Lemons, Market Shutdowns and Learning

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Outline

Introduction

The economy

Equilibrium under asymmetric information

Properties of the asymmetric information economy

Informative signals and learning

Conclusion

Introduction

- What makes financial markets fragile?
- Does this matter for the real economy?
- Understanding business cycles
- Financial stabilization policy

Asymmetric information

- One particular imperfection: asymmetric information about quality of assets
- Why this friction?
  - Selling assets (or claims to assets) is important and assets are heterogenous
  - Asymmetric information is a major concern in corporate finance
  - Markets shut down

Plan

1. Macroeconomic model where selling assets matters

   Implications of asymmetric information

2. Endogenous informational asymmetry through learning

1. Basic Framework

- Entrepreneurs have heterogeneous investment opportunities
- Cannot borrow - raise funds by selling assets
- Asymmetrically informed about the quality of assets they own (*lemons* and *nonlemons*)
- Good reason for selling assets: need funds for investment
- Bad reason for selling assets: getting rid of lemons

1. Results

- Equivalence between asymmetric information and taxes on financial transactions
- Implicit tax is countercyclical
  - Positive shock $\Rightarrow$ more demand for assets $\Rightarrow$ higher asset prices $\Rightarrow$ more sales of nonlemons
- Amplification of asset price and investment movements
- Market shutdowns under large negative shocks
- Risk/liquidity premium in asset prices

2. Learning

- Endogenize informational asymmetry
  - Each project issues signals
  - Imperfectly known correlation between signals and project quality
  - Better estimates of correlation $\Leftrightarrow$ signals are more informative $\Leftrightarrow$ less informational asymmetry.
  - Learning-by-doing through financial transactions
- Results
  - Temporary shocks can have persistent effects
  - Shocks to learning

Related work

- **Macroeconomics with financial-market imperfections**
  Kiyotaki & Moore (1997,2005,2008), Bernanke & Gertler (1989), Bernanke, Gertler & Gilchrist (1999), Carlstrom & Fuerst (1997)
- **Asymmetric information in corporate finance**
  Myers & Majluf (1984), Choe, Masulis, Nanda (1993)
- **Credit markets**
  Stiglitz & Weiss (1981), Mankiw (1986), de Meza & Webb (1987), House (2006)
- **Lemons markets and liquidity**
  Eisfeldt (2004), Bolton et. al. (2008), Malherbe (2009), Rocheteau (2009)
- **Financial crises**
  Gorton (2009), Claessens et. al. (2008), Cecchetti et. al. (2009), Cerra & Saxena (2008)
- **Speed of learning and business cycles**
  Caplin & Leahy (1996), Veldkamp (2004), Ordoñez (2009)

A true story

Dear Sir,

My client is selling a cheese factory in Córdoba, Argentina in order to raise funds for profitable investment opportunities in soybean processing.

In FY 2002 it made a loss (under Argentine inflationary accounting rules) of $30 million, but increased market share from 10% to 12%.

Would you be interested in purchasing it?

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Households

- Entrepreneurs have standard preferences

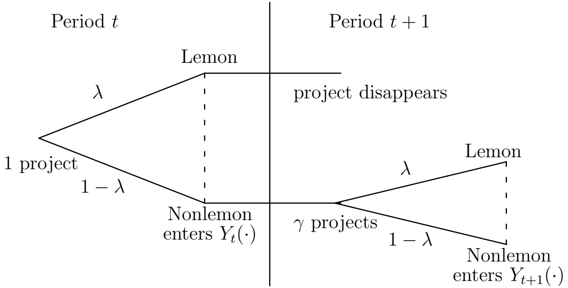
$$\mathbb{E} \sum \beta^t u(c_t^j)$$

with $u(c_t^j) = \log(c_t^j)$

- Workers supply labour L inelastically and live hand to mouth

Technology

- Capital consists of *projects*
- Fraction λ become useless lemons; the rest enter production function and then grow at rate γ
- Output is $Y_t = Y\left((1-\lambda) K_t, L; Z_t\right)$



Investment technology

- Each entrepreneur can convert consumption goods into projects at rate A_t^j
  - Better investment opportunities are modeled as creating *more* capital
- $A_t^j \sim F$ and is *iid* across entrepreneurs and across time
- Resource constraint:

$$Lc_t^w + \int \left(c_t^j + i_t^j\right) dj \leq Y\left(\left(1-\lambda\right) K_t, L; Z_t\right)$$

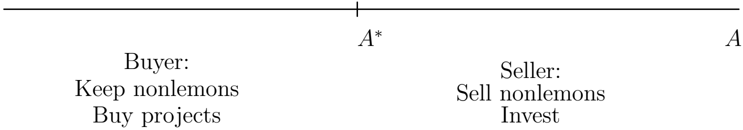
$$K_{t+1} = \gamma \left(1-\lambda\right) K_t + \int i_t^j A_t^j dj$$

Complete markets benchmark

- Spot factor markets: $w = Y_L$ and $r = Y_K$
- All physical investment undertaken by entrepreneurs with $A = A^{\max}$
- Finance by selling claims on future consumption goods (or projects)

Imperfection 1: no (uncollateralized) borrowing

- Entrepreneurs cannot pledge future goods or projects
  - Moral hazard
  - Outright stealing
- Selling existing projects is the only financial transaction
  - Selling used machines
  - Spinning off divisions
  - Issuing securities
  - Binary outcome + divisible projects $\Rightarrow$ selling is (almost) w.l.o.g.
  - Kurlat (2009) - security design
- Entrepreneurs sort into Buyers and Sellers:



Imperfection 2: asymmetric information

- Seller knows whether project is a lemon or a nonlemon
- Buyer only knows λ^M: equilibrium fraction of lemons among sold projects

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Entrepreneur's program

Choose consumption, investment, project demand, lemon supply and nonlemon supply

$$V\left(k,A,X\right)=\max_{c,k',i,s_L,s_{NL},d} u\left(c\right)+\beta\mathbb{E}\left[V\left(k',A',X'\right)|X\right]$$

s.t.

$$c+i+p\left(X\right)\left[d-s_L-s_{NL}\right]\leq r(X)\left(1-\lambda\right)k$$

$$k'=\gamma\left[\left(1-\lambda\right)k+\left(1-\lambda^M\left(X\right)\right)d-s_{NL}\right]+Ai$$

$$i\geq 0 \quad d\geq 0$$

$$s_L\in\left[0,\lambda k\right] \quad s_{NL}\in\left[0,\left(1-\lambda\right)k\right]$$

* X is aggregate state: productivity and the joint distribution $\Gamma(K,A)$

Recursive Competitive Equilibrium

- prices $\{p(X), r(X), w(X)\}$
- market proportions of lemons $\lambda^M(X)$
- law of motion for capital holdings $\Gamma'(X)$
- $c^w(X)$
- value function $V(k,A,X)$ and policy function $\{c(k,A,X), k'(k,A,X), i(k,A,X), s_L(k,A,X), s_{NL}(k,A,X), d(k,A,X)\}$

such that

- $w(X) = Y_L(X)$, $r(X) = Y_K(X)$
- $c^w(X) = w(X)$
- policy and value functions solve entrepreneur's problem
- $S(X) = \int s_L^j(X) + s_{NL}^j(X) dj \geq D(X) = \int d^j(X) dj \qquad (= \text{if } p(X) > 0)$
- $\lambda^M(X) = \frac{S_L(X)}{S(X)}$
- Law of motion of capital derives from entrepreneur's decisions

Entrepreneur's problem

Step 1: Linear in k

Step 2: Given k', choose d, s_L, s_{NL} and i to maximize c

- Simple arbitrage condition

Step 3: Solve relaxed problem (as though budget set were linear)

- Thanks to log preferences, solution can be found statically

Step 4: Show that in equilibrium, relaxed and original problem must coincide

Step 2: Entrepreneurs sort into Buyers, Keepers and Sellers

- Clearly all sell their lemons
- Return of buying: $A^M(p) = \frac{\gamma(1-\lambda^M(p))}{p}$
- $t+1$ projects given up when selling nonlemons: $\frac{\gamma}{p}$

Recall constraints:

$$c + i + p\left(X\right)\left[d - s_L - s_{NL}\right] \leq \left(1-\lambda\right) r\left(X\right) k$$
$$k' = \gamma\left[\left(1-\lambda\right) k + \left(1-\lambda^M\left(X\right)\right) d - s_{NL}\right] + Ai$$

Step 2: Entrepreneurs sort into Buyers, Keepers and Sellers

- Clearly all sell their lemons
- Return of buying: $A^M(p) = \frac{\gamma(1-\lambda^M(p))}{p}$
- $t+1$ projects given up when selling nonlemons: $\frac{\gamma}{p}$
- Sorting depending on A:

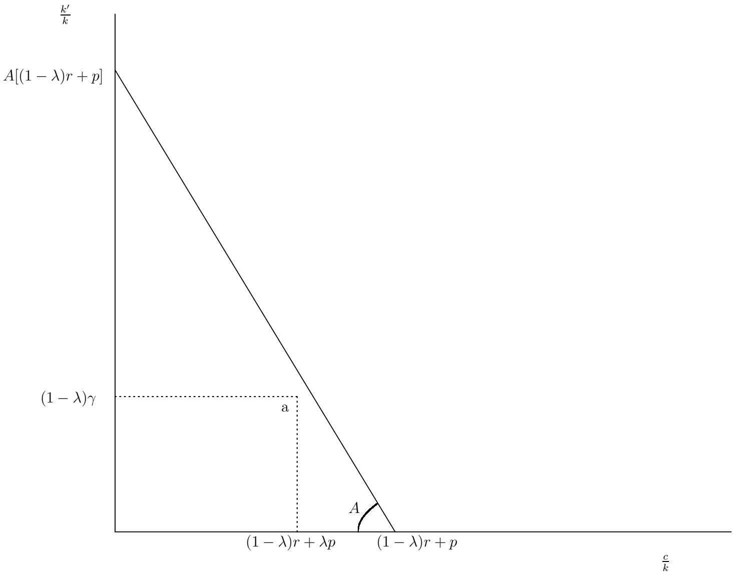
$A^M \equiv \frac{\gamma(1-\lambda^M)}{p}$ $\qquad$ $\frac{\gamma}{p}$ $\qquad$ A

Buyer:	Keeper:	Seller:
Sell lemons Keep nonlemons Buy projects	Sell lemons Keep nonlemons Invest	Sell lemons Sell nonlemons Invest

- The market proportion of lemons is

$$\lambda^M(p) = \frac{\lambda}{\lambda + (1-\lambda)\left(1 - F\left(\frac{\gamma}{p}\right)\right)}$$

Step 3: Budget constraints



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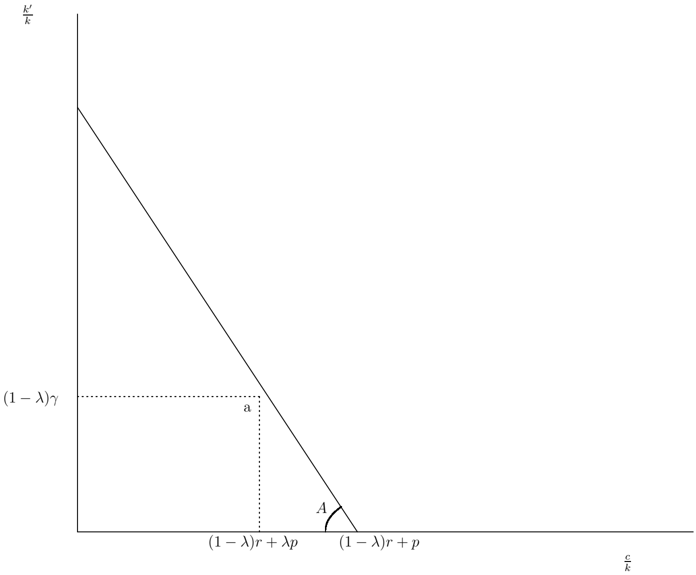

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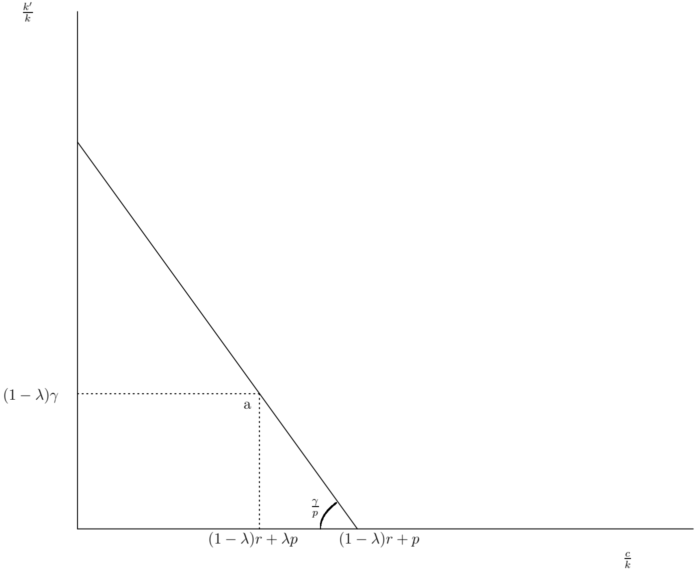

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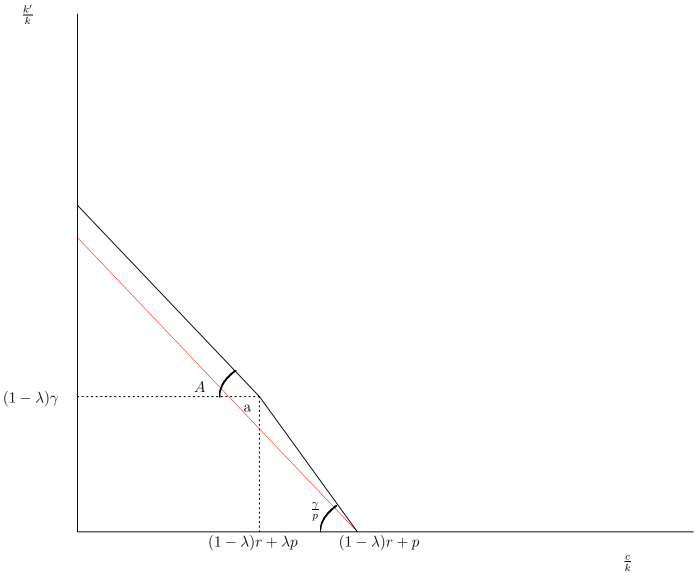

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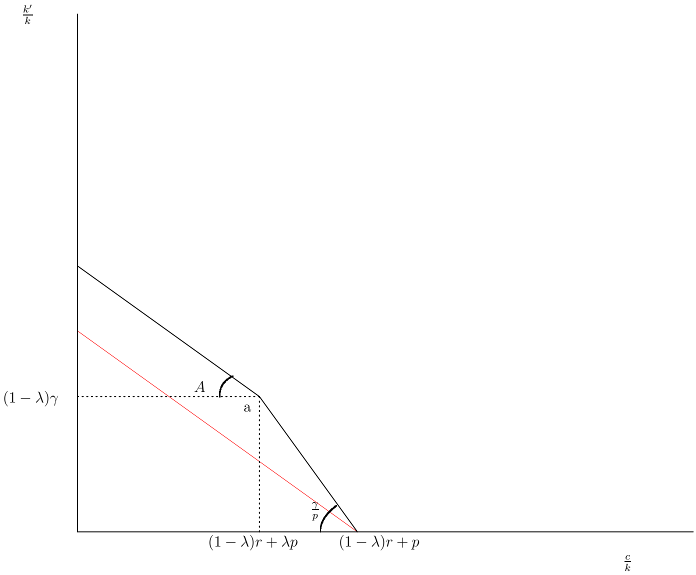

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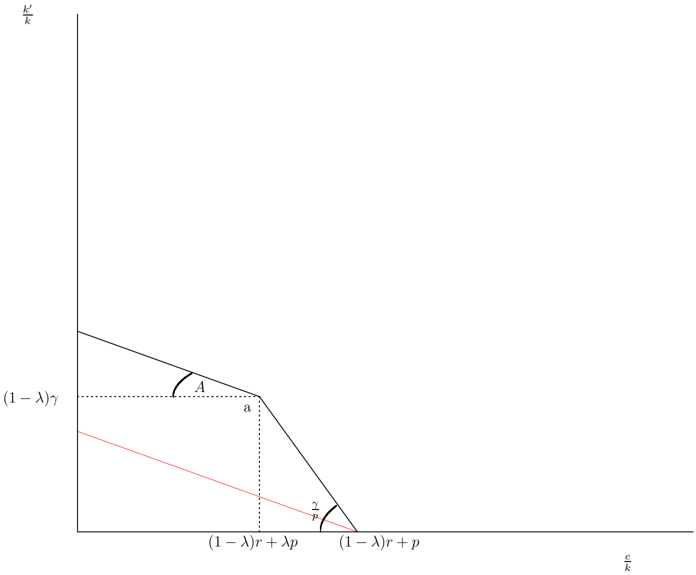

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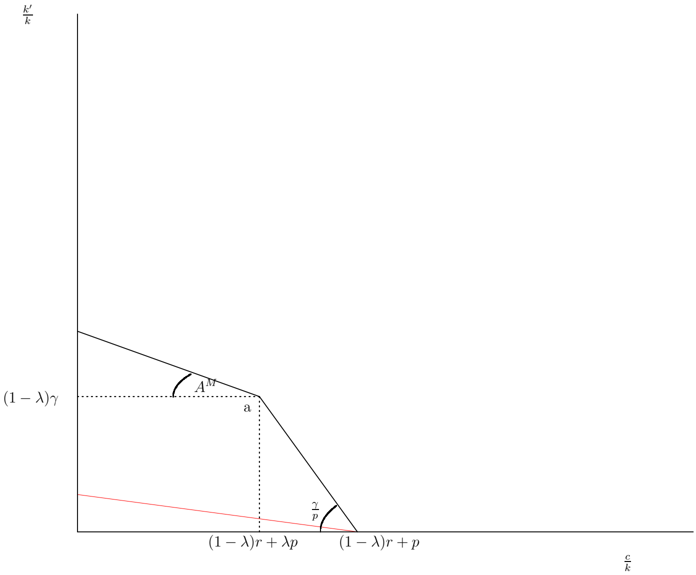

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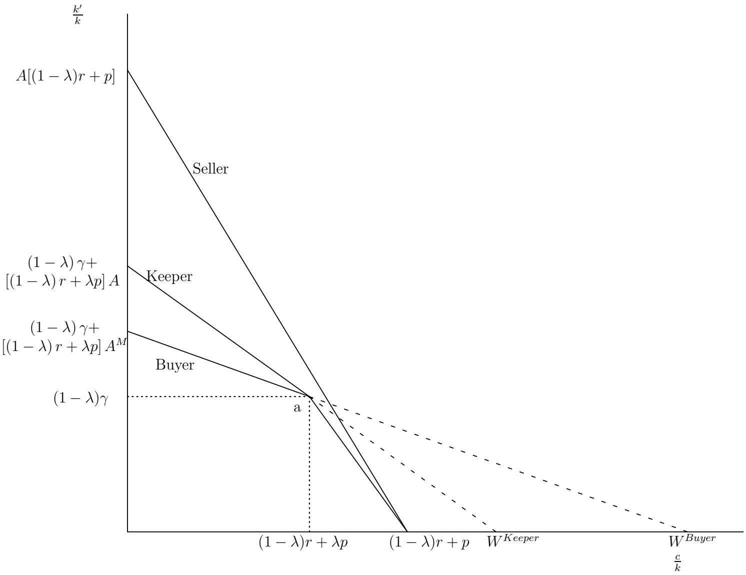
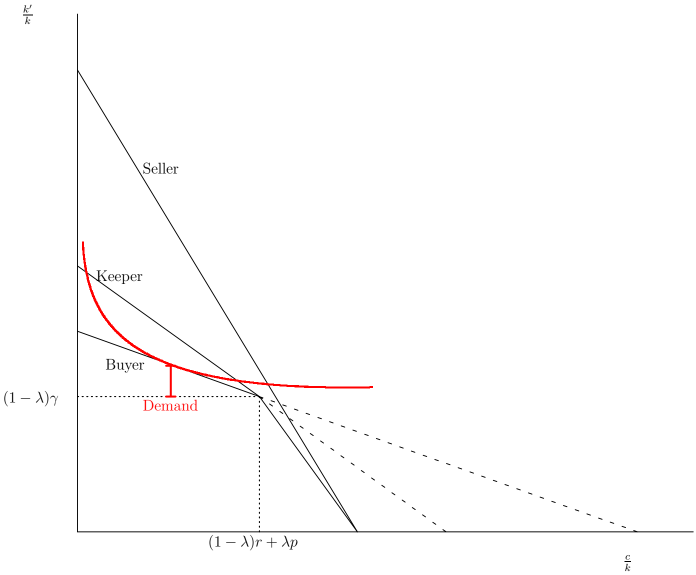


Demand



$\frac{k'}{k}$
Seller
Keeper
Buyer
$(1-\lambda)\gamma$
Demand
$(1-\lambda)r+\lambda p$
$\frac{c}{k}$

Equilibrium conditions

- Demand of projects from Buyers

$$D = \left[\beta\left[\lambda + (1-\lambda)\frac{r}{p}\right] - \frac{(1-\beta)(1-\lambda)}{(1-\lambda^M(p))}\right] F\left(\frac{\gamma(1-\lambda^M(p))}{p}\right) K$$

- Supply (lemons + nonlemons) from arbitrage conditions:

$$S = \left[\lambda + (1-\lambda)\left(1 - F\left(\frac{\gamma}{p}\right)\right)\right] K$$

- Market clearing:

$$S \geq D, \text{ with equality if } p > 0$$

- Same condition must hold if relaxed and full programs *don't* coincide
  - Because if they don't, $D < 0$

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Equivalence with taxes

- Assume
  - Symmetric information
  - An ad-valorem tax on sale of projects: Buyer pays $p(1+\tau)$
  - Revenue is redistributed in proportion to capital holdings

Symmetric info & taxes	Asymmetric info
$c+i+p\boldsymbol{(1+\tau)}\,d_{NL}-ps_{NL}-\boldsymbol{T}$ $\leq (1-\lambda)\,rk$	$c+i+pd-ps_{NL}-\boldsymbol{ps_L}$ $\leq (1-\lambda)\,rk$
$k'=\gamma\left[(1-\lambda)\,k+d_{NL}-s_{NL}\right]+Ai$	$k'=\gamma[(1-\lambda)k+\boldsymbol{(1-\lambda^M)}d-s_{NL}]+Ai$

If:

$$\tau(X)=\frac{\lambda^M(X)}{1-\lambda^M(X)}$$

$\Rightarrow$ budget constraints (and prices and allocations) coincide

* Part "intertemporal wedge", part "efficiency wedge" (Chari et. al., 2007)

Response to shocks

- Coconut-productivity shock:
  Proportional increase in $Y((1-\lambda)K, L)$
  - Higher r

  $\Rightarrow$ increased demand for projects (via wealth of Buyers)

  $\Rightarrow$ higher asset prices

  $\Rightarrow$ more sales of nonlemons

  $\Rightarrow$ lower implicit tax

- Project-productivity shock:
  Proportional shift in $F(A)$:
  - Physical investment more attractive

  $\Rightarrow$ more sales of nonlemons

  $\Rightarrow$ lower implicit tax

Amplification

Compare asymmetric information vs. symmetric information plus taxes

- Capital accumulation response
  - (fixing taxes) Positive output shock increases K'
  - Lower implicit taxes further increase K' *

  $\Rightarrow$ Asymmetric information amplifies the response of K'

- Asset price and interest rate responses
  - (fixing taxes) Positive output shocks increase p and lower A^M
  - Lower implicit taxes further increase p but increase A^M

  $\Rightarrow$ Asymmetric information
    - Amplifies asset price responses
    - Moderates A^M responses

* s.t. technical conditions

Market Shutdowns

- Due to selection effect, $A^M(p)$ can be bounded
- Compute the A^M required to tempt Buyers to choose k' above the kink: see graph

$$\frac{\gamma}{r}\frac{(1-\beta)}{\beta}$$

- For low enough r, then

$$\max_p A^M(p) < \frac{\gamma}{r}\frac{(1-\beta)}{\beta}$$

$\Rightarrow$ $p = 0$

$\Rightarrow$ A negative productivity shock can lead the market to shut down

Risk / liquidity premium

- Offer entrepreneur a safe asset yielding R^f consumption goods at $t+1$
- For each possible value for R^f and each entrepreneur, solve portfolio problem: invest in projects or in safe asset
- For each entrepreneur, define the implicit risk-free rate $R^{f,j}$ as the rate such that the entrepreneur invests zero in risk-free asset
- Compare this to the expected return on projects:

$$R^{p,j} \equiv \mathbb{E}\left[\max\{A^j, A^M\} W_k(k', A', X')\right]$$

where $W_k(k', A', X')$ is the shadow value of projects tomorrow

Risk / liquidity premium

Prop.: $R^{p,j} > R^{f,j}$

Proof: Higher A' means

- Lower $W_k(k', A', X')$
- Lower consumption $\Rightarrow$ higher marginal utility

$\Rightarrow$ shadow value of projects negatively correlated with $u'(c)$

- Under symmetric information and no aggregate risk, shadow value of projects is always $p \Rightarrow$ premium disappears
- Kiyotaki & Moore (2008) have similar result assuming exogenous "resaleability constraints"

Conclusions so far

- Amplification
  - As in Kiyotaki & Moore (1997,2008), mediated through asset prices
- Endogenous magnitude of the friction
  - In Kiyotaki & Moore (2008), this is a parameter
- Prediction about external financing across the cycle
  - Opposite to Bernanke & Gertler (1989)

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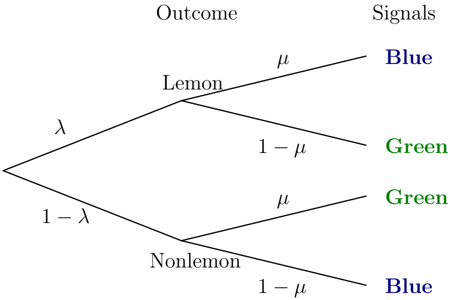
Why introduce signals and learning?

- Pure informational asymmetry is a limiting case
- Asymmetry can be a matter of degree
- Study how that degree is determined

Information structure

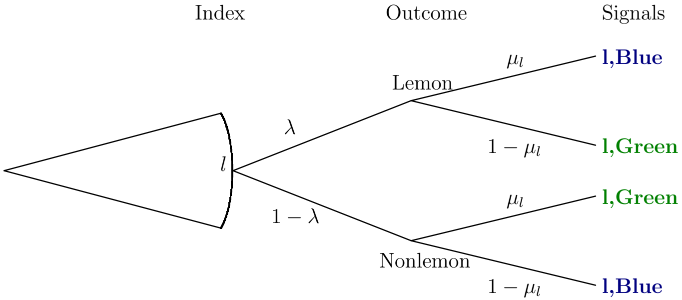
- Financial statements, analyst reports, etc.



- μ close to $\frac{1}{2}$ $\Rightarrow$ signals uninformative
- μ close to 0 or 1 $\Rightarrow$ signals informative

Information structure

- Financial statements, analyst reports, etc.



- μ close to $\frac{1}{2}$ $\Rightarrow$ signals uninformative
- μ close to 0 or 1 $\Rightarrow$ signals informative

Uncertainty about how to interpret signals

- $\mu_l \in \{\bar{\mu}, 1 - \bar{\mu}\}$
- For each l, μ_l follows independent Markov process with switching probability σ
- At any point in time, agents do not know μ_l
- Beliefs $B_l(\mu_l)$, with mean $\hat{\mu}_l$, derived from learning
- Next:
  1. Equilibrium given beliefs
  2. How beliefs are formed

Equilibrium given beliefs $B_l(\mu_l)$

- A different submarket for each value of l, s
- In each submarket, infer $\hat{\lambda}_{l,s} \equiv \Pr[Lemon|signal]$

$$\hat{\lambda}_{l,Blue} = \frac{\lambda\hat{\mu}_l}{\lambda\hat{\mu}_l + (1-\lambda)(1-\hat{\mu}_l)}$$
$$\hat{\lambda}_{l,Green} = \frac{\lambda(1-\hat{\mu}_l)}{\lambda(1-\hat{\mu}_l) + (1-\lambda)\hat{\mu}_l}$$

  - because of binary structure $\hat{\mu}_l$ is a sufficient statistic for beliefs $B_l(\mu_l)$

- Returns $A^M_{l,s}(p_{l,s}) = \frac{\gamma(1-\lambda^M_{l,s}(p_{l,s}))}{p_{l,s}}$ equated across submarkets $\Rightarrow$
  - $p_{l,s}$ decreasing in $\hat{\lambda}_{l,s}$
  - Submarkets with high $\hat{\lambda}_{l,s}$ shut down

Learning μ

- Could learn from prices (but $\exists$ nonrevealing equilibrium)
- Between t and $t+1$, observe sample of size N_l of t-dated signal-outcome pairs from index l
- Bernoulli trial: "success" (with probability μ_l) is $Blue, Lemon$ or $Green, Nonlemon$
- Bayesian updating about μ_l
- Filtering problem, since μ_l is not constant

Sample size

- $N_l \sim Poisson(\omega_l)$

$$\omega_l = [f_l \omega_S + (1 - f_l)\omega_K]$$

f_l: fraction of l-projects sold
$\omega_S > \omega_K$

- More activity in financial markets $\longrightarrow$ more signals observed

- Let $b_{l,t} \equiv \Pr[\mu_{l,t} = \bar{\mu}]$. Then by Bayesian updating

$$b_{l,t+1} = \frac{(1-\sigma)\,\bar{\mu}^{n_l}\,(1-\bar{\mu})^{N_l - n_l}\,\omega_l\,(\bar{\mu})^{N_l}\,e^{-\omega_l(\bar{\mu})} b_{l,t} + \sigma\,(1-\bar{\mu})^{n_l}\,\bar{\mu}^{N_l - n_l}\omega_l\,(1-\bar{\mu})^{N_l}\,e^{-\omega_l(1-\bar{\mu})}\,(1 - b_{l,t})}{\bar{\mu}^{n_l}\,(1-\bar{\mu})^{N_l - n_l}\,\omega_l\,(\bar{\mu})^{N_l}\,e^{-\omega_l(\bar{\mu})} b_{l,t} + (1-\bar{\mu})^{n_l}\,\bar{\mu}^{N_l - n_l}\omega_l\,(1-\bar{\mu})^{N_l}\,e^{-\omega_l(1-\bar{\mu})}\,(1 - b_{l,t})}$$

- $\omega_l \longrightarrow 0 \qquad \Rightarrow \hat{\mu}$ moves towards $\frac{1}{2}$ (knowledge “depreciates”)
- $\omega_l \longrightarrow \infty \qquad \Rightarrow \hat{\mu} \longrightarrow (1-\sigma)\bar{\mu}$ or $(1-\sigma)(1-\bar{\mu})$

There is a nonrevealing equilibrium

- Supply of projects in each submarket depends on true μ
- Expected returns $A^M_{l,s}(p_{l,s})$ (and therefore demand) depend on beliefs $\hat{\mu}$
- Will market prices reveal the true μ?
- Assume that
  - Entrepreneurs do not learn from own portfolio
  - Entrepreneurs do not observe quantities
  - When Buyers are indifferent between buying from different submarkets, demand adjusts to meet supply

$\Rightarrow$ $\exists$ equilibrium where prices do not depend on true μ. Prices and aggregate quantities are the same as if $\hat{\mu}$ were the true μ

Computation procedure

- Add a state variable: $H(\hat{\mu})$ - distribution function of means of beliefs about μ_l
- Solve period-by-period as though $\hat{\mu}$ were the true μ
- Compute the evolution of H and capital

Persistence

- Mechanism:
  - Negative shock
  - $\Rightarrow$ Fewer transactions in financial market (possibly complete shutdown)
  - $\Rightarrow$ Observe fewer signals
  - $\Rightarrow$ Beliefs $H(\hat{\mu})$ shift towards $\frac{1}{2}$
  - $\Rightarrow$ More informational asymmetry in future periods
    - $\Rightarrow$ Fewer transactions in future periods
    - $\Rightarrow$ Lower capital accumulation

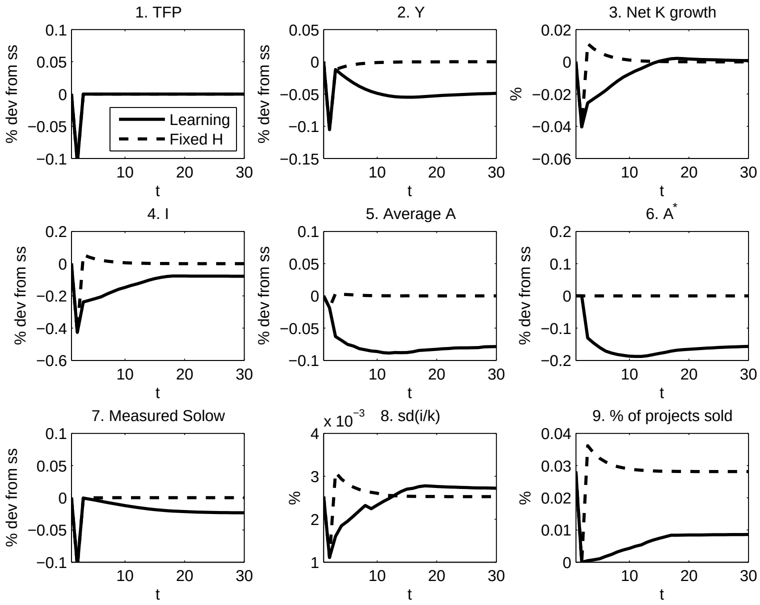
- If
  - In the no-signals steady state, the market shuts down
  - ω_S is sufficiently high
  - ω_K is sufficiently low

  then temporary productivity shocks can lead the economy to the autarky level of output for arbitrarily long periods of time

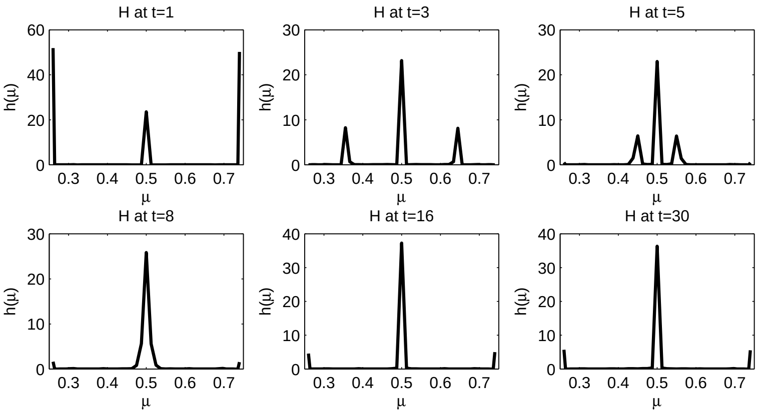
Simulations

Parameter	Value
β	0.92
γ	1.78
λ	0.5
σ	0.2
$\bar{\mu}$	0.9
$F(A)$	Gamma distribution with $E(A) = 1$ and $std(A) = 2$
Y	$Z[(1-\lambda)K]^{\alpha} L^{1-\alpha}$ with $\alpha = 0.3$
L	1
Z	1
ω_S	400
ω_K	0.07

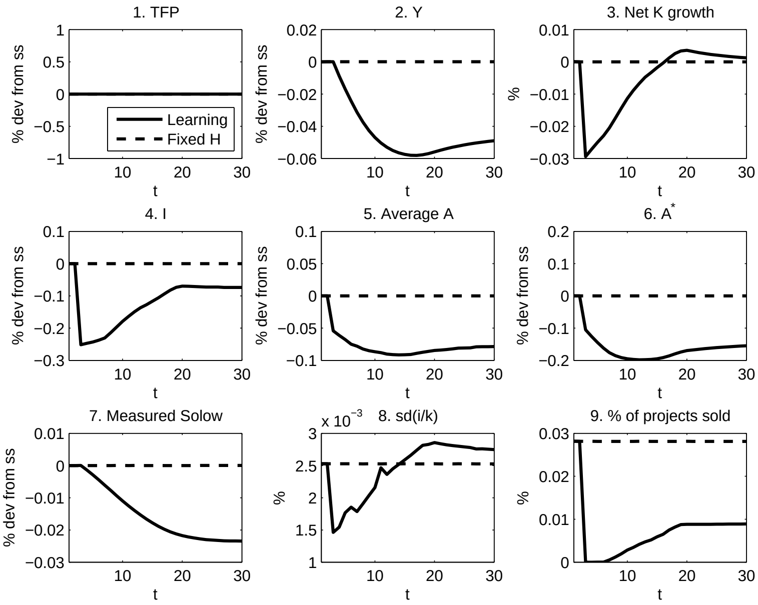
Simulation: productivity shock



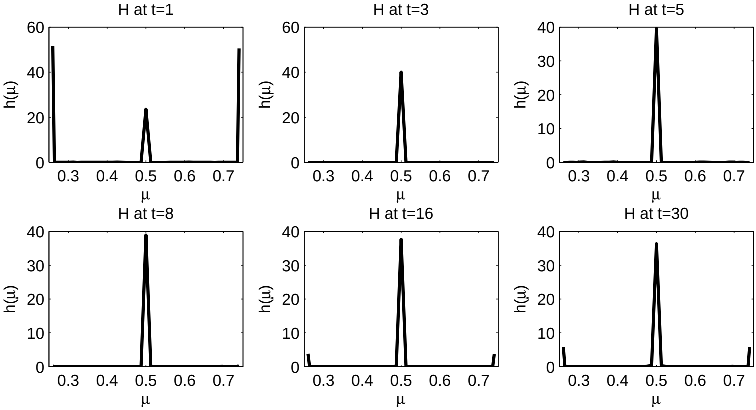
Simulation: productivity shock



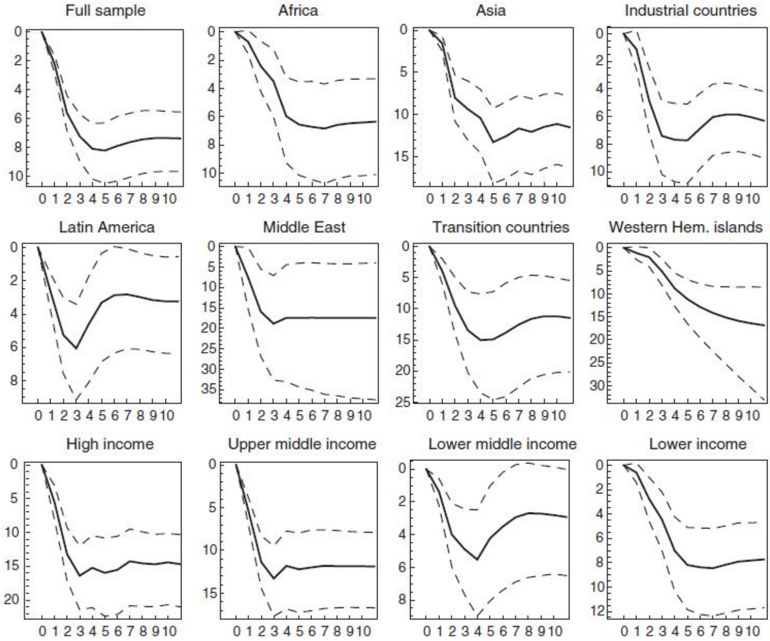
Simulation: "paradigm shift" ($\sigma = \frac{1}{2}$ for one period)



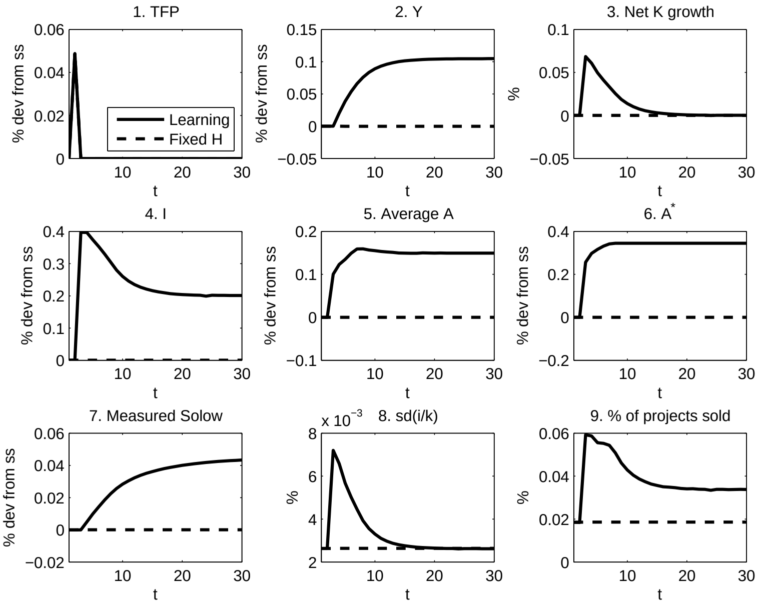
Simulation: “paradigm shift”



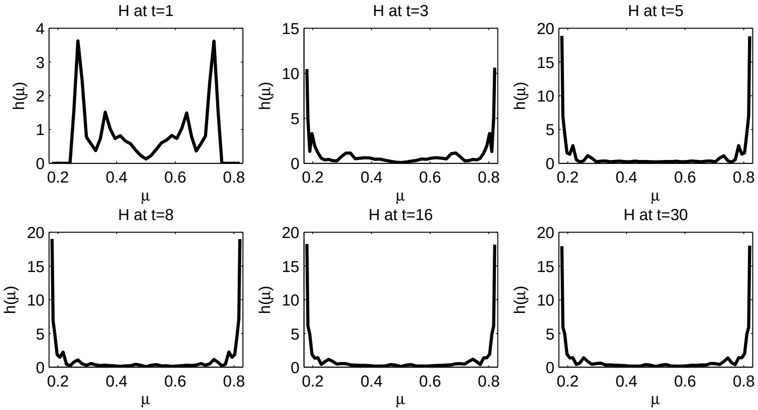
Evidence from Cerra & Saxena (2008)



Simulation: stabilization (permanent decrease in σ)



Simulation: stabilization



* Uses $\omega_S = 3$ and $\omega_K = 1$

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Final remarks

- Tractable framework to incorporate asymmetric information, lemons and macro shocks
- Severity of adverse selection problem responds endogenously
- Amplification of asset-price and investment effects of productivity shocks
- Persistent effect when learning is endogenous
- Learning by doing externality from financial market activity
- Liquidity = Experience
- Room for policy?