Booms and Systemic Banking Crises

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Disclaimer

The views expressed in this presentation are our own and do not necessarily reflect those of the European Central Bank or the Eurosystem

Motivation/Objective

- Better understand the joint dynamics of regular business cycles and systemic banking crises (SBCs)
- Account for the few features common to SBCs (Reinhart and Rogoff, 2009; Jordà et al., 2011; Claessens et al., 2011; Schularick and Taylor, 2012):
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  - Key Fact #3: SBCs are "**credit booms gone wrong**"

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  - DSGE–based crisis prevention policy analysis
  - DSGE–based early warning signals

Outline

- Stylized facts
- Comparison with the literature
- RBC model with systemic banking crises
- Quantitative analysis
- Concluding remarks

Stylized facts

SBCs are rare and bring about deep and long recessions

Frequency, magnitude, and duration of systemic banking crises

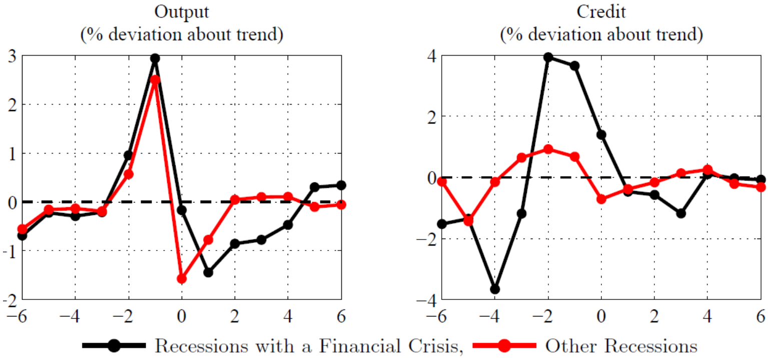
	Frequency (%)	Magnitude (%) from peak to trough	Duration (Years) from peak to trough
All banking crises	4.49	–	–
Systemic Banking Crises (SBC)	**2.42**	–	–
All recessions	10.20	4.86 (5.91)	1.85
Recessions with SBC (A)	23.86	**6.74** (6.61)	**2.59**
Recessions w/o SBC (B)	76.13	**4.27** (5.61)	**1.61**
Test A≠B, p-value (%)	–	2.61	0.00

Source: Schularik et al. (2011), data for 14 OECD countries, 1870-2008

Crises defined as in Laeven and Valencia (2008)

Stylized facts

SBCs follow credit booms



Stylized facts

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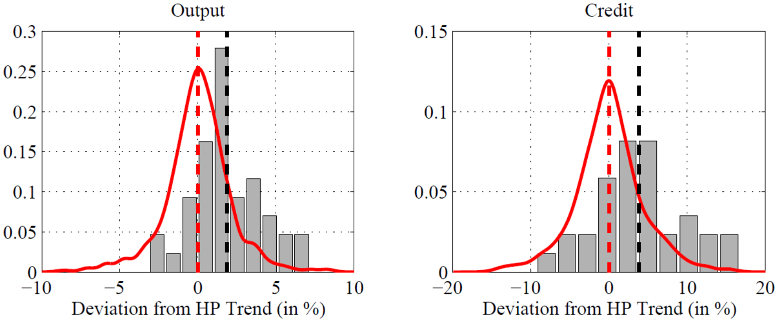

Our Framework

- Textbook stochastic optimal growth model (RBC)
- Heterogenous banks endowed with intermediation and storage technologies
- Interbank market subject to MH and AI
- A Systemic Banking Crisis is an inter-bank market freeze
- Spill-over effects between the interbank market, the retail corporate loan market, and the real economy

Main Results

1. Model features a (small) financial accelerator in normal times; calibrated to generate financial crises every 40 years

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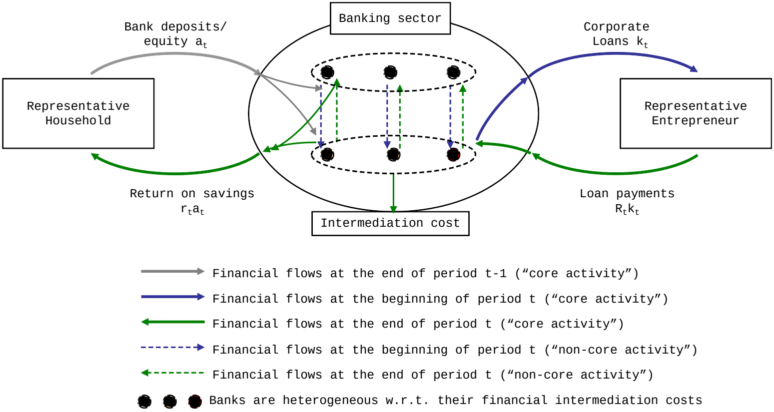
2. The **typical banking crisis follows upon an unusually long sequence of small, positive, transitory productivity shocks** — Not a large negative financial shock
3. Financial recessions follow credit booms. They are deeper and last longer because they come with a credit crunch
4. The likelihood, depth, and length of a financial recession increase with the intensity of the credit boom that precedes it

Related literature

- Gertler-Kiyotaki (2009), Gertler-Karadi (2010):
  - $\neq$ Full equilibrium non-linearities, such as sudden bank runs
- Bianchi (2009), Bianchi-Mendoza (2010):
  - $\neq$ Endogenous interest rates play a key role
- Brunnermeier-Sannikov (2012), He-Krishnamurthy (2012):
  - $\neq$ Typical crisis follows a rare, long sequence of positive TFP shocks
  - $\neq$ Typical crisis identified as a bank run, not as a binding borrowing constraint
- Gertler-Kiyotaki (2012)
  - $\neq$ Bank run is market based and rationally expected

Model setup

Overview



Representative Household and Firm

- Firm: $\max_{\{k_t,h_t\}} \pi_t = F(k_t, h_t; z_t) + (1-\delta)k_t - R_t k_t - w_t h_t$
- Household:

$$\max_{\{a_{t+\tau+1}, c_{t+\tau}, h_{t+\tau}\}_{\tau=0}^{\infty}} \mathbb{E}_t \sum_{\tau=0}^{\infty} \beta^{\tau} u\left(c_{t+\tau}, h_{t+\tau}\right)$$

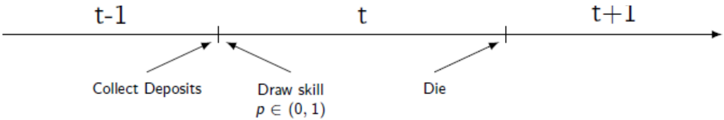
subject to budget constraint

$$c_t + a_{t+1} = r_t a_t + w_t h_t + \pi_t$$

- Notice that $r_t \leqslant R_t$ (spread) and $k_t \leqslant a_t$ (credit crunch)

The Banking Sector

- Banks are atomistic, competitive, and price takers
- Heterogeneous 1–period banks



- Bank p's net return per unit of corporate loan is pR_t
- Beneficial to relocate funds: unskilled banks lend to skillful banks on an interbank market. But relocation impaired due to:

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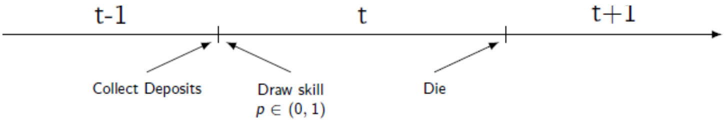

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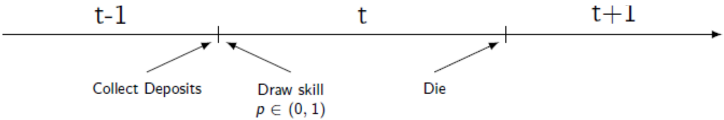

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  - **Asymmetric information:** p is private information
  - **Moral hazard**: bank p may borrow ϕ_t and run away

The Banking Sector

- Bank p has 4 options:
    1. Lend to other banks on the market $\Longrightarrow \rho_t$
    2. Store goods $\Longrightarrow \gamma$
    3. Raise funds ϕ_t from market and lend to firm $\Longrightarrow pR_t\,(1+\phi_t)$
    4. Raise funds ϕ_t from market and walk away $\Longrightarrow \gamma\,(1+\theta\phi_t)$
- Notice that the incentive to divert depends on corporate loan R_t
    - The higher R_t, the lower the incentive to divert

The Borrowing Bank's Problem

- Borrowing bank p solves:

$$\max_{\phi_t} r_t(p) \equiv pR_t(1+\phi_t) - \rho_t\phi_t$$

$$PC: \quad pR_t(1+\phi_t) - \rho_t\phi_t \geqslant \rho_t \qquad \Rightarrow p \geqslant \overline{p}_t \equiv \frac{\rho_t}{R_t}$$

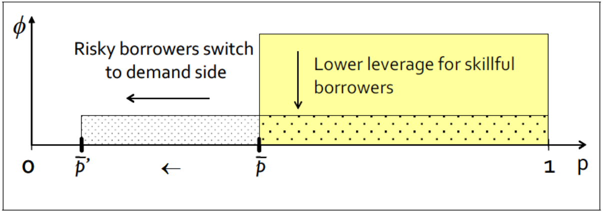
$$IC: \quad \gamma(1+\theta\phi_t) \leqslant \rho_t \qquad \Rightarrow \phi_t = (\rho_t - \gamma)/\theta\gamma$$

- Profits are fully distributed to household: $r_t \equiv \int_0^1 r_t(p)\,\mathrm{d}\mu(p)$

Interbank Market Equilibrium

Interbank market clearing condition

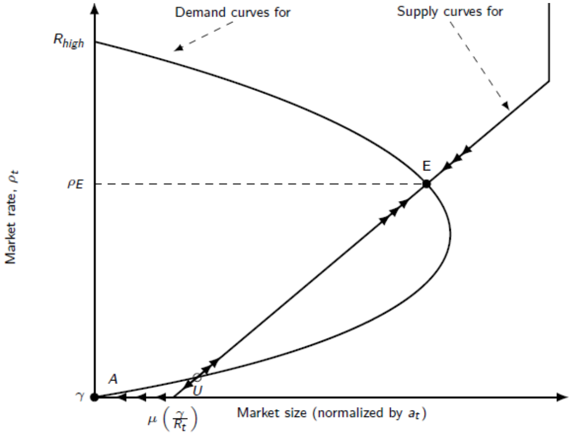
$$\overbrace{\mu\left(\overline{p}_t\right)}^{\text{Supply }(+)} = \overbrace{\underbrace{\left(1-\mu\left(\overline{p}_t\right)\right)}_{\text{"extensive margin" }(-)} \times \underbrace{\phi_t}_{\text{"intensive margin" }(+)}}^{\text{Demand bends backward }(+\text{ or }-)}$$



Two opposite effects on aggregate demand of a decrease in ρ_t

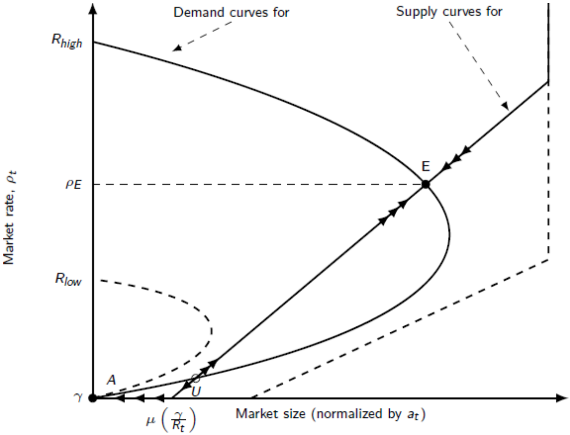
Interbank Market Equilibrium

Trade takes place when the corporate loan rate is high



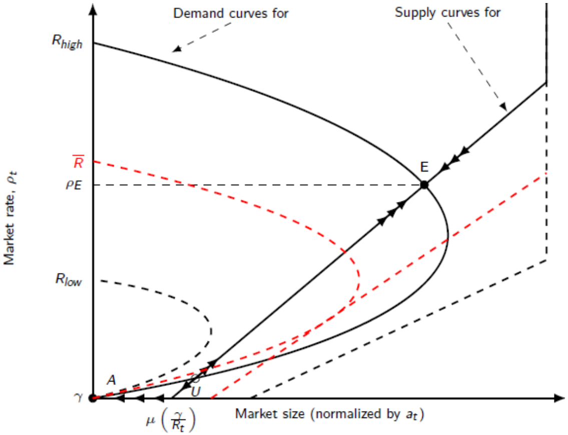
Interbank Market Equilibrium

Trade is impossible when the corporate loan rate is low



Interbank Market Equilibrium

Corporate loan rate threshold



The Banking Sector

Return on equity and corporate loan supply

- Return on equity:

$$r_t = \begin{cases} R_t \int_{\overline{p}_t}^{1} p \frac{\mathrm{d}\mu(p)}{1-\mu(\overline{p}_t)} & \text{, if an equilibrium with trade exists} \\ R_t \left(\frac{\gamma}{R_t} \mu\left(\frac{\gamma}{R_t}\right) + \int_{\frac{\gamma}{R_t}}^{1} p \, \mathrm{d}\mu\left(p\right) \right) & \text{, otherwise.} \end{cases}$$

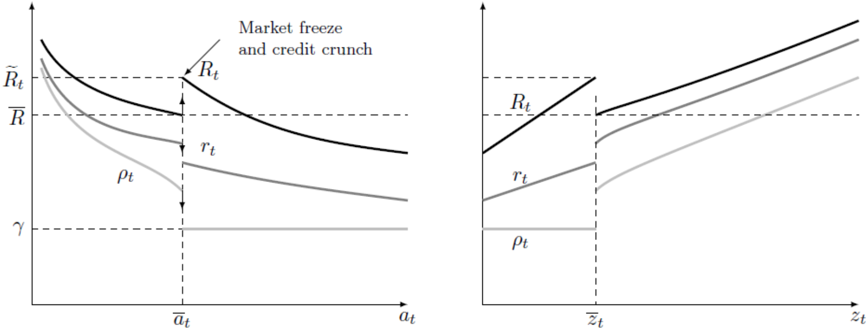
- Corporate loan supply

$$k_t^s = \begin{cases} a_t & \text{, if an equilibrium with trade exists} \\ \left(1 - \mu\left(\frac{\gamma}{R_t}\right)\right) a_t & \text{, otherwise} \end{cases}$$

- **Proposition 2 (Interbank loan market freeze):** *The interbank loan market is at work if and only if* $a_t \leqslant \bar{a}_t \equiv f_k^{-1}(\overline{R} + \delta - 1; z_t)$, *and freezes otherwise.*
- **Proposition 3 (Credit crunch):** *An interbank market freeze is accompanied with a sudden fall in the supply of corporate loans* k_t^s *(i.e. given* z_t, $\lim_{a_t \searrow \bar{a}_t} k_t^s < \lim_{a_t \nearrow \bar{a}_t} k_t^s$*), as well as by a sudden increase in the interest rate spread* R_t / r_t *(i.e. given* z_t, $\lim_{a_t \searrow \bar{a}_t} R_t / r_t > \lim_{a_t \nearrow \bar{a}_t} R_t / r_t$*).*

- Interbank market improves efficiency but freezes when $R_t < \overline{R}$
- In general equilibrium, R_t is driven by savings (a_t) and technology (z_t). Hence the interbank market freezes when $a_t > \overline{a}(z_t)$
- **Threshold $\overline{a}(\mathbf{z}_t)$ is the banking sector's "absorption capacity"**
- A measure of financial imbalances is $\overline{a}_t(z_t) - a_t$

Figure 4: Interest Rates



(a) Interest Rates vs Assets

(b) Interest Rates vs Technology Shock

The Banking Sector

Core and non–core liabilities

Bank balance sheets

Normal times

A	L
$(1+\phi_t)\,a_t$	a_t
	$\phi_t a_t$

$p \geqslant \overline{p}_t$

$\longleftarrow$

A	L
	a_t
a_t	

$p < \overline{p}_t$

Size is $a_t + (1-\mu(\overline{p}_t))\,\phi_t a_t$

Crisis times

A	L
a_t	a_t

$p \geqslant \frac{\gamma}{R_t}$

A	L
	a_t
a_t	

$p < \frac{\gamma}{R_t}$

Size is a_t

The Banking Sector

Two-way relationship between the retail and the wholesale loan markets

- Whether the interbank market is functioning depends on the corporate loan market equilibrium rate R_t^*
- R_t^* depends on whether the interbank market is functioning
- The model must be solved taking these interactions into account:
  1. Conjecture the interbank market operates and solve for R_t^*
  2. Verify whether indeed the internbank market operates ($R_t^* \geqslant \overline{R}$)
  3. In the negative, solve for R_t^* under a credit crunch

Quantitative Analysis
Calibration

- Production function: $F(k_t, h_t; z_t) \equiv z_t k_t^\alpha h_t^{1-\alpha}$ with $\alpha \in (0,1)$
- Utility function: $u(c_t, h_t) = \frac{1}{1-\sigma}\left(c_t - \vartheta \frac{h_t^{1+\upsilon}}{1+\upsilon}\right)^{1-\sigma}$
- Cdf of bank skills: $\mu(p) = p^\lambda$
- Real economy: standard calibration on US (annual) post–WWII data
- Financial sector $(\gamma, \theta, \lambda)$ is calibrated so that:
    - Crisis probability is 2.5%
    - Average interest rate spread is 1.71%
    - Average corporate loan rate of 4.35%

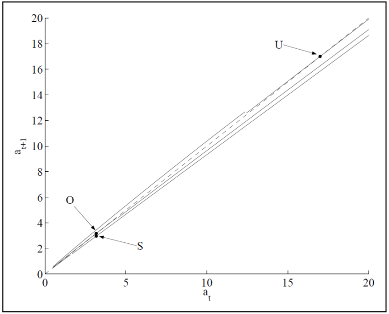
Parameters of the model

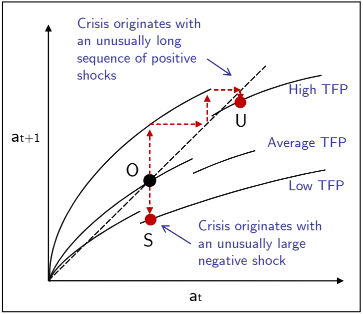
Discount factor	β	1/1.03
Risk aversion	σ	4.500
Frish elasticity	υ	1/3
Labor disutility	ϑ	0.944
Capital elasticity	α	0.300
Capital depreciation rate	δ	0.100
Standard dev. productivity shock	σ_z	0.018
Persistence of productivity shock	ρ_z	0.900
Bank distribution; $\mu(p) = p^\lambda$	λ	24
Diversion cost	θ	0.1
Storage technology	γ	0.936

- The model is solved numerically by a collocation method
- Discretize the TFP level (Tauchen and Hussey, 1991)
- Decision rule for a_{t+1} is approximated by a function of Chebychev polynomials
- The optimal decision rule is obtained as the fixed point solution to the Euler equation

Quantitative Analysis

Optimal savings rule: exogenous versus endogenous crises

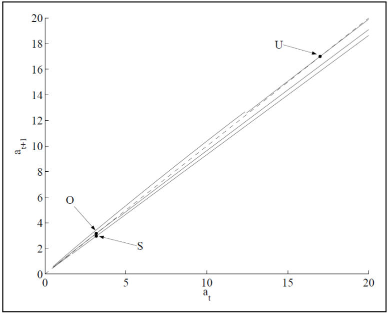


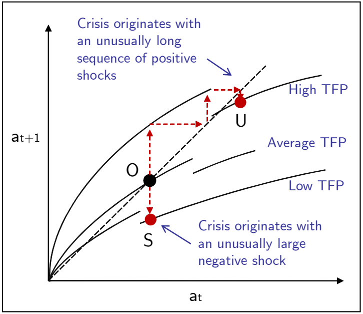


- Variety of crises: shock–driven (S) and credit boom–driven (U)

Quantitative Analysis

Optimal savings rule: exogenous versus endogenous crises





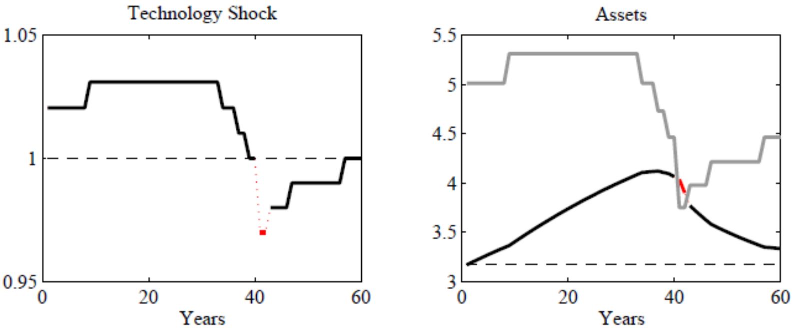
- Variety of crises: shock–driven (S) and credit boom–driven (U)
- History suggests that credit–boom driven crises prevail

Quantitative Analysis

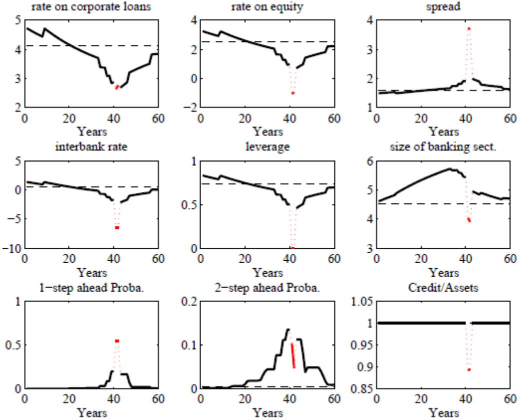
Intuition behind endogenous SBCs

1. At the beginning, a positive shock brings TFP above its mean
    - Credit demand rises. Return on savings goes up. The household accumulates assets for *consumption smoothing*
    - The **credit boom is initially demand–driven**
2. TFP goes down back to mean but remains above it for a long time
    - Credit demand decreases, while the household keeps on accumulating savings
    - The **credit boom becomes supply–driven**
3. The household accumulates assets for *precautionary motives*, which works to reduce interest rates and to raise further the likelihood of a crisis
4. A SBC breaks out as the corporate loan rate crosses its threshold

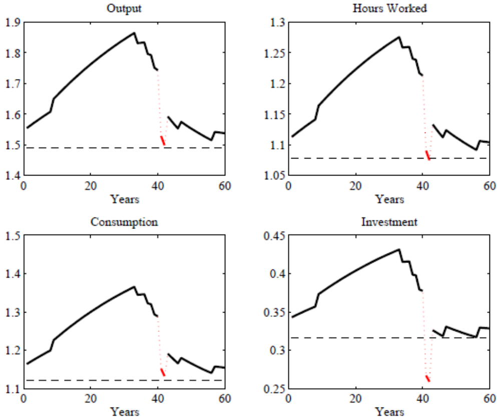
Typical path



Financial variables dynamics along typical path

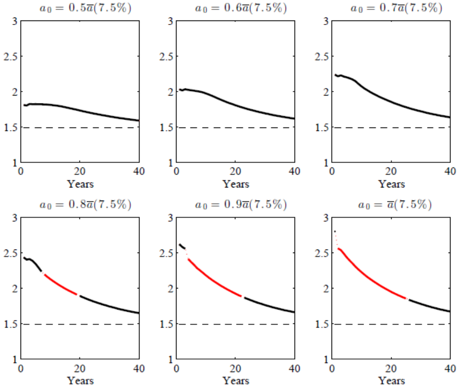


Real variables dynamics along typical path



Sensitivity of output dynamics to initial conditions

TFP is initially7.5% above mean



Dynamics in normal times, Dynamics in a systemic banking crisis, long–run average. $\overline{a}(7.5\%)$ denotes the banks' absorption when productivity is 7.5% above average

Sensitivity of credit dynamics to initial conditions

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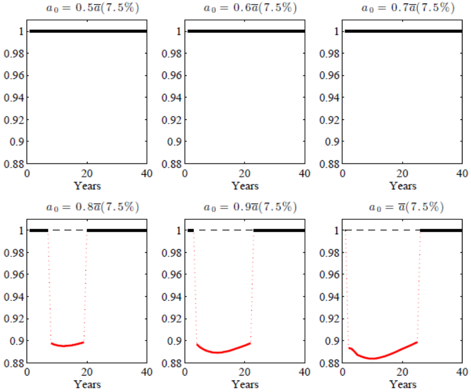

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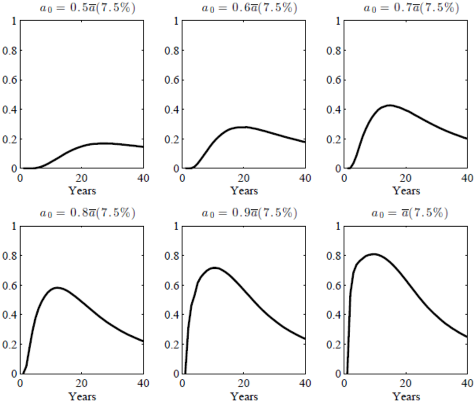
Sensitivity of the frequency of SBCs to initial conditions

TFP is initially7.5% above mean



This figure reports the evolution of the frequency of SBCs during the transition toward the average steady state.

Sensitivity of the frequency of SBCs to initial conditions

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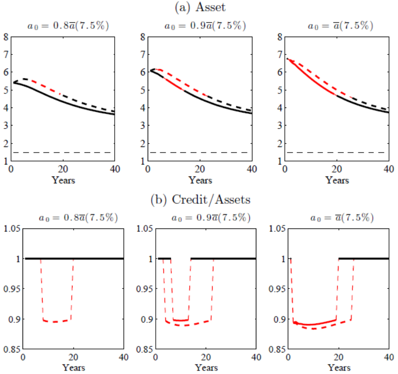


—— (- - - -) Dynamics in normal times in the Solow version (Benchmark Model), —— (- - - -) Dynamics in a systemic banking crisis in the Solow version (Benchmark Model), - - - - long–run average. $\overline{a}(7.5\%)$ denotes the banks' absorption when productivity is 7.5% above average.

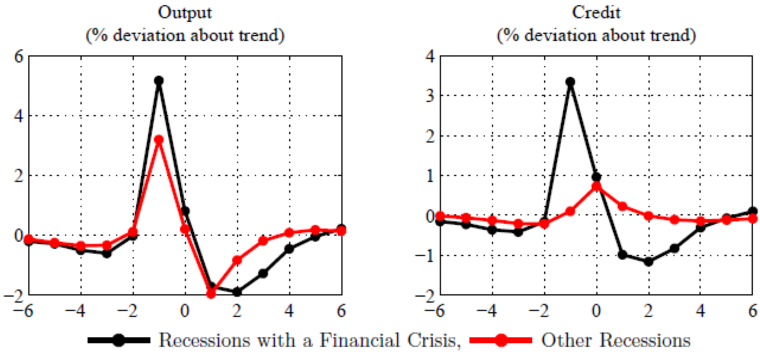
Quantitative Assessment

SBCs are rare and bring about deep and long recessions

Frequency, magnitude, and duration of systemic banking crises

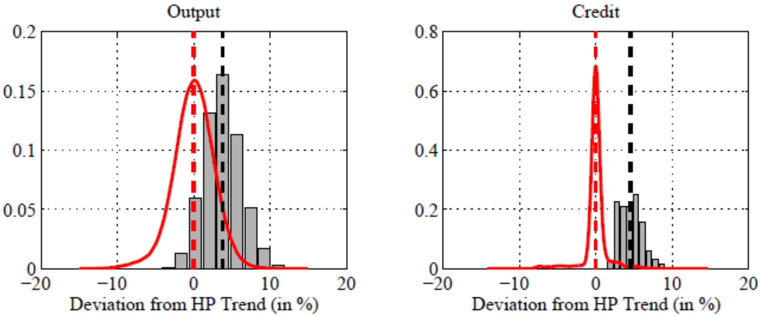
	Frequency (%)	Magnitude (%) from peak to trough	Duration (Years) from peak to trough
Systemic Banking Crises (SBC)	**2.69**	–	–
All recessions	10.00	12.08 (7.30)	2.08
Recessions with SBC (A)	13.00	**17.87** (10.50)	**2.62**
Recessions w/o SBC (B)	87.00	**10.04** (6.73)	**1.90**

Quantitative Assessment
SBCs follow credit booms

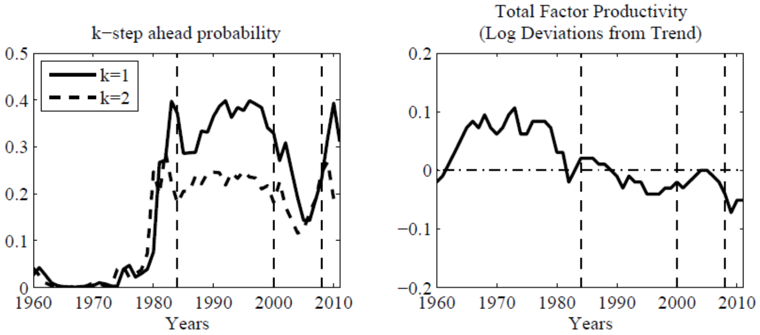


Quantitative Assessment

SBCs are not random



Crisis probabilities for the US



Note: The vertical thin dashed lines correspond to the 1984 Savings & Loans, the 2000 dotcom and 2008 crises.

Sensitivity Analysis

Changes in standard parameters

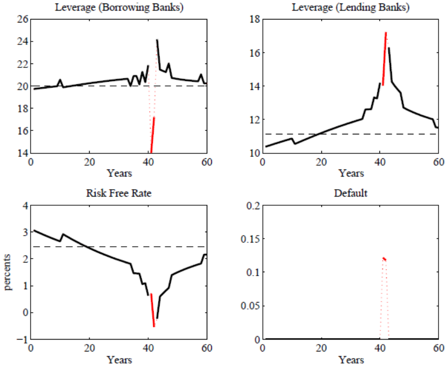
	Benchmark	σ 10	θ 0.20	λ 35	σ_z 0.02	ρ_z 0.95
interbank rate (ρ)	0.86	0.23	0.40	1.34	0.89	0.72
Corporate rate (R)	4.35	3.70	5.50	3.70	4.32	4.29
Return on deposit/equity (r)	2.64	1.61	2.61	2.67	2.55	2.59
Spread ($R - r$)	1.71	2.09	2.89	1.03	1.77	1.70
$\overline{R}$	2.43	2.43	4.83	0.41	2.43	2.43
Probability of a crisis	2.69	5.43	7.34	0.16	3.35	1.90
Average duration	2.62	4.08	5.06	1.87	2.82	2.92
Average amplitude	17.87	19.00	16.90	15.80	19.36	16.08

Bank Leverage, Bank Defaults

- Absent frictions between banks and household, bank leverage is undeterminate and bank default is not defined
- Two more assumptions to pin down leverage:
  - Bank deposits are safe assets (non state contingent return)
  - Bank managers are risk neutral (unlike household)
- One more assumption to introduce defaults:
  - Household (bank shareholder) has partial liability

Leverage and bank default dynamics along typical path

Figure 19: Typical Path: Leverage and Default



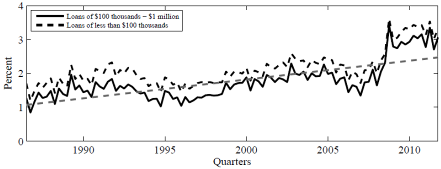
Dynamics in normal times, Dynamics in a systemic banking crisis, long–run average.

Concluding Remarks

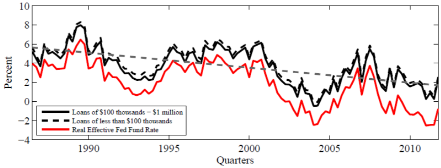
- Develop a simple DSGE model with SBCs
- SBCs are not caused by large, negative, financial shocks but rather by long sequences of small, positive, productivity shocks
- Highlight the role of financial imbalances, consumption smoothing, and precautionary savings
- From a policy making perspective:
  - Framework for both crisis management and crisis prevention
  - DSGE-based probability of a crisis

Figure C.4: Evolution of Various Corporate Loan Spreads

(a) Spread: Corporate loan rates - Federal Fund Rate



(b) Underlying Real Corporate Loan Rates



- - - - - Trend line.

The Model in a Nutshell

$$y_t = z_t k_t^{\alpha} h_t^{1-\alpha} + (\gamma + \delta - 1)(a_t - k_t)$$

$$R_t = \alpha k_t^{\frac{-\upsilon(1-\alpha)}{\upsilon+\alpha}} z_t^{\frac{1+\upsilon}{\upsilon+\alpha}} \left(\frac{1-\alpha}{\vartheta}\right)^{\frac{1-\alpha}{\upsilon+\alpha}} + 1 - \delta$$

$$\left(c_t - \vartheta \frac{h_t^{1+\upsilon}}{1+\upsilon}\right)^{-\sigma} = \beta \mathbb{E}_t \left[\left(c_{t+1} - \vartheta \frac{h_{t+1}^{1+\upsilon}}{1+\upsilon}\right)^{-\sigma} r_{t+1}\right]$$

$$h_t = \left(\frac{(1-\alpha) z_t}{\vartheta}\right)^{\frac{1}{\upsilon+\alpha}} k_t^{\frac{\alpha}{\upsilon+\alpha}}$$

$$\overline{a}_t \equiv \left((1-\alpha)/\vartheta\right)^{\frac{1}{\upsilon}} \left(\alpha / \left(\overline{R} + \delta - 1\right)\right)^{\frac{\upsilon+\alpha}{\upsilon(1-\alpha)}} z_t^{\frac{1+\upsilon}{\upsilon(1-\alpha)}}$$

$$i_t = a_{t+1} - (1-\delta) a_t$$

Normal times	*Crisis times*
$k_t = a_t$	$k_t = a_t - \mu(\gamma/R_t)\, a_t$
$\frac{r_t}{R_t} = \int_{\overline{p}_t}^{1} p \frac{\mathrm{d}\mu(p)}{1-\mu(\overline{p}_t)}$	$\frac{r_t}{R_t} = \frac{\gamma}{R_t}\mu(\gamma/R_t) + \int_{\gamma/R_t}^{1} p\, \mathrm{d}\mu(p)$
$\overline{p}_t = \frac{\rho_t}{R_t}$	$\overline{p}_t = \gamma/R_t$
$R_t = \frac{\rho_t}{\mu^{-1}\left(\frac{\rho_t - \gamma}{\rho_t - (1-\theta)\gamma}\right)}$	$\rho_t = \gamma$
$y_t = c_t + i_t + (R_t - r_t)\, a_t$	$y_t = c_t + i_t + (R_t - r_t)\, a_t - (R_t - \gamma)(a_t - k_t)$

The Banking Sector

A reduced form

- Interest rate spread:

$$R_t - r_t = \begin{cases} \Delta_t^n & \text{if } a_t \leqslant \bar{a}_t(z_t) \\ \Delta_t^c & \text{otherwise} \end{cases}, \text{ with } \Delta_t^c > \Delta_t^n > 0$$

- Credit crunch:

$$a_t - k_t = \begin{cases} \psi_t^n = 0 & \text{if } a_t \leqslant \bar{a}_t(z_t) \\ \psi_t^c > 0 & \text{otherwise} \end{cases}$$

- Notice that all this is micro-founded