0.278)		
Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	99027	99027	86294	86294	86294	86294	14291997	14291997
adj. R^2	0.038	0.069	0.063	0.089	0.078	0.095	0.116	0.180

More severe information frictions $\Rightarrow$ less inaction

Empirical Exercise 1: Information Frictions & Inv. Inaction

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1 SD in $\xi_s \Rightarrow$ 5.1 p.p. (14%) less inaction

Empirical Exercise 2: Information Frictions & Inv. Sensitivity

- Do we see lower investment sensitivity to productivity shocks in industries with stronger information frictions?
- We estimate

$$\text{inaction}_{it} = \beta(w_{it} \times \xi_s) + \gamma w_{it} + \Gamma z_{it} + \gamma_i + \gamma_{st} + \epsilon_{it}$$

  - w_{it} : productivity shock (random walk or AR(1))
  - z_{it}: firm-level controls
  - γ_i: firm fixed effects
  - γ_{st}: industry-time fixed effects
  - Standardize ξ_s

Empirical Exercise 2: Information Frictions & Inv. Sensitivity

	inaction = 1					
	Data				Model	
$\xi_s \times w_{i,t}$	**0.010****	**0.011****	**0.011****	**0.010****	0.012	0.013
	(0.005)	(0.005)	(0.005)	(0.005)	(——)	(——)
w_{it}	-0.036	-0.030	-0.036	-0.029	-0.188	-0.188
	(0.031)	(0.031)	(0.032)	(0.032)	(——)	(——)
a_{it-1}	-0.028**	-0.015	-0.029**	-0.016	-0.670	-0.670
	(0.012)	(0.012)	(0.011)	(0.011)	(——)	(——)
Productivity	Rand. Walk	Rand. Walk	Auto. Reg(1)	Auto. Reg(1)	Rand. Walk	Rand. Walk
Firm FE	Y	Y	Y	Y	Y	Y
Time FE	Y	Y	Y	Y	Y	Y
Industry-Time FE	N	Y	N	Y	N	Y
N	84656	84656	84313	84313	14274640	14274640
adj. R^2	0.446	0.451	0.446	0.451	0.450	0.450

Dampened inaction responses to prod. shocks in industries with higher ξ

Empirical Exercise 2: Information Frictions & Inv. Sensitivity

	inaction = 1					
	Data				Model	
$\xi_s \times w_{i,t}$	**0.010****	**0.011****	**0.011****	**0.010****	0.012	0.013
	(0.005)	(0.005)	(0.005)	(0.005)	(——)	(——)
w_{it}	-0.036	-0.030	-0.036	-0.029	-0.188	-0.188
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	(0.012)	(0.012)	(0.011)	(0.011)	(——)	(——)
Productivity	Rand. Walk	Rand. Walk	Auto. Reg(1)	Auto. Reg(1)	Rand. Walk	Rand. Walk
Firm FE	Y	Y	Y	Y	Y	Y
Time FE	Y	Y	Y	Y	Y	Y
Industry-Time FE	N	Y	N	Y	N	Y
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1 SD in $\xi_s \Rightarrow$ reduces prod shock response by $\sim 1/3$

Conclusions

- Information and investment frictions interact in rich ways
- Parsimonious model delivers testable predictions, consistent with the data
- Information frictions are easily incorporated into continuous time inaction models (there are many applications beyond investment)
- An alternative structure for investment frictions:
  - Old paradigm: fixed costs to get inaction, + large or convex adjustment costs to get attenuation
  - New paradigm: *irreversibility* to get inaction, + *information frictions* to get attenuation
- Strong empirical evidence, and robust to many alternative specifications

Appendix

References

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How Do Firms Nowcast?

Lemma (1.a)

For a firm with information set $\Omega(t)$, productivity is conditionally distributed

$$a(t)|\Omega(t) \sim N\left(a(t-\tau) + \gamma\left(s(t) - s(t-\tau)\right), \nu\right)$$

where

$$\gamma \equiv \frac{\sigma_a^2}{\sigma_a^2 + \sigma_n^2} \qquad \nu \equiv \frac{\tau\sigma_a^2\sigma_n^2}{\sigma_a^2 + \sigma_n^2}$$

How Do Nowcasts Behave?

Lemma (1.b)

A firm's expected productivity $\hat{a} \equiv \mathbb{E}[a|\Omega]$ *and nowcast error* u *follow the diffusions*

$$d\hat{a} = \sigma_a dW^{\hat{a}} \qquad du = \sigma_u dW^u$$

where

$$dW_t^{\hat{a}} = (1-\gamma)dW_{t-\tau}^A + \gamma dW_t^A + \gamma\frac{\sigma_n}{\sigma_a}(dW_t^n - dW_{t-\tau}^n)$$

$$dW_t^u = (1-\gamma)\frac{\sigma_a}{\sigma_u}(dW_t^A - dW_{t-\tau}^A) + \gamma\frac{\sigma_n}{\sigma_u}(dW_t^n - dW_{t-\tau}^n)$$

$$\sigma_u^2 = 2\frac{\sigma_n^2\sigma_a^2}{\sigma_a^2+\sigma_n^2}$$

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Boundary Solution

The critical value $\hat{b}$ depends on: the variance of nowcast errors ν, the capital share α, the cost of investment ψ, as well as ϱ and m defined as:

$$\varrho \equiv \frac{\mu - \sqrt{\mu^2 + 2\sigma_a^2 r}}{\sigma_a^2} \qquad m \equiv \frac{1}{r + \mu\alpha - \frac{\sigma_a^2}{2}\alpha^2}$$

Lemma (3)

The critical value of expected normalized capital is

$$\hat{b} = \underbrace{\frac{1}{(1-\alpha)} \log\left(\frac{m\alpha(\alpha-\varrho)}{\psi(1-\varrho)}\right)}_{b^{FI} \text{ full info. boundary}} + \frac{\alpha^2\nu}{2(1-\alpha)}$$

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Solving the Firm's Problem: Normalization

- Standard approach: define normalized capital

$$X \equiv \frac{K}{A} \qquad\qquad x \equiv k - a$$

- HJB is simpler in one dimension:

$$rV(X) = X^{\alpha} - \delta X V'(X) + \frac{\sigma_a^2 X^2}{2} V''(X)$$

or in logs

$$rv(x) = e^{\alpha x} - \mu v'(x) + \frac{\sigma_a^2}{2} v''(x)$$

where $\mu \equiv \delta + \frac{\sigma_a^2}{2}$

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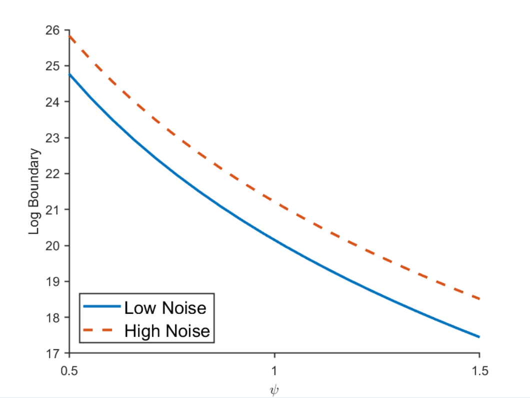
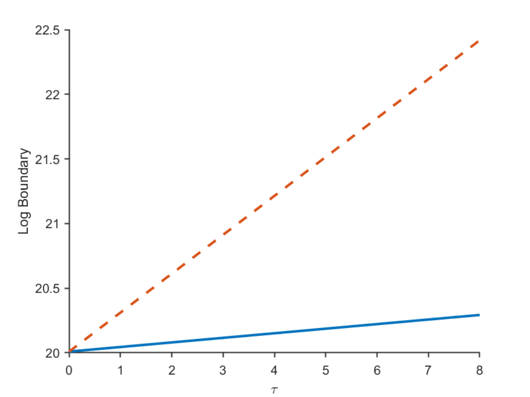
How the Boundary $\hat{b}$ Depends on the Information Friction

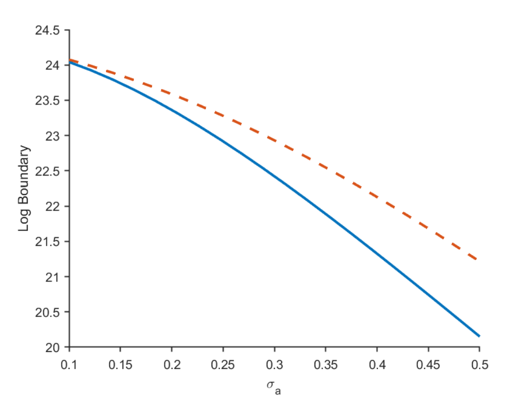


Investment Cost ψ



Revelation Delay τ

How the Boundary $\hat{b}$ Depends on "Uncertainty"



- Full info option-value effect of uncertainty over *future* productivity: higher volatility $\Longrightarrow$ lower capital threshold

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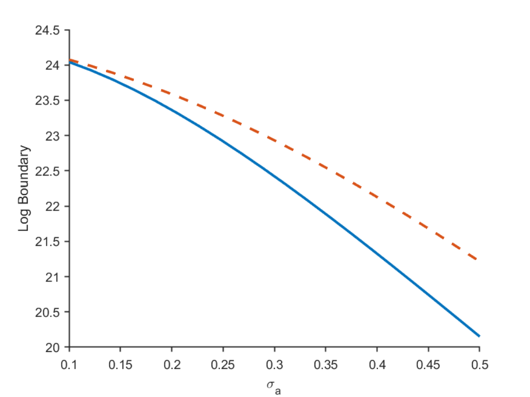
How the Boundary $\hat{b}$ Depends on "Uncertainty"



- Full info option-value effect of uncertainty over *future* productivity: higher volatility $\implies$ lower capital threshold
- ... but uncertainty over *current* productivity has opposite effect: more noise ($\sigma_n \uparrow$) $\implies$ *higher* capital threshold

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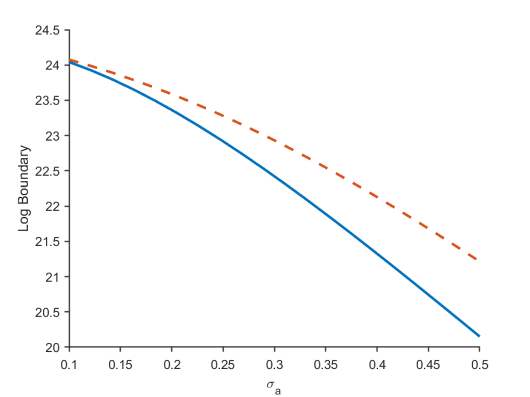

- Full info option-value effect of uncertainty over *future* productivity: higher volatility $\implies$ lower capital threshold
- ... but uncertainty over *current* productivity has opposite effect: more noise ($\sigma_n \uparrow$) $\implies$ *higher* capital threshold
- Noise interacts nonlinearly with the original effect!

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Firm Entry and Exit

- Firm entry/exit keeps the size distribution non-degenerate

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- Firms exit randomly at rate η, with value returned to owners. Measure η of firms enter at every moment

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  - Enter with distribution $\hat{a} \sim N(0, \varsigma)$
  - Entering firms are as uncertain about productivity as existing firms: $a \sim N(\hat{a}, \nu)$
  - Their expected normalized capital $\hat{x}$ enters at the critical value $\hat{b}$

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Summary of the Japanese Firm-level Data

Table 1: Sample Comparison (Quarterly)

Moments	Merged Dataset	Entire Sample (FSS)
Number of obs. (Non-missing sales)	392,158	1,260,836
Average employment	1040.582	491.6123
Average sales (million JPY)	19991.75	8541.767
Average fixed capital stock	59919.34	24842.79

Table 2: Investment Moments Using Fixed Capital at Both Frequencies

Frequency	Exit Rate	Agg. Inv. Rate	Inv. Rate Mean	Inv. Rate S.D.	Inaction Rate	Spike Rate
Quarterly	2.00%	1.23%	2.27%	6.10%	60.00%	0.90%
Semiannual	3.96%	2.64%	4.00%	8.3%	36.6%	2.45%

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Model Calibration

Table 3: Parametrization of the Stylized Model

Parameter	r	α	τ	ψ	η	ς	δ	σ_a	σ_n^0	σ_n^{30}	$\Delta\sigma_n$
Value	1%	0.85	1	1	2%	0	1.23%	0.15	0.00	$0.75\sigma_a$	$0.025\sigma_a$

Table 4: Information Incompleteness and Investment Moments

Industry	σ_n	ξ_s	Inv. Rate Mean	Inv. Rate S.D.	Inaction Rate	Spike Rate
Full Information	0.000	0.000	2.37%	6.7%	81.0%	3.9%
Median Noise	$0.375\sigma_a$	0.018	2.29%	6.1%	79.8%	3.3%
Highest Noise	$0.75\sigma_a$	0.055	2.20%	5.53%	77.7%	2.4%

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Partial Irreversibility

- If firms invest, they do so at cost $\Psi(I)$:

$$\Psi(I) = \begin{cases} \psi_+ I & I \geq 0 \\ \psi_- I & I < 0 \end{cases}$$

  with $\psi_+ > \psi_- > 0$
- Instantaneous profit is $\pi = A^{1-\alpha} K^{\alpha} - \Psi(I)$
- Optimal firm behavior: for a range of capital values, firms choose to neither invest nor divest. Usual HJB in the inaction region.
- Solving the firm's problem comes down to finding the optimal choice of $\hat{B}_L$ and $\hat{B}_U$

Partial Irreversibility

Lemma

Under incomplete information, the boundary conditions consist of two value-matching conditions:

$$\hat{V}'(\hat{B}_L) = \psi_+ \qquad \hat{V}'(\hat{B}_U) = \psi_-$$

and two super contact conditions:

$$\hat{V}''(\hat{B}_L) = 0 \qquad \hat{V}''(\hat{B}_U) = 0$$

Partial Irreversibility

Proposition (7)

The critical values of expected normalized capital are

$$\hat{b}_L = b_L^{FI} + \frac{\alpha^2 \nu}{2(1-\alpha)} \qquad \hat{b}_H = b_H^{FI} + \frac{\alpha^2 \nu}{2(1-\alpha)}$$

where b_L^{FI} and b_H^{FI} denote the full information solutions such that $\nu = 0$.

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