Macroeconomics of Investment with Heterogeneity

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Outline

1. Kekre Lenel (2022)
2. Ottonello Winberry (2021)
3. Bierdel, Drenik, Herreño, Ottonello (2023)
4. Zwick Mahon (2017)
5. Winberry (2021)

Outline

Fundamental Asset Pricing Equations

- When thinking about returns of any asset:

$$\mathbb{E}_t(M_{t,t+1}R_{t+1}) = 1$$

- When thinking about a risk-free return:

$$\frac{1}{\mathbb{E}_t M_{t,t+1}} = R^f_{t+1}$$

- When thinking about excess returns:

$$\mathbb{E}_t(M_{t,t+1}(R^a_{t+1} - R^b_{t+1})) = 0$$

Fundamental Asset Pricing Equations

M is the stochastic discount factor

- The right discount rate to value a claim to future payments
- Different asset pricing theories take a stance on what the right M is
- Consumption-based asset pricing is one of such stances: M is given by the contribution of a payment to the marginal utility of consumption
- Asset Pricing by John Cochrane is in my view the best reference

Fundamental Asset Pricing Equations

- Consumer's Euler equation.
- In the margin, indifference between paying 1 unit of goods today and receive R_{t+1} units tomorrow

$$u'(c_t) = \beta \mathbb{E}_t[u'(c_{t+1})R_{t+1}]$$

- Or

$$\mathbb{E}_t(M_{t,t+1}R_{t+1}) = 1$$

- for

$$M_{t,t+1} = \beta \frac{u'(c_{t+1})}{c_t}$$

- making obvious that M is a random variable

Fundamental Asset Pricing Equations

$$\mathbb{E}_t(M_{t,t+1}R_{t+1}) = 1$$

- Remembering that $cov(x,y) = \mathbb{E}(xy) - \mathbb{E}(x)\mathbb{E}(y)$

$$cov_t(M_{t,t+1}R_{t+1}) + \mathbb{E}_t M_{t,t+1} \mathbb{E}_t R_{t,t+1} = 1$$

- And remembering that the risk-free rate is risk-free

$$\mathbb{E}_t R_{t,t+1} = R^f_{t+1}(1 - cov_t(M_{t,t+1}R_{t+1}))$$

- An asset has a positive excess return iff:

$$cov_t(M_{t,t+1}R_{t+1}) < 0$$

Fundamental Asset Pricing Equations

$$cov_t(M_{t,t+1}R_{t+1}) < 0$$

- $M_{t,t+1}$ is increasing in $u'(c_{t+1})$
- And as a consequence decreasing in c_{t+1}
- a negative covariance between M and R implies a positive covariance between R and c_{t+1}
- Positive excess returns for assets that pay badly in bad states of the world ($=$ pay well in good states)
- Benchmark examples:
  - Insurance pays in terrible states of the world. Negative excess returns
  - The stock market pays well in good times. Positive excess returns.

Risk Premia Effects of Monetary Policy

- Kekre Lenel (2022): *Expansionary monetary policy lowers risk premia*
- Why?
- Let's think about the stock market
- Expansionary monetary policy makes the covariance between stock returns and consumption lower
- When the CB lowers rates the stock market booms
- The CB lowers rates in bad times for c

Setting

- Heterogeneous investors that can invest in capital or bonds
- The return on capital is risky. It is a function of a future productivity shock
- The return on bonds is not. Assumption: The central bank commits to zero inflation
- The portfolio weight on capital ω^i

$$\omega^i \approx \frac{1}{\gamma^i} \frac{\mathbb{E}_0 \log R_1^k - \log R_1 + \frac{1}{2}\sigma^2}{\sigma^2}$$

- high ω if γ (risk aversion) is low
- Can you verbalize how to get this expression?
- Why is it not an explicit function of consumption c, or savings a?

Risk Premia

$$\frac{d\left[\mathbb{E}_0 \log R_1^k - \log R_1\right]}{d\varepsilon_0^m} = \gamma\sigma^2 \int_0^1 \frac{d\left[a_0 / \int_0^1 a_0^{i'} di'\right]}{d\varepsilon_m^0} (1-\omega_0^i) di$$

- If wealth is flowing towards people with high capital shares
- then the risk premium goes down
- The return on capital is decreasing in investment
- An expansionary monetary policy shock has an additional effect. It reallocates wealth to people who are prone to invest
- Or High Marginal Propensity to take Risk (MPR)

REDISTRIBUTION OF WEALTH

Given (17) and defining $n_0 \equiv \int_0^1 n_0^i di$, the change in its wealth share is in turn

$$\frac{d\left[n_0^i / \int_0^1 n_0^{i'} di'\right]}{d\epsilon_0^m} = \frac{1}{n_0}\left[-\frac{1+i_{-1}}{P_0} B_{-1}^i \frac{d\log P_0}{d\epsilon_0^m} + \left(k_{-1}^i - \frac{n_0^i}{n_0} k_{-1}\right)\left(\frac{d\pi_0}{d\epsilon_0^m} + (1-\delta)\frac{dq_0}{d\epsilon_0^m}\right)\right]. \quad (21)$$

Proposition 2. *The change in investment in response to a monetary shock is*

$$\frac{dk_0}{d\epsilon_0^m} = -\frac{k_0}{1-\alpha+\chi^x}\left[\frac{d\left[\mathbb{E}_0 \log(1+r_1^k) - \log(1+r_1)\right]}{d\epsilon_0^m} + \frac{d\log(1+r_1)}{d\epsilon_0^m}\right]. \tag{18}$$

The change in consumption $c_0 \equiv \int_0^1 c_0^i di$ *in response to a monetary shock is*

$$\frac{dc_0}{d\epsilon_0^m} = \frac{1-\beta}{\beta} q_0 (1+\chi^x) \frac{dk_0}{d\epsilon_0^m}.$$

The change in output $y_0 \equiv \ell_0^{1-\alpha} k_{-1}^{\alpha}$ *in response to a monetary shock is*

$$\frac{dy_0}{d\epsilon_0^m} = \frac{dc_0}{d\epsilon_0^m} + q_0\left(1+\chi^x \frac{x_0}{k_0}\right)\frac{dk_0}{d\epsilon_0^m}. \tag{19}$$

<table>
<tr><th colspan="2" rowspan="2"></th><th colspan="2">$\frac{A^i}{W\ell^i}$</th></tr>
<tr><th>$\geq p60$</th><th>$< p60$</th></tr>
<tr><td rowspan="2">$\frac{Qk^i}{A^i}$</td><td>$\geq p90$</td><td>Group a
Share households: 4%
$\sum_{i \in a} W\ell^i / \sum_i W\ell^i$: 3%
$\sum_{i \in a} A^i / \sum_i A^i$: 18%
$\sum_{i \in a} Qk^i / \sum_{i \in a} A^i$: 2.0</td><td rowspan="2">Group c
Share households: 60%
$\sum_{i \in c} W\ell^i / \sum_i W\ell^i$: 83%
$\sum_{i \in c} A^i / \sum_i A^i$: 23%
$\sum_{i \in c} Qk^i / \sum_{i \in c} A^i$: 1.1</td></tr>
<tr><td>$< p90$</td><td>Group b
Share households: 36%
$\sum_{i \in b} W\ell^i / \sum_i W\ell^i$: 14%
$\sum_{i \in b} A^i / \sum_i A^i$: 58%
$\sum_{i \in b} Qk^i / \sum_{i \in b} A^i$: 0.5</td></tr>
</table>

Table II: heterogeneity in wealth to labor income and the capital portfolio share

Notes: observations are weighted by SCF sample weights.

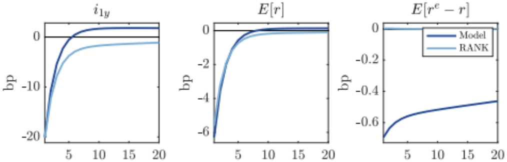

Figure 2: expected returns after negative monetary policy shock

Notes: series are quarterly (non-annualized) measures, except for the 1-year nominal bond yield Δi_{1y}. Impulse responses are the average response (relative to no shock) starting at 1,000 different points drawn from the ergodic distribution of the state space, itself approximated using a sample path over 50,000 quarters after a burn-in period of 5,000 quarters. *bp* denotes basis points (0.01%).

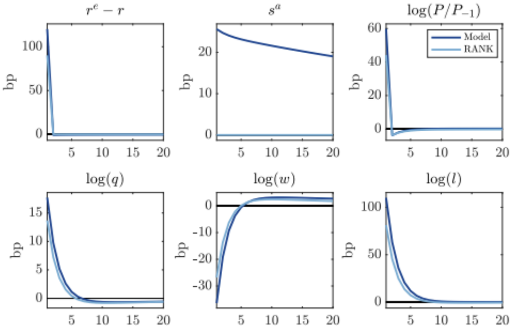

Figure 3: redistribution after negative monetary policy shock

Notes: see notes accompanying Figure 2 on construction of impulse responses.

% Real stock return	Data [90% CI]	Model	RANK
Dividend growth news	33% [-13%,71%]	52%	65%
−Future real rate news	8% [-6%,21%]	16%	35%
−Future excess return news	59% [19%,108%]	32%	0%

Table VII: Campbell-Shiller decomposition after monetary shock

Notes: estimates from data correspond to Table I. Comparable estimates obtained in the model assuming a debt/equity ratio of 0.5 on a stock market claim.

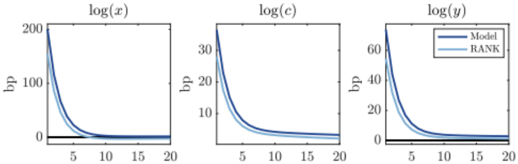

Figure 4: quantities after negative monetary policy shock

Notes: see notes accompanying Figure 2 on construction of impulse responses.

Outline

Motivation

- Investment is the most cyclical component of aggregate demand
- Investment Channel of Monetary Policy
- What determines the strength of this effect?
- Underlying notion of state-dependence

Two Possibilities

- Two possibilities on which firms respond more:

  1. More constrained firms: Monetary policy expansions ease financial frictions. More constrained firms respond by more. Financial accelerator story

  2. Less constrained firms: More constrained firms have steeper marginal cost curves, so they react by less to the same aggregate demand shock

- Ultimately an empirical question

Specification

- Basic specification

$$\Delta \log k_{j,t+1} = \alpha_j = \alpha_j + \alpha_{st} + \beta(x_{jt-1} - \mathbb{E}_j(x_{jt}))\varepsilon_t^m + \Gamma' Z_{jt-1} + e_{jt}$$

- Where ε^m is determined using HFI

$$\varepsilon_t^m = \tau(t) \times (ffr_{t+\Delta_+} - ffr_{t-\Delta_-})$$

- Size of the window: -15 to +45 minutes
- Thoughts? Identifying assumption?
- Stronger or weaker assumption than time series variation using HFI shocks?

Basic Result

TABLE III

HETEROGENEOUS RESPONSES OF INVESTMENT TO MONETARY POLICY[a]

	(1)	(2)	(3)	(4)	(5)
leverage × ffr shock	−0.69	−0.57		−0.26	−0.14
	(0.29)	(0.27)		(0.35)	(0.58)
dd × ffr shock			1.14	1.01	1.16
			(0.41)	(0.40)	(0.47)
ffr shock					2.14
					(0.61)
Observations	219,402	219,402	151,027	151,027	119,750
R^2	0.113	0.124	0.141	0.142	0.151
Firm controls	no	yes	yes	yes	yes
Time sector FE	yes	yes	yes	yes	no
Time clustering	yes	yes	yes	yes	yes

[a]Results from estimating $\Delta \log k_{jt+1} = \alpha_j + \alpha_{st} + \beta(x_{jt-1} - \mathbb{E}_j[x_{jt}])\varepsilon_t^{\mathrm{m}} + \Gamma' Z_{jt-1} + e_{jt}$, where α_j is a firm fixed effect, α_{st} is a sector-by-quarter fixed effect, $x_{jt} \in \{\ell_{jt}, \mathrm{dd}_{jt}\}$ is leverage or distance to default, $\mathbb{E}_j[x_{jt}]$ is the average of x_{jt} for firm j in the sample, $\varepsilon_t^{\mathrm{m}}$ is the monetary shock, and Z_{jt-1} is a vector of firm-level controls containing x_{jt-1}, sales growth, size, current assets as a share of total assets, an indicator for fiscal quarter, and the interaction of demeaned financial position with lagged GDP growth. Standard errors are two-way clustered by firms and quarter. We have normalized the sign of the monetary shock $\varepsilon_t^{\mathrm{m}}$ so that a positive shock corresponds to a decrease in interest rates. We have standardized $(\ell_{jt} - \mathbb{E}[\ell_{jt}])$ and $(\mathrm{dd}_{jt} - \mathbb{E}[\mathrm{dd}_{jt}])$ over the entire sample. Column (5) removes the sector-quarter fixed effect α_{st} and estimates $\Delta \log k_{jt+1} = \alpha_j + \alpha_{sq} + \gamma\varepsilon_t^{\mathrm{m}} + \beta(x_{jt-1} - \mathbb{E}_j[x_{jt}])\varepsilon_t^{\mathrm{m}} + \Gamma_1' Z_{jt-1} + \Gamma_2' Y_{t-1} + e_{jt}$, where Y_t is a vector with four lags of GDP growth, the inflation rate, and the unemployment rate.

Dynamic Response

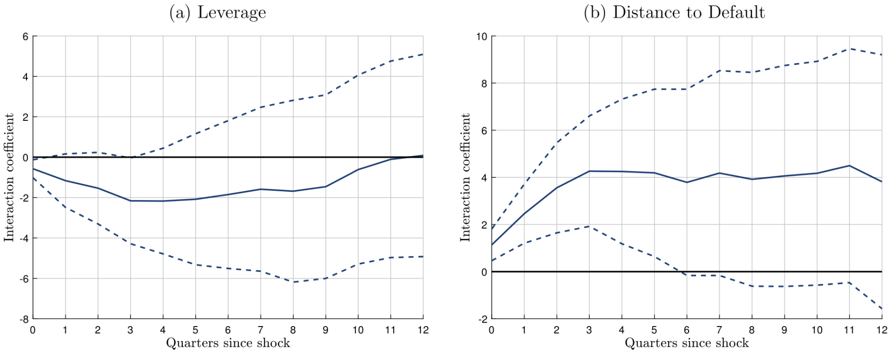

FIGURE 1.—Dynamics of differential response to monetary shocks. Notes: dynamics of the interaction coefficient between financial positions and monetary shocks over time. Reports the coefficient β_h over quarters h from $\log k_{jt+h} - \log k_{jt} = \alpha_{jh} + \alpha_{sth} + \beta_h(x_{jt-1} - \mathbb{E}_j[x_{jt}])\varepsilon_t^{\mathrm{m}} + \Gamma_h' Z_{jt-1} + e_{jth}$, where all variables are defined in the notes for Table III. Dashed lines report 90% error bands.

Model - Financial structure

- No aggregate uncertainty
- MIT shock later on
- Firms can borrow in defaultable debt
  - This is the optimal contract of Costly State Verification models (Townsend 1979)
  - Backbone of financial accelerator models (BGG 1999)
- Retain earnings, not issue equity (think of infinite costs of equity issuance)
- Without financial frictions need to keep track of only net worth, not k and b separately. Not possible with financial frictions
- Economics: External finance premium/One unit of external finance is more costly

Capital Producers

- Capital producer sector
- Relative price of investment q
- q-theory FOC

$$q_t = \frac{1}{\Psi'(I_t/K_t)}$$

Retailers - NK firms

- Set prices subject to Rotemberg (1982) frictions

- Relative price of retail goods p

- Gives rise to a standard NK Phillips Curve

Lenders

- Intermediary, gets funds from the household, lends to firms

- CSV block. Upon default (or verification) the lender gets α fraction of the market value of the firm stock

- Price contracts at $\mathscr{Q}(z, k', b')$ to get zero profits (free entry in the background)

Production Firms

- DRS
- exit shocks
- Fixed costs of operation
- Need a source of variation that suddenly brings firms closer to default
- Capital quality shock *We view capital quality shocks as capturing unmodeled forces which reduce the value of the firm's capital, such as frictions in the resale market, breakdown of machinery, or obsolescence.*
- Effective units of capital ωk
- Firms decide whether to default or not

When to default

- A firm receives a capital-quality shock ω
- The firm has some debt b and the value of its capital goes down ωk
- Its net worth $n = \max_l p_t z(\omega k)^\theta l^\nu - w_t l + q_t(1-\delta)\omega k - b\frac{1}{\Pi_t} - \xi$ goes down
- $\exists\ \underline{n}$ such that the firm cannot respect the non-negativity on equity issuance

$$n - q_t k' + \mathcal{Q}(z, k', b')b' \geq 0$$

MAIN MECHANISM

Impact on Decision Rules. The optimal choice of investment k' and borrowing b' satisfy the following two conditions:

$$q_t k' = n + \frac{1}{R_t(z,k',b')} b', \tag{9}$$

$$\left(q_t - \varepsilon_{Q,k'}(z,k',b') \frac{Q_t(z,k',b')b'}{k'}\right) \frac{R_t^{\mathrm{sp}}(z,k',b')}{1-\varepsilon_{R,b'}(z,k',b')}$$

$$= \frac{1}{R_t} \mathbb{E}_t[\mathrm{MRPK}_{t+1}(z',k')]$$

$$+ \frac{1}{R_t} \frac{\mathbb{C}ov_t(\mathrm{MRPK}_{t+1}(z',\omega' k'), 1+\lambda_{t+1}(z',\hat{n}_{t+1}(z',\omega',k',b')))}{\mathbb{E}_t[1+\lambda_{t+1}(z',\hat{n}_{t+1}(z',\omega',k',b'))]}$$

$$- \frac{1}{R_t} \mathbb{E}_{\omega'}[v_{t+1}^0(\omega',k',b') g_z(\underline{z}(\omega',k',b')|z) \hat{\underline{z}}_{t+1}(\omega',k',b')], \tag{10}$$

Intuition Main Mechanism

2488 P. OTTONELLO AND T. WINBERRY

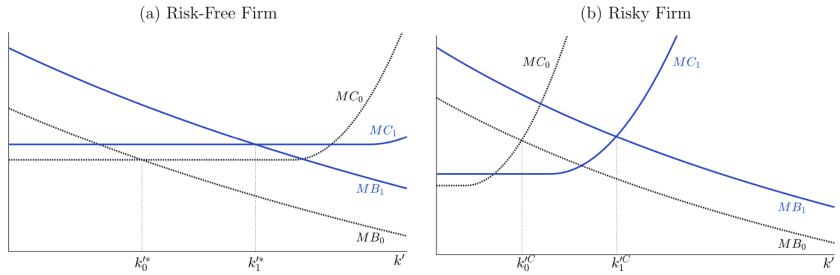

FIGURE 2.—Response to monetary policy for risk-free and risky firms. Notes: Marginal benefit and marginal cost curves as a function of capital investment k' for firms with same productivity. Left panel is for a firm with high initial net worth and right panel is for a firm with low initial net worth. Marginal cost curve is the left-hand side of (10) and marginal benefit the right-hand side of (10). Dashed black lines plot the curves before an expansionary monetary policy shock, and solid blue lines plot the curves after the shock.

Intuition Main Mechanism

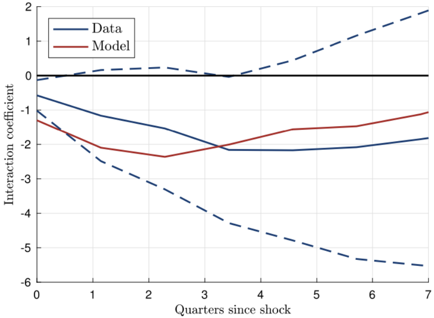

FIGURE 5.—Dynamics of differential responses, model vs. data. Notes: dynamics of the interaction coefficient between leverage and monetary shocks. Reports the coefficient β_h over quarters h from $\log k_{jt+h} - \log k_{jt} = \alpha_{jh} + \alpha_{sth} + \beta_h(\ell_{jt-1} - \mathbb{E}_j[\ell_{jt}])\varepsilon_t^{\mathrm{m}} + \Gamma_h' Z_{jt-1} + \Gamma_{2h}'(\ell_{jt-1} - \mathbb{E}_j[\ell_{jt}])Y_{t-1} + e_{jt}$, where all table notes from Columns (1) and (2) of Table VII apply. Dashed lines report 90% error bands.

Intuition Main Mechanism

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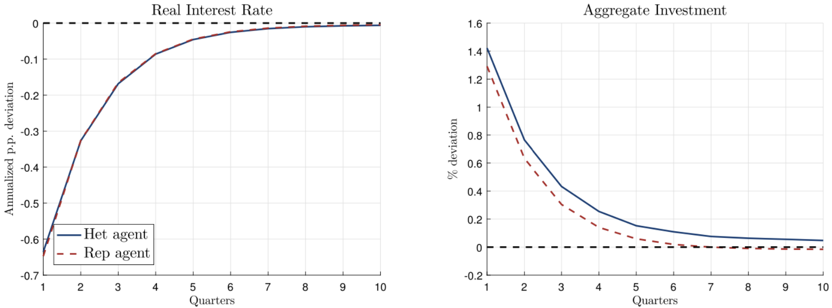

FIGURE 8.—Aggregate impulse responses in full model vs. rep firm model. Notes: "Het agent" refers to calibrated heterogeneous firm model from the main text. "Rep agent" refers to a version of the model in which the heterogeneous production sector is replaced by a representative firm with the same production function and no financial frictions.

Intuition Main Mechanism

TABLE VIII

AGGREGATE RESPONSE DEPENDS ON INITIAL DISTRIBUTION[a]

(everything rel. to steady state)	Bad distribution	Medium distribution
Avg. capital response	0.67	0.84
Avg. net worth	0.48	0.75
Frac. risky constrained	1.37	1.17

[a] Dependence of aggregate response on initial distribution. We compute the change in aggregate capital for different initial distributions as described in the main text. “Bad distribution” corresponds to $\widehat{\omega} = 1$ and “Medium distribution” corresponds to $\widehat{\omega} = 0.5$.

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Motivation

- Information asymmetries are a salient phenomenon of real asset markets
  - Capital heterogeneous in quality, sellers have more info than buyers (Akerlof 1970)
- Changes in degree of asymmetric info play key role in classic narrative of crises
  - E.g., subprime crisis, Euro crisis, historical events in Reinhart Rogoff 2011
- How capital heterogeneity and asymmetric information affect the macroeconomy?
- This paper: Micro-to-macro approach, motivated by two ideas:
  1. Capital markets are illiquid, involving delayed trade (Ramey Shapiro 2001)
  2. In illiquid mkts, asymmetric info distorts terms-of-trade (Guerrieri Shimer Wright 2010)

$\Rightarrow$ Study AI by measuring the liquidity of different capital units listed for trade

What We Do

1. **Capital-accumulation model with illiquid mkts and asymmetric information**
   - Build GE framework with heterogenous capital quality traded in decentralized mkts
   - Degree of AI: accuracy of buyers' technology to detect lemons
   - AI distorts listed prices and selling prob for sellers of high-quality capital
     $\Rightarrow$ Degree of AI can be identified from relationship between prices and duration

What We Do

1. Capital-accumulation model with illiquid mkts and asymmetric information

2. **Measurement of distortions from asymmetric information**

   - Dataset on capital units listed for trade, with listed price, duration, characteristics
     - ★ Panel of structures (office, retail, industrial space) listed online in Spain
   - Empirical evidence consistent with AI distorting listed prices and liquidity
     - ★ Distortions increase during Euro crisis

What We Do

1. **Capital-accumulation model with illiquid mkts and asymmetric information**
2. **Measurement of distortions from asymmetric information**
3. **Quantifying the macroeconomic implications of asymmetric information**
    - Combine model and empirical measurement
    - Find that changes in degree of asymmetric info have large macro effects
        - Measured $\uparrow$ in degree of AI during Euro crisis leads to 2% output slump, slow recovery
    - Transmission through liquidity of capital, effects on investment and capital allocation

Related Literature

- **Asymmetric information in asset markets**
  - Akerlof 1970, Stiglitz Weiss 1981, Guerrieri Shimer Wright 2010, Delacroix and Shi, 2013
  - Eisfeldt, 2004; Kurlat, 2013; Guerrieri and Shimer, 2014; Bigio, 2015; Lester et al., 2018,...
- **Illiquid asset markets**
  - Ramey Shapiro 2001, Gavazza 2011, Kermani Ma, 2020
  - Kurmann Petrosky-Nadeau 2007, Cao Shi 2017, Ottonello 2017, Wright et al. 2018,...
  - Lagos Rocheteau Wright 2017, Kaplan Violante 2014, ...
- **Misallocation and capital reallocation**
  - Eisfeldt Rampini 2006, Restuccia Rogerson 2008, Hsieh Klenow 2009, Hopenhayn, 2014, Cui 2017, Lanteri 2018, David Venkateswaran 2019, Kehrig and Vincent 2019, ...

Outline

1. **Model**
2. The Micro Effects of Asymmetric Information
3. Measurement
4. The Macro Effects of Asymmetric Information

Model Overview

- Neoclassical capital-accumulation model
  - Discrete infinite time, final and capital goods
- Additional ingredients:
  1. Capital-quality heterogeneity
  2. Decentralized capital markets
  3. Asymmetric information

Neoclassical Block

- **Households**
  - Preferences $\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t u(c_t, h_t)\gamma_n^t$
  - Access to a linear technology to produce new capital goods using final goods
- **Firms** (owned by households)
  - Technology $y_{jt} = f_t(\mathscr{K}_{jt}, l_{jt}) \equiv \mathscr{K}_{jt}^{\alpha}(\gamma^t l_{jt})^{1-\alpha}$

Neoclassical Block

- **Households** $\Rightarrow$ hold unemployed capital, capital seller
  - Preferences $\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t u(c_t, h_t)\gamma_n^t$
  - Access to a linear technology to produce new capital goods using final goods

- **Firms** $\Rightarrow$ hold employed capital, capital buyer
  - Technology $y_{jt} = f_t(\mathscr{K}_{jt}, l_{jt}) \equiv \mathscr{K}_{jt}^{\alpha}(\gamma^t l_{jt})^{1-\alpha}$
  - Every period: prob. φ a firm exits the economy, new mass of firms φ enters

Capital-quality heterogeneity

- Capital stock composed of infinitesimal indivisible units
- Capital units are heterogeneous in two dimensions
  - observed quality $\omega \in \Omega \equiv [\omega_1, \dots, \omega_{N_\omega}]$
    - E.g., location, type, size, number of rooms,...
  - unobserved quality $a \in \mathscr{A} \equiv [a_1, \dots, a_{N_a}]$
    - private information of owner
    - E.g., physical conditions, atmosphere for customers, neighbors,...
- Capital services unit i: $\omega_i a_i$
  - firm j's capital input: $\mathscr{K}_{jt} = \sum_{\omega \in \Omega} \sum_{a \in \mathscr{A}} \omega a k_{jt+1}(\omega, a)$
- Maintenance costs: $\delta \omega_i a_i$ (depreciation) Timing

Decentralized Capital Market

- Capital goods traded in a decentralized mkt with **search-and-matching frictions**
  - Consistent with microlevel evidence (Ramey Shapiro 2001, Gavazza 2011, Ottonello 2015)
- Organized in a continuum of submarkets, indexed by $\boldsymbol{(\omega, \hat{a}, q)} \in \Omega \times \mathscr{A} \times \mathbb{R}_+$
- Search is directed (Shimer 1996, Moen 1997, Menzio Shi 2011)
  - Sellers list price $q(\omega, a)$ and announced quality $\hat{a}(\omega, a)$
  - Buyers dedicate hours of work to search and match $v_t(\omega, \hat{a}, q)$
- Cobb-Douglas matching technology in each submarket (w. matching elasticity η)
- Tightness $\theta_t(\omega, \hat{a}, q)$: ratio of buyers' hours of search to capital posted by sellers
- Sellers' matching probability $p(\theta_t(.))$, buyers' matching yield/hour $\mu_t(\theta_t(.))$

Degree of Asymmetric information

- Buyers have access to **information-revealing technology** (similar to Menzio Shi 2011)
  - prob ψ: buyer learns the true type (ω, a) of the capital good
  - prob $1-\psi$: inspection is uninformative

ψ parameterizes the degree of asymmetric information in the economy

Degree of Asymmetric information

- Buyers have access to **information-revealing technology** (similar to Menzio Shi 2011)
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  ψ parameterizes the degree of asymmetric information in the economy

- **Trading protocol upon inspection**
  - If no new info is revealed: trade at listed price q
  - If quality a is revealed (and there are gains from trade): trade at adjusted price

    $$q_t^P(\omega, a, \hat{a}, q) = \begin{cases} q \text{ if } a \geq \hat{a} \\ \min\{\text{bargain price}, q\} \text{ if } a < \hat{a} \end{cases}$$

  - In the paper we provide sufficient conditons for general $q_t^P(\omega, a, \hat{a}, q)$

Bargaining | Sufficient conditions post-inspection price | Timing

Households' Capital Accumulation

- Law of motion households' unemployed capital of type (ω, a)

$$k_{Ht+1}(\omega,a) = \underbrace{(1-p(\theta_t(\omega,\hat{a}_t(\omega,a),q_t(\omega,a))))k_{Ht}(\omega,a)}_{\text{unsold capital}} + \underbrace{g(\omega,a)i_t}_{\text{investment}} + \underbrace{\varphi K_{Ft}(\omega,a)}_{\text{separations}}$$

where $g : \Omega \times \mathscr{A} \to [0,1]$ governs the production of different capital qualities

Households' Capital Accumulation

- Law of motion households' unemployed capital of type (ω, a)

$$k_{Ht+1}(\omega,a) = \underbrace{(1 - p(\theta_t(\omega,\hat{a}_t(\omega,a),q_t(\omega,a))))k_{Ht}(\omega,a)}_{\text{unsold capital}} + \underbrace{g(\omega,a)i_t}_{\text{investment}} + \underbrace{\varphi K_{Ft}(\omega,a)}_{\text{separations}}$$

where $g : \Omega \times \mathscr{A} \to [0,1]$ governs the production of different capital qualities

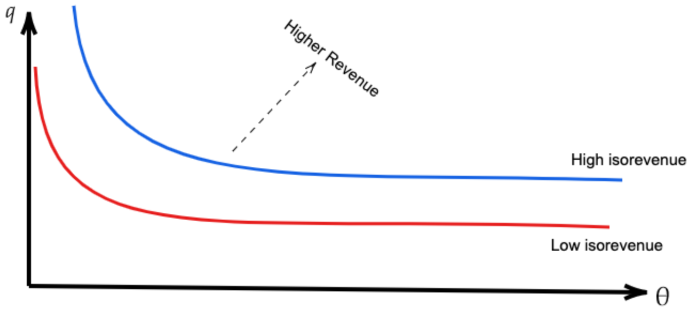
- Euler equation for investment

$$1 = \sum_{\omega\in\Omega}\sum_{a\in\mathscr{A}} g(\omega,a)\lambda_t(\mathbf{k})v^{s}_{t+1}(\omega,a,\mathbf{k}),$$

▸ Households' recursive problem

- Marginal value of capital

$$v_t^s(\omega, a, \mathbf{k}) = \max_{\hat{a}, q} p(\theta_t(\omega, \hat{a}, q))((1-\psi)q + \psi q_t^P(\omega, a, \hat{a}, q))$$
$$+ (1 - p(\theta_t(\omega, \hat{a}, q)))(\lambda_t(\mathbf{k}) v_{t+1}^s(\omega, a, k_{Ht}(\mathbf{k})) - \delta\omega a)$$



Firms' Capital Accumulation

- Law of motion firms' employed capital of type (ω, a)

$$k_{jt+1}(\omega,a) = \underbrace{\sum_{\hat{a}\in\mathscr{A}} \int_{q\in\mathbb{R}_+} \iota_t(a|\omega,\hat{a},q)\mu_t\left(\theta_t\left(\omega,\hat{a},q\right)\right) v_{jt}(\omega,\hat{a},q)\,\mathrm{d}q}_{\text{purchases of capital type } (\omega,a)} + \underbrace{k_{jt}(\omega,a)}_{\text{initial capital}}$$

where $\iota_t(a|\omega,\hat{a},q)$: share of capital quality a in submarket $(\omega,\hat{a},q)$

Firms' Capital Accumulation

- Law of motion firms' employed capital of type (ω, a)

$$k_{jt+1}(\omega,a) = \underbrace{\sum_{\hat{a}\in\mathscr{A}} \int_{q\in\mathbb{R}_+} \iota_t(a|\omega,\hat{a},q)\mu_t\left(\theta_t\left(\omega,\hat{a},q\right)\right) v_{jt}(\omega,\hat{a},q)\,\mathrm{d}q}_{\text{purchases of capital type } (\omega,a)} + \underbrace{k_{jt}(\omega,a)}_{\text{initial capital}}$$

where $\iota_t(a|\omega,\hat{a},q)$: share of capital quality a in submarket $(\omega,\hat{a},q)$

- Marginal value of capital

$$v_t^{\mathrm{b}}(\omega,a) = (Z_t-\delta)\omega a + \Lambda_{t,t+1}\left[(1-\varphi)v_{t+1}^{\mathrm{b}}(\omega,a) + \varphi v_{t+1}^{\mathrm{s}}(\omega,a,\mathbf{K}_{Ht})\right],$$

where $Z_t \equiv \alpha\left(\frac{\gamma^t(1-\alpha)}{w_t}\right)^{\frac{1-\alpha}{\alpha}}$

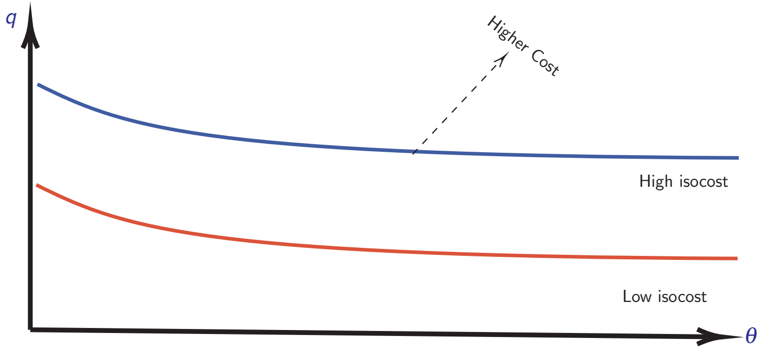
Firms' problem

Firms as Capital Buyers

- Optimal search activity across submarkets

$$\underbrace{((1-\psi)q+\psi\mathbb{E}_a(q_t^P(\omega,a,\hat{a},q))|\omega,\hat{a},q))}_{\text{Expected price}}+\underbrace{\frac{w_t}{\mu_t(\theta(\omega,\hat{a},q))}}_{\text{Search cost}}\geq\underbrace{\mathbb{E}_a\left(v_t^b(\omega,a)|\omega,\hat{a},q\right)}_{\text{Expected value}},$$

with equality if $v_t(\omega,\hat{a},q)>0$

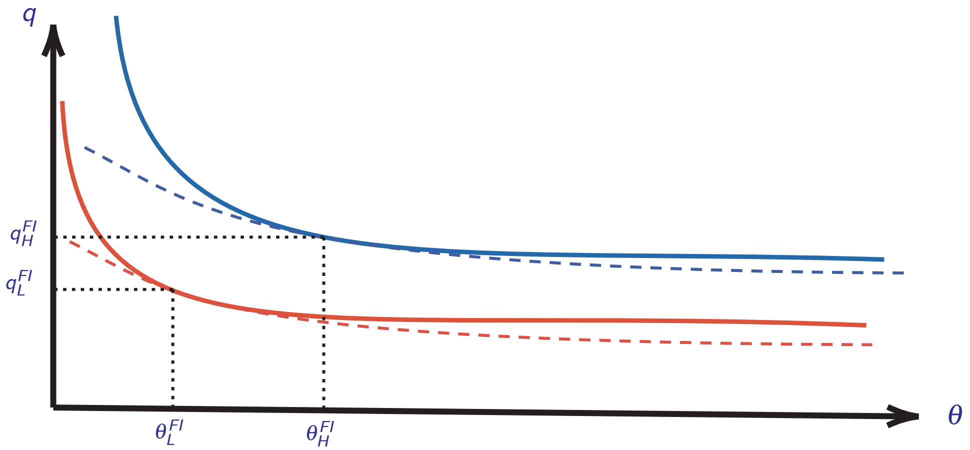


Outline

1. Model
2. **The Micro Effects of Asymmetric Information**
3. Measurement
4. The Macro Effects of Asymmetric Information

Equilibrium Under Full Information

- Suppose $\Omega = \{\omega_L, \omega_H\}$, $\mathscr{A} = \{\bar{a}\}$, focus on BGP ▸ BGP



Prices and Duration for Observed Capital Qualities

Prediction I: Under FI there is a **negative relationship between prices and duration**

$q^{\mathrm{FI}}(\omega_H, a) > q^{\mathrm{FI}}(\omega_L, a), p\left(\theta^{\mathrm{FI}}(\omega_H, a)\right) > p\left(\theta^{\mathrm{FI}}(\omega_L, a)\right)$

▸ Proposition

Intuition: Submarkets with higher quality attract more buyers resulting on higher prices and lower matching probability for buyers

$$\underbrace{(1-\eta)\left(v^{\mathrm{b}}(\omega, a) - \Lambda v^{\mathrm{s}}(\omega, a)\right)}_{\text{benefit purchasing quality } (\omega, a)} = \underbrace{\frac{w}{\mu\left(\theta(\omega, a)\right)}}_{\text{search cost}}$$

Equilibrium Under Asymmetric Information

- We illustrate for $\mathscr{A} = \{a_L, a_H\}$ and $\Omega = \overline{\omega}$
  - In the paper, we characterize the unique fully revealing separating equilibrium under the D1 criterion for multiple types
- Equilibrium resembles that of the Spence (1973) model
  - "effort" corresponds to selling with a lower probability
  - high-quality sellers have a lower marginal cost of not trading than low-quality sellers

▸ Definition of equilibrium ▸ Definition of types of equilibrium ▸ Conditions for separating ▸ Sketch proof

Constructing the Equilibrium

- For **low type**

$$v^s(\omega, a_L) = \max_{\{q(\omega,a_L)\}} p(\theta(\omega, a_L, q(\omega, a_L)))\, q(\omega, a_L) + (1 - p(\theta(\omega, a_L, q(\omega, a_L))))\,(\Lambda v^s(\omega, a_L) - \delta \omega a_L)$$

subject to

$$\theta(\omega, a_L, q(\omega, a_L)) = \mu^{-1}\left(\frac{w}{v^b(\omega, a_L) - q(\omega, a_L)}\right)$$

Constructing the Equilibrium

- For low type
- For **high type**:

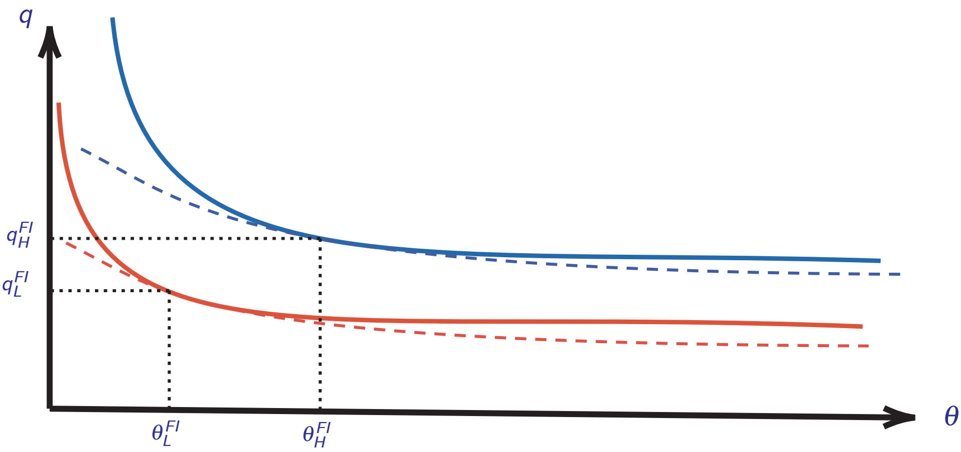
$$v^{s}(\omega,a_H)=\max_{\{q(\omega,a_H)\}} p\left(\theta\left(\omega,a_H,q(\omega,a_H)\right)\right)q(\omega,a_H)$$
$$+\left(1-p(\theta(\omega,a_H,q(\omega,a_H)))\right)\left(\Lambda v^{s}(\omega,a_H)-\delta\omega a_H\right)$$

subject to

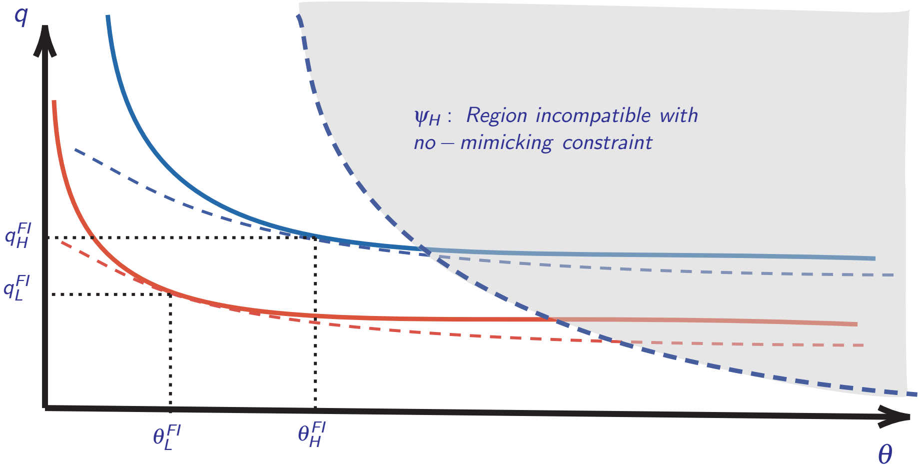
$$\theta(\omega,a_H,q(\omega,a_H))=\mu^{-1}\left(\frac{w}{v^{b}(\omega,a_H)-q(\omega,a_H)}\right),$$

$$v^{s}(\omega,a_L)\geq p\left(\theta\left(\omega,a_H,q(\omega,a_H)\right)\right)\Big((1-\psi)q(\omega,a_H)+\psi q_t^{P}(\omega,a_L,\hat{a}(\omega,a_H),q(\omega,a_H))\Big)$$
$$+\left(1-p(\theta(\omega,a_H,q(\omega,a_H)))\right)\left(\Lambda v^{s}(\omega,a_L)-\delta\omega a_L\right)$$

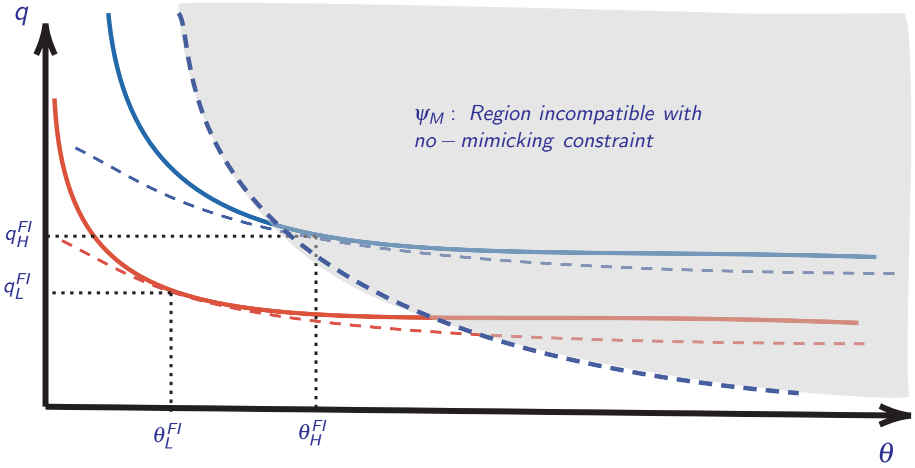
Equilibrium Under Asymmetric Information



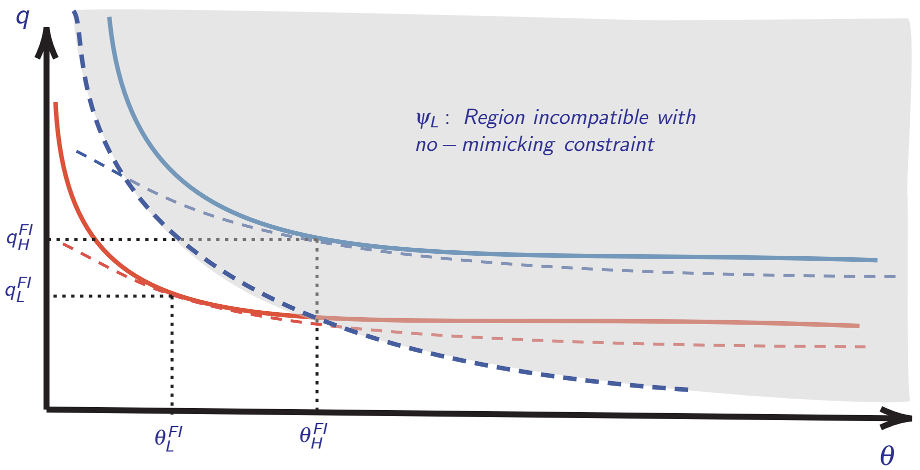
Equilibrium Under Asymmetric Information



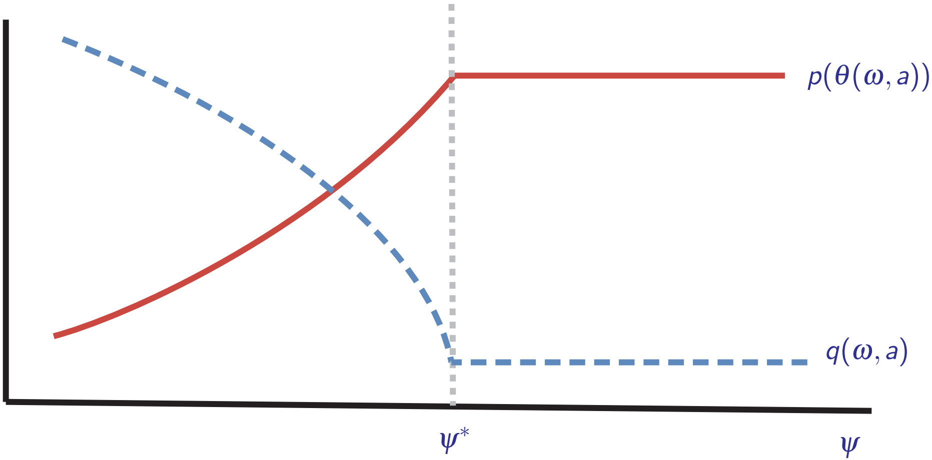
Equilibrium Under Asymmetric Information



Equilibrium Under Asymmetric Information



Equilibrium Under Asymmetric Information



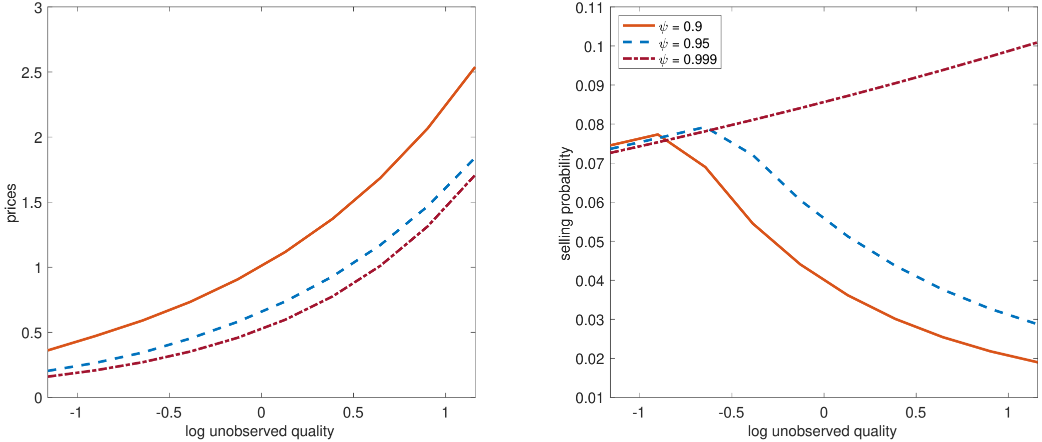
Prices and Duration for Unobserved Capital Quality

Prediction II:
AI (i.e., $\psi < \psi^*$) affects terms of trade of high-quality capital
$q(\omega, a_H) > q^{FI}(\omega, a_H), p(\theta(\omega, a_H)) < p\left(\theta^{FI}(\omega, a_H)\right)$

▸ Proposition

- Intuition: a_H chooses higher price to signal its quality, willing to accept lower trading probability
- Distortions governed by ψ: $\left.\frac{d\left[ln \frac{p(\theta(\omega,a_L))}{p(\theta(\omega,a_H))}\right]}{d\psi}\right|_{\psi<\psi^*} < 0$
- **Relationship between prices and duration is informative about ψ**

Prices and Duration for Multiple Types: A Quantitative Illustration



Mapping Model to Data

- Researcher observes micro data on capital units listed for sale with:
  - Prices, duration, vector of obseved characteristics X_i
- Assume independent log-normal distributions for capital qualities with variances $\{\sigma_\omega^2, \sigma_a^2\}$ and $\log \omega_i = \tau X_i$
- Consider estimating the following regressions:

$$\log(q_i) = \iota_\omega X_i + \varepsilon_i^q$$

$$\log(Duration_i) = \upsilon_\omega \hat{q}_i + \upsilon_q \hat{\varepsilon}_i^q + \varepsilon_i^d$$

- Let $\hat{q}_i = \hat{\iota}_\omega X_i$: predicted prices, $\hat{\varepsilon}_i^q$: residual prices
- Proposition: If $\left(\frac{w_t}{\mu_t(\theta(\omega,\hat{a},q))}\right) / v_t^b(\omega, a) \to 0$ and $\varphi \to 0$, then up to first-order, $(\psi, \sigma_\omega^2, \sigma_a^2)$ are identified by the estimated moments $\hat{\sigma}_\omega^2 \equiv Var(\hat{q}_i)$, $\hat{\sigma}_a^2 \equiv Var(\hat{\varepsilon}_i^q)$, and $\hat{\upsilon}_q$.

▸ Sketch proof ▸ Quantitative

Outline

The Data

- Panel of capital structures posted for sale and rent
  - Retail, office space, and warehouses
  - Monthly listed price
  - Contain information on listed characteristics:
    location, age, size, number of rooms, etc
  - Duration and monthly search intensity (clicks and emails)
- Source: *Idealista*, leading online platform in the real estate market in Europe
- Coverage: 8.5 million observations from Spain
  - $>$ 1.1 million capital units
  - Period: 2005–2018

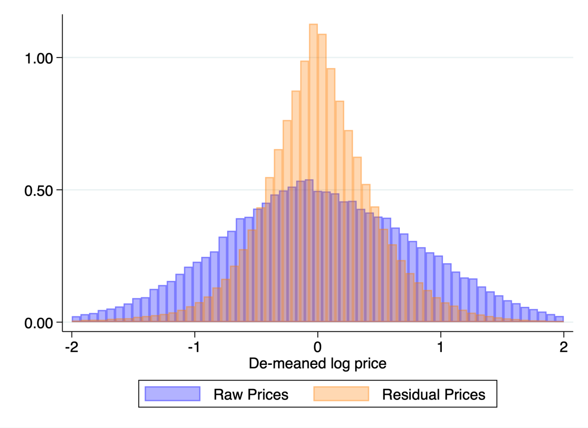
Online Platform | Benchmarking | Descriptive statistics | Dist. Duration

Price Variation Explained by Listed Characteristics

(Log) price per sq. ft. of property i in location l in month t:

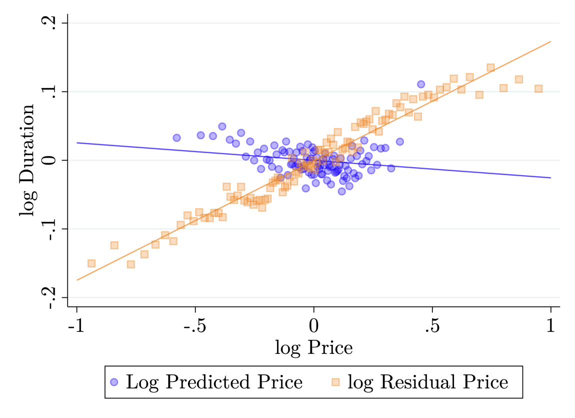
$$log(q_{it}) = v_{l(i)t} + \gamma X_i + \varepsilon_{it}$$

	St. Dev.	R^2
Raw data	0.83	0.00
Year	0.79	0.09
Location	0.59	0.49
Year $\times$ Location $\times$ Type	0.56	0.54
… + Area	0.53	0.59
… + Age	0.53	0.59
Benchmark	0.51	0.62



▸ Location ▸ Time

Relationship Between Duration and Prices



	(1) log Duration	(2) log Duration
log Price	0.013***	
	(0.004)	
log Predicted Price		-0.025**
		(0.011)
log Residual Price		0.148***
		(0.004)
Observations	456351	439680
R^2	0.226	0.228

$$\log Duration_{it} = \beta_0 + \beta_1 \hat{\varepsilon}_{it} + \beta_2 \widehat{\log(q_{it})} + u_{it}$$

Consistent with model predictions for observed and unobserved capital quality

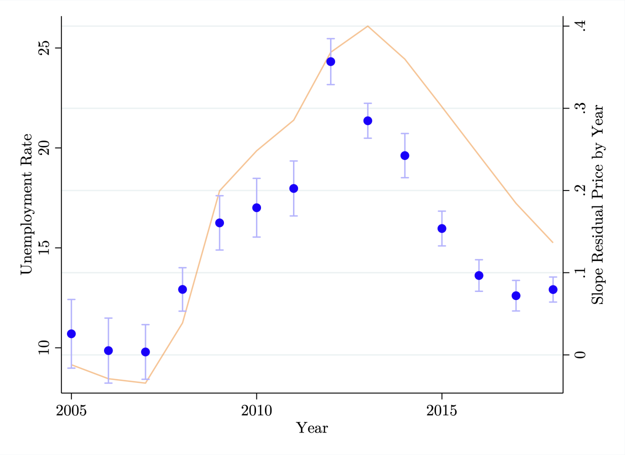
Robust to other measures

Clicks | Rental market | Detailed Table

Alternative Interpretations and Additional Results

1. Homogeneous capital qualities and sellers' indifference between prices & duration
   - Expected net present revenues are increasing in residual prices ▸ Details
2. Homogeneous capital qualities and sellers' heterogeneity in holding costs
   - Holding costs that equalize net present revenues to that of higher residual prices appear unplausibly large ▸ Details
3. Buyers' wealth heterogeneity
   - Similar relationship between duration and residual prices observed within different (total) price ranges ▸ Details

The Euro Crisis and the Slope between Duration and Residual Prices



▸ Price Dispersion

Outline

1. Model
2. The Micro Effects of Asymmetric Information
3. Measurement
4. **The Macro Effects of Asymmetric Information**

Parameterization

Two-step procedure

1. **Fix a subset of parameters to standard values**
2. Calibrate targeting moments on model simulated data

Parameter	Description	Value
β	Discount factor	0.9966
α	Share of capital	0.35
δ	Depreciation rate	0.0074
γ	Technology growth	1.004
γ_n	Population growth	1.0027
φ	Firms' exit rate	0.0027
η	Curvature matching technology	0.8
ϕ	Bargaining power of seller	0.5

Parameterization

Two-step procedure

1. Fix a subset of parameters to standard values
2. **Calibrate targeting moments on model simulated data**

Parameter	Description	Value	Target	Model	Data
ψ	Accuracy information tech.	0.9795	Regression coefficient	0.148	0.148
σ_ω	SD observed quality	0.72	SD log predicted prices	0.65	0.65
σ_a	SD unobserved quality	0.58	SD log residual prices	0.51	0.51
$\bar{m}$	Matching efficiency	0.267	Mean duration	11.46	11.44

- Also match untargeted slope between duration and predicted prices ▸ Detail
- As a benchmark: Targeting the slope during the Euro crisis, get $\psi = 0.96$

▸ Contour plots

Aggregation and Macro Channels

$$
\begin{aligned}
Y_t &\equiv \left(\gamma^t L_t\right)^{1-\alpha} \mathscr{K}_t^{\alpha} \\
&= \left(\gamma^t L_t\right)^{1-\alpha} \left(\left[\sum_{\omega \in \omega} \sum_{a \in \mathscr{A}} K_t(\omega, a) \right] \left[\mathbb{E}(\omega a)\left(1 - \mathbb{E}(u_t(\omega, a))\right) - \mathbb{C}ov\left(\omega a, u_t(\omega, a)\right) \right] \right)^{\alpha},
\end{aligned}
$$

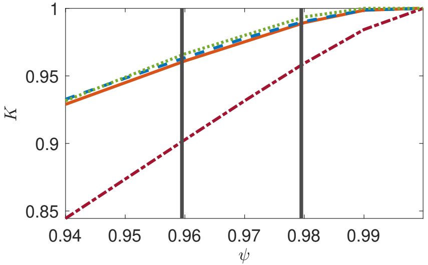
where

- $L_t \equiv h_t(\mathbf{k})\gamma_n^t - \int \int \sum_\omega \sum_{\hat{a}} v_{jt}(\omega, \hat{a}, q)\,\mathrm{d}q\,\mathrm{d}j$ denotes labor used in production
- $\mathscr{K}_t \equiv \int \mathscr{K}_{jt}\,\mathrm{d}j$ denotes the aggregate capital input
- $u_t(\omega, a)$: unemployment rate of capital type (ω, a)

Macro Channels: Investment

$$Y_t \equiv \left(\gamma^t L_t\right)^{1-\alpha} \mathscr{K}_t^{\alpha}$$

$$= \left(\gamma^t L_t\right)^{1-\alpha} \left(\left[\sum_{\omega \in \omega} \sum_{a \in \mathscr{A}} \boldsymbol{K_t(\omega, a)} \right] \left[\mathbb{E}(\omega a)(1 - \mathbb{E}(u_t(\omega, a))) - \mathbb{C}ov(\omega a, u_t(\omega, a)) \right] \right)^{\alpha}$$



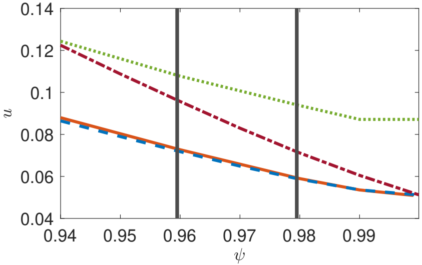
Investment channel:

Higher information asymmetries

$\Rightarrow$ lower returns to producing capital goods

Macro Channels: Capital Unemployment

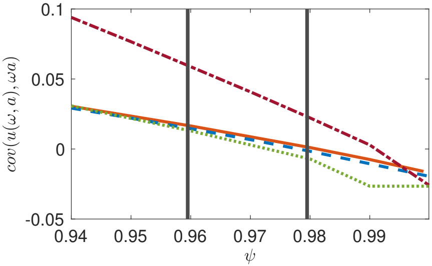
$$
\begin{aligned}
Y_t &\equiv \left(\gamma^t L_t\right)^{1-\alpha} \mathscr{K}_t^{\alpha} \\
&= \left(\gamma^t L_t\right)^{1-\alpha} \left(\left[\sum_{\omega \in \omega} \sum_{a \in \mathscr{A}} K_t(\omega, a) \right] \left[\mathbb{E}(\omega a) \left(1 - \mathbb{E}\left(\boldsymbol{u_t(\omega, a)}\right)\right) - \mathbb{C}ov\left(\omega a, u_t(\omega, a)\right) \right] \right)^{\alpha}
\end{aligned}
$$



Capital-unemployment channel:
Higher information asymmetries
$\Rightarrow$ lower trading probabilities,
longer unemployment durations

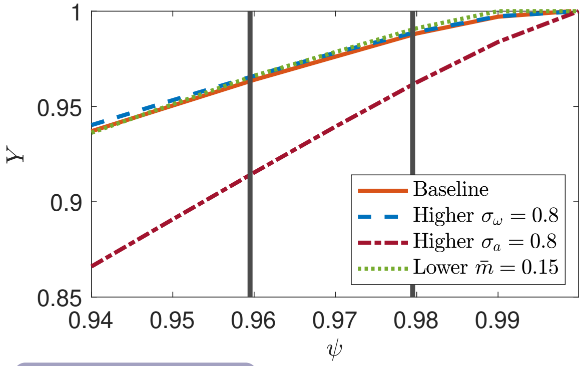
Macro Channels: Quality of Employed Capital

$$
\begin{aligned}
Y_t &\equiv \left(\gamma^t L_t\right)^{1-\alpha} \mathscr{K}_t^{\alpha} \\
&= \left(\gamma^t L_t\right)^{1-\alpha} \left(\left[\sum_{\omega \in \omega} \sum_{a \in \mathscr{A}} K_t(\omega, a) \right] \left[\mathbb{E}(\omega a)\left(1 - \mathbb{E}(u_t(\omega, a))\right) - \mathbb{C}\boldsymbol{ov}\left(\boldsymbol{\omega a}, \boldsymbol{u_t(\omega, a)}\right)\right] \right)^{\alpha}
\end{aligned}
$$



Employed-capital quality channel:
Higher information asymmetries
$\Rightarrow$ relative decrease in trading probabilities of high-quality capital

Asymmetric Information and Economic Activity



	Change	Contribution
$Y/Y^{FI}-1$	1.22%	100%
$\mathscr{K}/\mathscr{K}^{FI}-1$	2.55%	74%
$K/K^{FI}-1$	1.12%	32%
$u-u^{FI}$	0.92%	25%
$cov-cov^{F}I$	0.01	16%
$L/L^{FI}-1$	0.5%	26%

▸ Alternative parameterizations

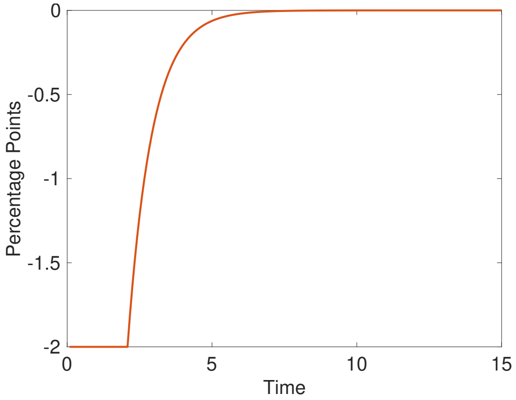
Crisis Experiment

- Study macro dynamics from changes in the degree of asymmetry information
- Assume at $t = 0$ the economy experiences an unexpected change in the accuracy of information technology
- Captures classic narrative during economic crises:
  - Sellers innovate to make their assets more opaque
  - Buyers realize the lower quality of information-revealing technologies
- Discipline change and persistence of ψ_t with the of dynamics of the slope between duration and residual prices observed during the Euro crisis

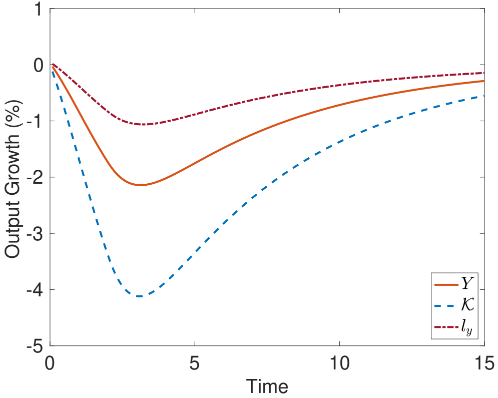
▸ Contour plots

Macroeconomic Reponses to Changes in Information Technologies

(a) Accuracy of Information Technology



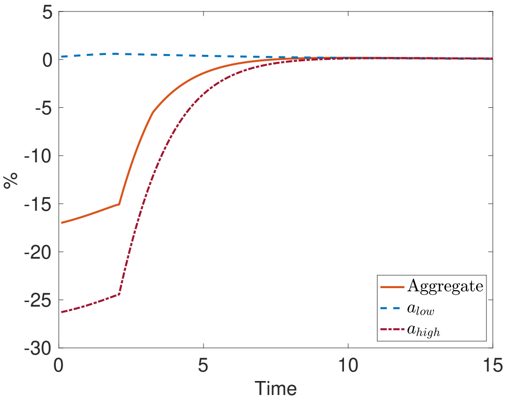
(b) Economic Activity



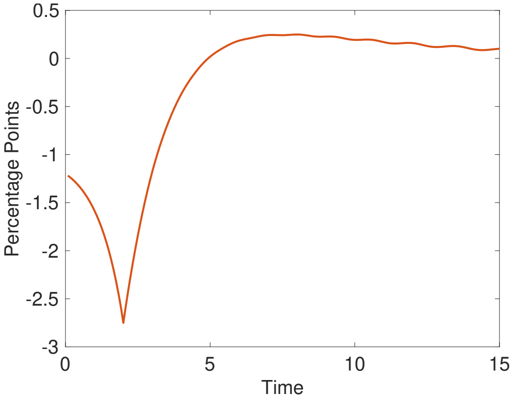
Additional variables

Macroeconomic Reponses to Changes in Information Technologies

(a) Selling Probabilities



(b) Expected Marginal Value of Capital



▸ Analytical expression

Conclusions

- Capital heterogeneity and trading frictions in capital markets have important macro implications
  - Large elasticity of economic activity to changes in the degree of asymmetric info
  - Transmission operates through the liquidity of capital and its effects on investment and capital allocation
- Role for studying policies aimed at preventing signaling
  - Measurement developed in the paper can help inform policies

Outline

BONUS DEPRECIATION

- Firms pay taxes on income net of business expenses
- Can fully expense wages, advertising, etc. immediately
- Investment gets expensed over time according to tax depreciation schedules
- Bonus depreciation accelerates this depreciation schedule

TABLE 1—REGULAR AND BONUS DEPRECIATION SCHEDULES FOR FIVE-YEAR ITEMS

Year:	0	1	2	3	4	5	Total
Normal depreciation							
Deductions (000s)	200	320	192	115	115	58	1,000
Tax benefit ($\tau = 35$ percent)	70	112	67.2	40.3	40.3	20.2	350
Bonus depreciation (50 percent)							
Deductions (000s)	600	160	96	57.5	57.5	29	1,000
Tax benefit ($\tau = 35$ percent)	210	56	33.6	20.2	20.2	10	350

Notes: This table displays year-by-year deductions and tax benefits for a $1 million investment in computers, a five-year item, depreciable according to the Modified Accelerated Cost Recovery System (MACRS). The top schedule applies during normal times. It reflects a half-year convention for the purchase year and a 200 percent declining balance method (2× straight line until straight line is greater). The bottom schedule applies when 50 percent bonus depreciation is available.

Source: Authors' calculations. See IRS publication 946 for the recovery periods and schedules applying to other class lives (https://www.irs.gov/uac/about-publication-946).

Source: Zwick-Mahon (2017)

- Bonus depreciation allows firm to deduct a per dollar bonus of θ at the time of investment and the remaining $1-\theta$ according to regular schedule

- Table shows bonus depreciation of $\theta = 0.5$

Value of Bonus Depreciation

Frictionless markets view:

- Bonus depreciation only matters due to discounting

$$z^0 = D_0 + \sum_{t=1}^{T} \frac{1}{(1+r)^t} D_t$$

- D_t allowable deduction in period t per dollar of investment in period 0
- r risk-adjusted discount rate used by firm
- Without discounting $z_0 = 1$ (100%), with discounting $z_0 < 1$
- Bonus raises z_0 by bringing deductions forward in time

$$z = \theta + (1 - \theta) z_0$$

Value of Bonus Depreciation

- Frictionless markets view:
  - Value of bonus modest for short-lived investments
  - E.g., with $r = 0.07$, bonus in Table 1 raised z by 2%
  - Value of bonus greater for long-lived investments
- With financial frictions, bonus may have large effect on investment
  - Effect on current cash flow large ($140,000 in Table 1)

Zwick-Mahon (2017)

- Estimate the effect of bonus on investment
- Bonus occurs in recessions
  - Correlated with other determinants of investment
- Use difference-in-difference identification strategy
  - Bonus more valuable for industries with longer lived investments
  - Compare effect of bonus on industries with differing duration of investments

Zwick-Mahon (2017): Policy Variable

- Main policy variable: $z_{N,t}$
  - Where N is a 4-digit NAICS industry
- Compute baseline z_N for pre-period (1993-2000)
  - For each firm-year: weighted average of z across duration categories using a 7% discount rate
  - z_N computed as simple average of these firm-year z
- In bonus years adjust z_N for bonus

$$z_{N,t} = \theta_t + (1 - \theta_t) z_N$$

Zwick-Mahon (2017): Specification

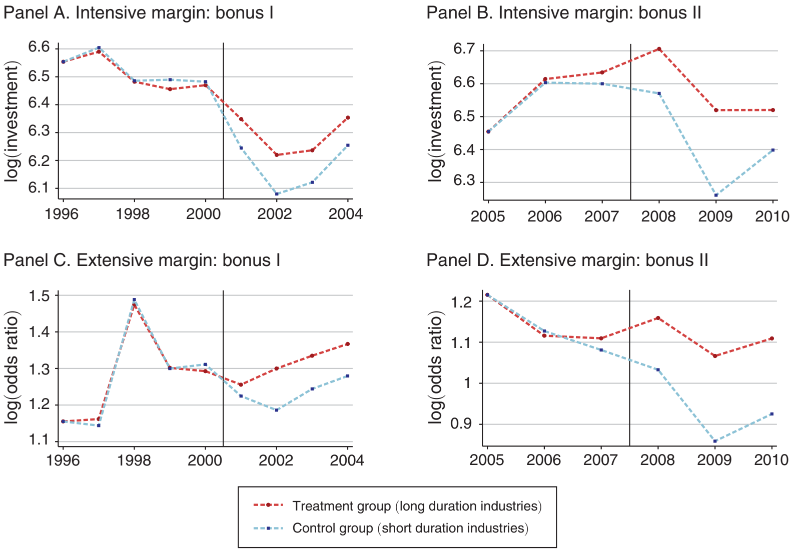
- Baseline difference-in-difference specification:

$$\log(I_{it}) = \alpha_i + \beta z_{N,t} + \gamma X_{it} + \delta_t + \varepsilon_{it}$$

  - β is coefficient of interest
  - Industry fixed effects: Allow for average differences in industry investment
  - Time fixed effects: Take out aggregate effects

Zwick-Mahon (2017): Identification

- Identifying assumption: **Parallel trends**
  - Industries with long- and short-duration investment patterns would have evolved in parallel absent bonus
- Threat to identification:
  - Durable investment industries more resilient in downturns



Source: Zwick-Mahon (2017)

$$f(I_{it}) = \alpha_i + \delta_t + \beta g(z_{N,t}) + \gamma X_{it} + \varepsilon_{it}$$

	All	CF	Pre-2005	Post-2004	Controls	Trends
	LHS Variable is Log(Eligible Investment)					
$z_{N,t}$	3.69***	3.78***	3.07***	3.02***	3.73***	4.69***
	(0.53)	(0.57)	(0.69)	(0.81)	(0.70)	(0.62)
Observations	735341	580422	514035	221306	585914	722262
Clusters (Firms)	128001	100883	109678	63699	107985	124962
R^2	0.71	0.74	0.73	0.80	0.72	0.71
	LHS Variable is Log(Odds Ratio)					
$z_{N,t}$	3.79**	3.87**	3.12	3.59**	3.99*	4.00***
	(1.24)	(1.21)	(2.00)	(1.14)	(1.69)	(1.13)
Observations	803659	641173	556011	247648	643913	803659
Clusters (Industries)	314	314	314	274	277	314
R^2	0.87	0.88	0.88	0.93	0.90	0.90
	LHS Variable is Eligible Investment/Lagged Capital					
$\frac{1-t_c z}{1-t_c}$	-1.60***	-1.53***	-2.00***	-1.42***	-2.27***	-1.50***
	(0.096)	(0.095)	(0.16)	(0.13)	(0.14)	(0.10)
Observations	637243	633598	426214	211029	510653	631295
Clusters (Firms)	103890	103220	87939	57343	90145	103565
R^2	0.43	0.43	0.48	0.54	0.45	0.44

All regressions include firm and year effects. Controls: cash flow in (2); 4-digit Q, quartics in sales, assets, profit margin, age in (5); 2-digit NAICS $\times t^2$ in (6).

Source: Zwick-Mahon (2017)

Zwick-Mahon (2017): Effects Are Large

- Average change in $z_{N,t}$:
  - Early episode: 4.8 cents
  - Later episode: 7.8 cents
- Average change in investment:
  - Early episode: 17.7 log points ($3.69 \times 0.048 = 0.177$)
  - Later episode: 28.8 log points ($3.69 \times 0.078 = 0.288$)

Zwick-Mahon (2017): Effects Are Large

- In simple investment model:
  - Elasticity of investment with respect to net of tax rate, $1-\tau z$, equals price and interest elasticity

$$\log(I_{it}) = \alpha + \beta \log(1-\tau z_{N,t}) + \varepsilon_{it}$$

- Zwick-Mahon's regressor is $z_{N,t}$ not $\log(1-\tau z_{N,t})$

- Linear approximation:

$$\log(1-\tau z_{N,t}) = \log(1-\tau z_N) - \frac{\tau}{1-\tau z_N}(z_{N,t} - z_N)$$

- Imply price and interest rate elasticities of investment equal to

$$-3.69 \div \frac{\tau}{1-\tau z} \approx -7.2$$

Outline

Neoclassical Firms very sensitive to changes in the Real Interest Rate

- Time is discrete time, each period is a year.
- Simplest determination of capital $\delta = 0$

$$AF_k = r$$

- Assume that $F(K, L) = K^{\alpha} L^{1-\alpha}$. Therefore:

$$1 + r_t = 1 + A_t \alpha K_t^{\alpha-1} L_t^{1-\alpha}$$

- Make a log-linear approximation. Hatted variables are log changes:

$$\hat{r}_t = \frac{r}{1+r}\left(\hat{a}_t - (1-\alpha)\hat{k}_t + (1-\alpha)\hat{l}_t\right)$$

- where $\hat{r}_t = \log \frac{1+r_t}{1+r}$

Neoclassical Firms very sensitive to changes in the Real Interest Rate

$$\hat{k}_t = -\hat{r}_t\left(\frac{1+r}{(1-\alpha)r}\right) + \frac{\hat{a}_t}{1-\alpha} + \hat{l}_t$$

- Assume an exogenous decrease of 1% in interest rates.
- Capital would have to increase 31.5%
- Including reasonable depreciation would change this number to 14%.
- Letting labor increase would further increase this number
- Assume 100% of GDP could be transformed to capital.
- Capital-output ratios are between 2 and 4 (depending on land and housing)
- To increase capital by 31%, it would take 61%-124% of GDP
- With δ: to increase capital by 14%, it would take 28-56% of GDP

Another way of seeing the same

- Another way of illustrating the same issue is to compute the semi-elasticity of investment to interest rates
- Imagine firms with DRS

$$y_j = z\varepsilon_j k_j^{\alpha}$$

- Then

$$\frac{\partial i_{jt}/i_{jt}}{\partial r_t} = -\frac{1}{\delta}\frac{1}{1-\alpha}\left(\frac{1+r_t}{r_t+\delta}\right)$$

- As $\alpha \to 1$, the semi-elasticity becomes infinite
- Under $\alpha = 0.7$, $\delta = 0.025$ $r_t = 0.01$
- The semi-elasticity is equal to -3,847

Capital Adjustment Frictions

- Very large literature
- 70s: Abel (1979)
- 80s: Hayashi (1982)
- 90s: Doms and Dunne (1998), Caballero (1999), Caballero and Engel (1999)
- 2000s: Thomas (2000), Cooper and Haltiwanger (2006), Khan and Thomas (2003, 2008), Gourio Kashyap (2007)
- Just to name a few

Some Context

- Capital accumulation models tend to have adjustment costs
- One reason is what we saw before
- in CT: Without any costs, in a standard model investment functions are not well-defined
- Convex Adjustment costs. Two main results:
  1. Investment is a function of q: The marginal value of one extra unit of capital
  $$\frac{i_{jt}}{k_{jt}} = h(q_t)$$
  2. Marginal (q) and average (Q) values of capital are equal, when some conditions apply
  $$q_t = Q_t$$
- Very tractable problem. Block in medium-scale DSGE models

Some Context

Issue:

- Evidence of lumpiness of investment at the individual level
- Lumpy investment: Periods of inaction followed by spikes in investment
- Obviously convex adjustment costs do not get that
- Documented originally by Doms and Dunne (1998)
- The literature proposed fixed costs of adjustment as a possible answer
- Cooper and Haltiwanger (2006) interpret the microdata as exhibiting both convex and non-convex costs
- For the purpose of our class: Does micro-level frictions of capital adjustment matter in the aggregate?

METRIC

- What does it mean that micro frictions “matter” for the aggregate
- Is the response to shocks the same in models with and without fixed costs
- One particular dimension receives interest: Pent-up demand
- Or in more technical jargon, state-dependence of the elasticity of investment to aggregate shocks
- Is the response of investment to a TFP shock higher or lower in a recession?
- RBC model: It’s the same
- Alternative: Pent-up demand, the elasticity depends on the distribution of capital imbalances
- At the start of the recovery firms have “excess capital”, so an additional shock may not trigger large adjustments

Early findings

- Response by Thomas (2002): No
- Micro level lumpiness is irrelevant
- Meaning: Models with and without lumpiness as observed in the data have the same aggregate dynamics

Winberry 2021

$$\frac{\partial i_{jt}/i_{jt}}{\partial r_t} = -\frac{1}{1-\alpha}\frac{1}{\delta}\frac{1+r_t}{r_t+\delta}$$

- Under a reasonable calibration:
- $\alpha = 0.7$, $\delta = 0.025$, $r_t = 0.01$: $\frac{\partial i_{jt}/i_{jt}}{\partial r_t} = -3,847$
- r_t is an equilibrium outcome, so much depends on how r_t behaves.
- The standard model has very strong strategic substitutability
- That others do not adjust induces higher incentives to adjust
- Mediated by the response of the real interest rate to aggregate shocks

Generic Setting

Firms have a DRS production function

$$y = e^z e^a k^\alpha n^\gamma$$

a captures idiosyncratic productivity (iid across firms)

$$a_{it} = \rho_a a_{t-1} + \varepsilon_{it} \sigma_a.$$

z captures aggregate productivity

$$z_t = \rho_z z_{t-1} + \xi_t \sigma_z.$$

Firms discount period τ future profits with the household stochastic discount factor $\Lambda_{t,t+\tau}$

Setting

$$V(k,a,\chi,\mathscr{S}) = \max_n [e^z e^a k^\alpha n^\gamma - w(\mathscr{S})n] + \max[V^n(k,a,\chi,\mathscr{S}), V^a(k,a,\chi,\mathscr{S}) - \chi w(\mathscr{S})]$$

The value function conditional on non-adjustment is given by:

$$V^n(k,a,\chi,\mathscr{S}) = \mathbb{E}(\Lambda(\mathscr{S},\mathscr{S}')V(k',a',\chi',\mathscr{S}')|a,\mathscr{S}),$$

subject to

$$k' = k(1-\delta)$$

The value function conditional on adjustment is given by:

$$V^a(k,a,\chi',\mathscr{S}) = \max_i -i - \phi\left(\frac{i}{k}\right)^2 k + \mathbb{E}((\Lambda(\mathscr{S},\mathscr{S}')V(k',a',\chi',\mathscr{S}')|a,\mathscr{S}),$$

subject to

$$k' = k(1-\delta) + i$$

.

Setting

In the background there is a representative household that supplies labor, and consumes.

- There is a labor supply function in the background
- The Stochastic Discount Factor will capture household preferences for consumption smoothing

Habits in Consumption

- Fix the dynamics of r by changing optimal consumption decisions

$$\mathbb{E}_t \sum_{t=0}^{\infty} \beta^t \log \left(C_t - \chi \frac{N_t^{1+\xi}}{1+\xi} - X_t \right)$$
$$X_t = \lambda \hat{C}_t$$

$$\hat{C}_t = C_t - \chi \frac{N_t^{1+\xi}}{1+\xi}$$

Winberry 2021

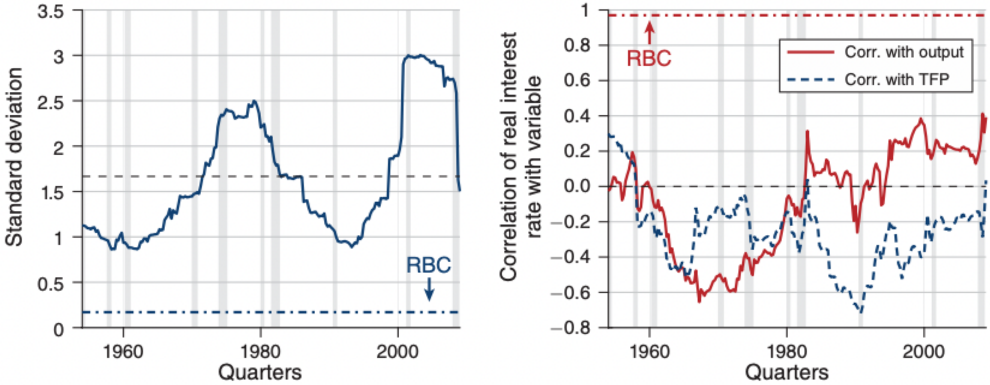


Figure 1. Stability of Cyclical Dynamics of Risk-Free Rate

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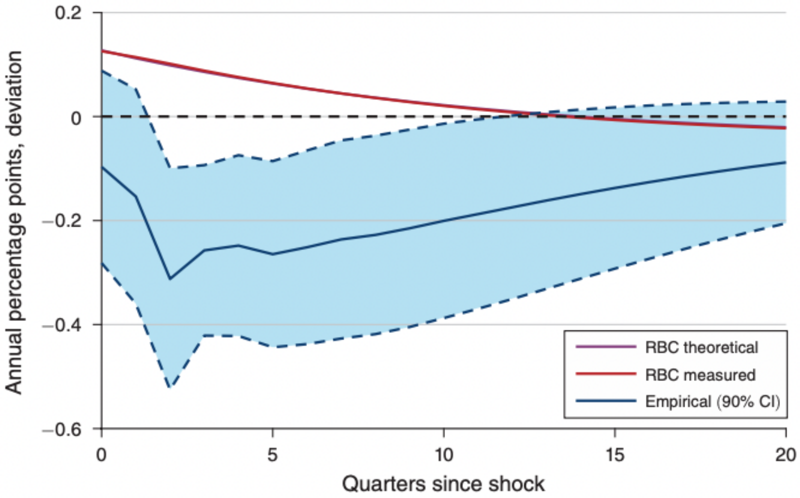

FIGURE 2. IMPULSE RESPONSE OF THE REAL INTEREST RATE TO TFP SHOCK

Winberry 2021

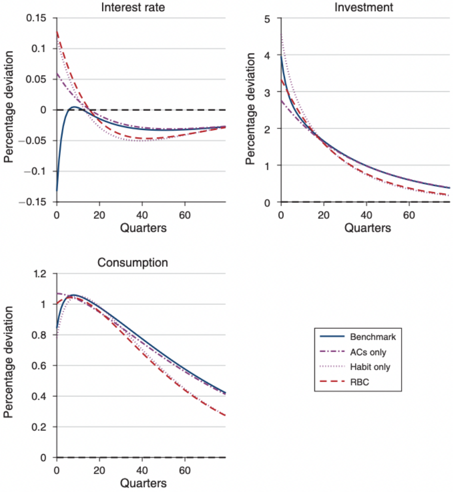

Figure 3. Identification of Habit Formation and Adjustment Costs

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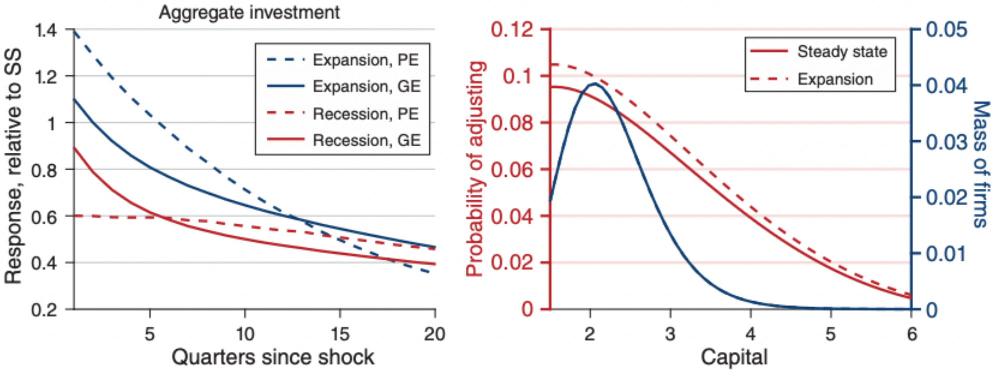

FIGURE 5. PROCYCLICAL IMPULSE RESPONSES OF AGGREGATE INVESTMENT

How to tell models apart?

- Koby and Wolf (2021) proposal: Use Zwick and Mahon (2017)
- Semi-elasticity of investment to bonus depreciation reforms
- Preview: Semi-Elasticity of investment in the data is consistent with Winberry (2021), not with Khan and Thomas (2008)