

Booms and Systemic Banking Crises

F. Boissay, F. Collard and F. Smets

Second Conference of MaRS, Frankfurt, 30-31 October 2012

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

- 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):
 - Key Fact #1: SBCs are **rare events** – on average 1 every 40 years in OECD countries

- 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):
 - Key Fact #1: SBCs are **rare events** – on average 1 every 40 years in OECD countries
 - Key Fact #2: Recessions that follow SBCs are **deeper and last longer** – output loss during a SBC is 60% larger

- 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):
 - Key Fact #1: SBCs are **rare events** – on average 1 every 40 years in OECD countries
 - Key Fact #2: Recessions that follow SBCs are **deeper and last longer** – output loss during a SBC is 60% larger
 - Key Fact #3: SBCs are "**credit booms gone wrong**"

- In most DSGE models with financial frictions banking crises are big negative shocks amplified

- In most DSGE models with financial frictions banking crises are big negative shocks amplified
 - Can explain Key Facts #1 & #2

- In most DSGE models with financial frictions banking crises are big negative shocks amplified
 - Can explain Key Facts #1 & #2
 - **Cannot explain Key Fact #3** ← SBCs are not random

- In most DSGE models with financial frictions banking crises are big negative shocks amplified
 - Can explain Key Facts #1 & #2
 - **Cannot explain Key Fact #3** ← SBCs are not random
- Explaining Key Fact #3 requires to model the economic dynamics leading to SBCs

- In most DSGE models with financial frictions banking crises are big negative shocks amplified
 - Can explain Key Facts #1 & #2
 - **Cannot explain Key Fact #3** ← SBCs are not random
- Explaining Key Fact #3 requires to model the economic dynamics leading to SBCs
- From a policy perspective, our framework is a step forward towards:

- In most DSGE models with financial frictions banking crises are big negative shocks amplified
 - Can explain Key Facts #1 & #2
 - **Cannot explain Key Fact #3** ← SBCs are not random
- Explaining Key Fact #3 requires to model the economic dynamics leading to SBCs
- From a policy perspective, our framework is a step forward towards:
 - **DSGE-based crisis prevention policy analysis**

- In most DSGE models with financial frictions banking crises are big negative shocks amplified
 - Can explain Key Facts #1 & #2
 - **Cannot explain Key Fact #3** ← SBCs are not random
- Explaining Key Fact #3 requires to model the economic dynamics leading to SBCs
- From a policy perspective, our framework is a step forward towards:
 - DSGE-based crisis prevention policy analysis
 - **DSGE-based early warning signals**

Stylized facts

SBCs are rare and bring about deep and long recessions

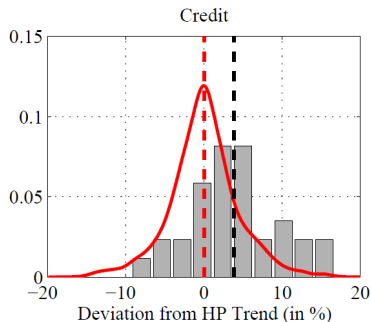
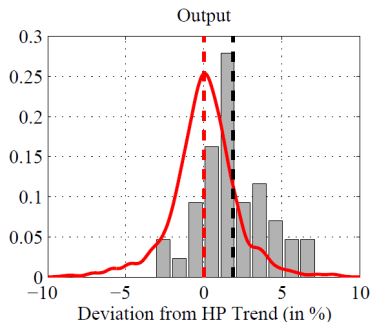
Frequency, magnitude, and duration of systemic banking crises

	Frequency (%)	Magnitude (%) from peak to trough	Duration (Years)
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 $A \neq B$, 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; they are not random



- 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 and feedback 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

Main Results

- 1 Model features a (small) financial accelerator in normal times; calibrated to generate financial crises every 40 years
- 2 The **typical banking crisis follows upon an unusually long sequence of small, positive, transitory productivity shocks** —
Not a large negative financial shock

Main Results

- 1 Model features a (small) financial accelerator in normal times; calibrated to generate financial crises every 40 years
- 2 The **typical banking crisis follows upon an unusually long sequence of small, positive, transitory productivity shocks** — Not a large negative financial shock
- 3 SBCs follow credit booms. They occur when the banking sector grows too big relative to its absorption capacity, and when real interest rates are too low

Main Results

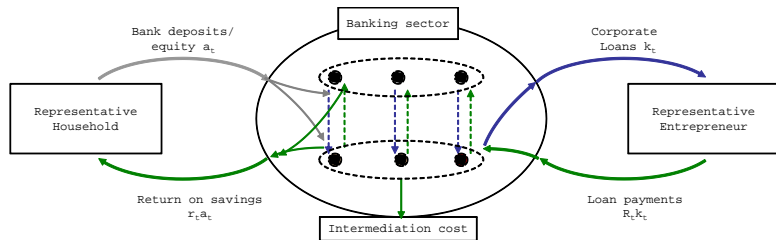
- 1 Model features a (small) financial accelerator in normal times; calibrated to generate financial crises every 40 years
- 2 The **typical banking crisis follows upon an unusually long sequence of small, positive, transitory productivity shocks** — Not a large negative financial shock
- 3 SBCs follow credit booms. They occur when the banking sector grows too big relative to its absorption capacity, and when real interest rates are too low
- 4 **SBCs may occur without shock happening at the same time**

Main Results

- 1 Model features a (small) financial accelerator in normal times; calibrated to generate financial crises every 40 years
- 2 The **typical banking crisis follows upon an unusually long sequence of small, positive, transitory productivity shocks** — Not a large negative financial shock
- 3 SBCs follow credit booms. They occur when the banking sector grows too big relative to its absorption capacity, and when real interest rates are too low
- 4 SBCs may occur without shock happening at the same time
- 5 SBCs bring about recessions that are deeper and last longer than other recessions because they also come with a credit crunch. The likelihood, depth, and length of these recessions increase with the intensity of the credit boom that precedes it

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:

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

subject to budget constraint

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

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

The Banking Sector

A reduced form

- Interest rate spread:

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

- Credit crunch:

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

- Notice that all this is micro-founded

The Banking Sector

Intuition (I)

- Banks face bank specific intermediation costs
- In normal times, inefficient banks lend to efficient banks
- In crisis times, banks do not trust/lend to each other
 - Even inefficient banks do the intermediation → higher spread
 - The least efficient banks do not intermediate and store → credit crunch

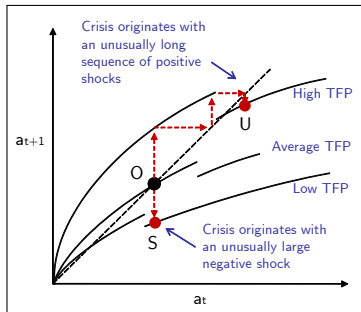
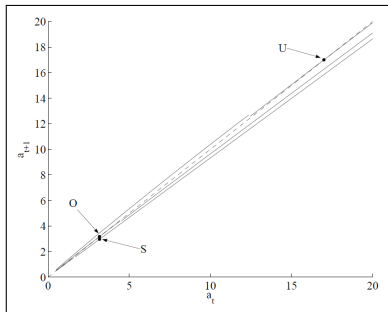
The Banking Sector

Intuition (II)

- The interbank market freezes when banks have too much incentives to misbehave, which happens when the corporate loan rate is "too low", i.e:
 - when $R_t < \bar{R}$
 - when $a_t > \bar{a}_t(z_t)$
- Threshold $\bar{a}_t(z_t)$ is the banking sector's "absorption capacity"
- A measure of financial imbalances is $\bar{a}_t(z_t) - a_t$

Quantitative Analysis

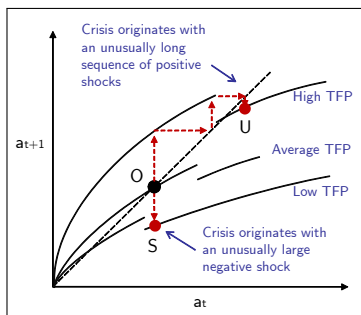
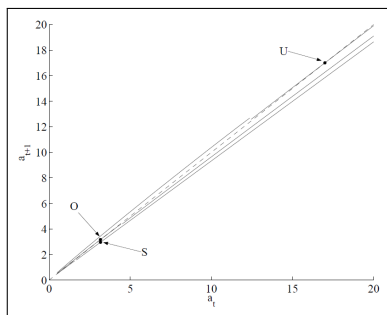
Optimal savings rule: exogenous versus endogenous crises



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

Quantitative Analysis

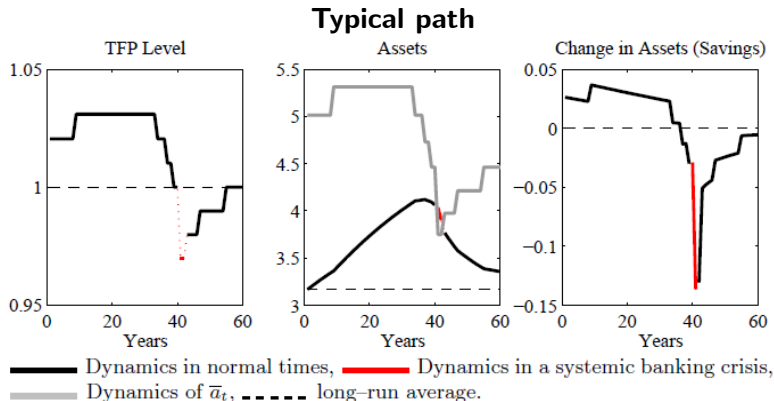
Optimal savings rule: exogenous versus endogenous crises



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

Quantitative Analysis

Typical path to crisis

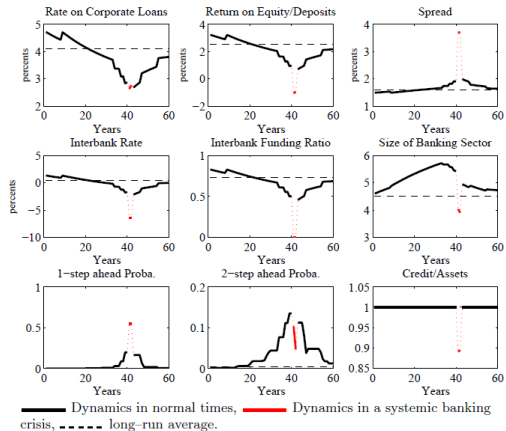


Quantitative Analysis

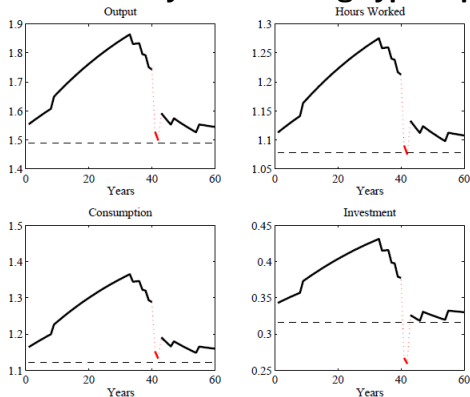
Intuition behind credit boom–driven SBCs

- 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**, interest rates go down
- 3 As the probability of a crisis increases, the household accumulates assets for *precautionary motives*, which works to reduce interest rates and to raise the likelihood of a crisis even further
- 4 A SBC breaks out as the corporate loan R_t rate crosses its threshold \bar{R}

Financial variables dynamics along typical path



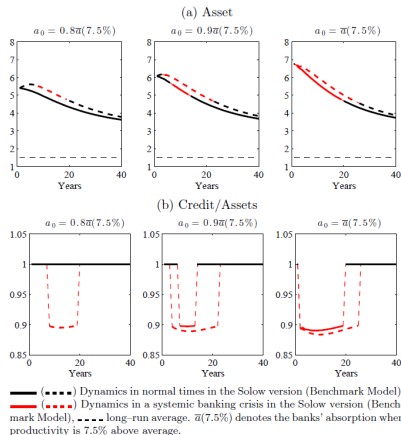
Real variables dynamics along typical path



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

Comparison with a Solow framework

TFP is initially 7.5% above mean



Quantitative Assessment

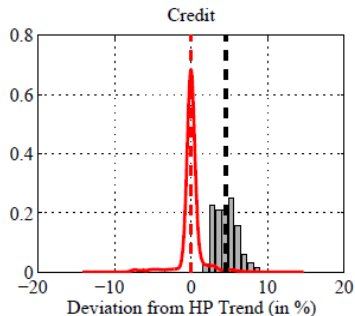
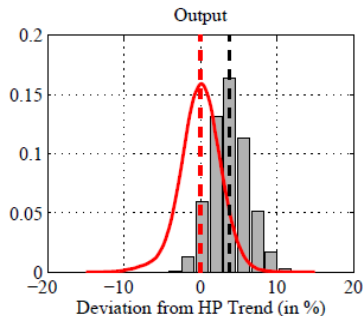
SBCs are rare and bring about deep and long recessions

Frequency, magnitude, and duration of systemic banking crises

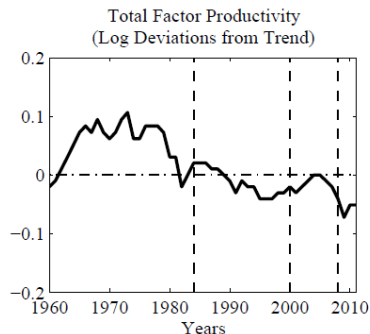
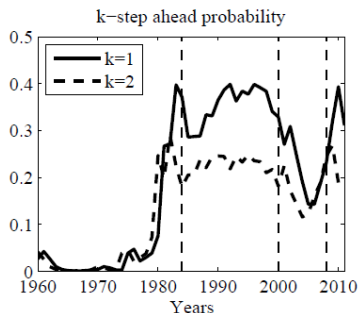
	Frequency (%)	Magnitude (%) from peak to trough	Duration (Years)
Systemic Banking Crises (SBC)	2.69	–	–
All recessions	10.00	12.08 (7.30)	2.08
Recessions with SBC (A)	13.00	17.87 (10.50)	2.62
Recessions w/o SBC (B)	87.00	10.04 (6.73)	1.90

Quantitative Assessment

SBCs follow credit booms ; they are not random



Crisis probabilities for the US



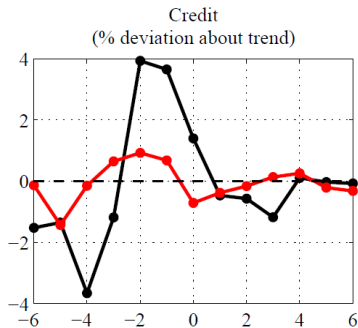
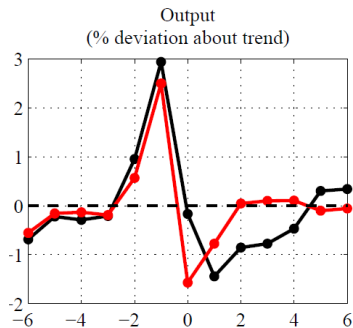
Note: The vertical thin dashed lines correspond to the 1984 Savings & Loans, the 2000 dotcom and 2008 crises.

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

Stylized facts

SBCs follow credit booms



—●— Recessions with a Financial Crisis, —●— Other Recessions

Quantitative Assessment

SBCs follow credit booms

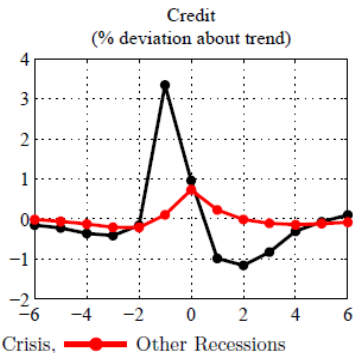
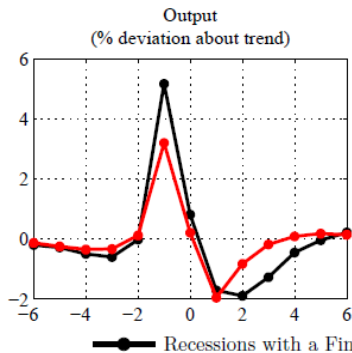
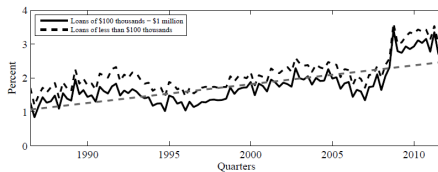
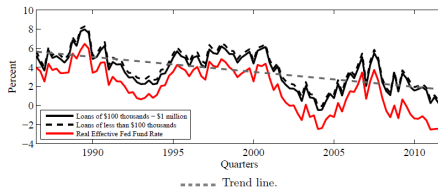


Figure C.4: Evolution of Various Corporate Loan Spreads

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



(b) Underlying Real Corporate Loan Rates



The Model in a Nutshell

$$\begin{aligned}
 y_t &= z_t k_t^\alpha h_t^{1-\alpha} + (\gamma + \delta - 1) (a_t - k_t) \\
 R_t &= \alpha k_t^{\frac{-v(1-\alpha)}{v+\alpha}} z_t^{\frac{1+v}{v+\alpha}} \left(\frac{1-\alpha}{\vartheta} \right)^{\frac{1-\alpha}{v+\alpha}} + 1 - \delta \\
 \left(c_t - \vartheta \frac{h_t^{1+v}}{1+v} \right)^{-\sigma} &= \beta \mathbb{E}_t \left[\left(c_{t+1} - \vartheta \frac{h_{t+1}^{1+v}}{1+v} \right)^{-\sigma} r_{t+1} \right] \\
 h_t &= \left(\frac{(1-\alpha)z_t}{\vartheta} \right)^{\frac{1}{v+\alpha}} k_t^{\frac{\alpha}{v+\alpha}} \\
 \bar{a}_t &\equiv \left((1-\alpha)/\vartheta \right)^{\frac{1}{v}} \left(\alpha / (\bar{R} + \delta - 1) \right)^{\frac{v+\alpha}{v(1-\alpha)}} z_t^{\frac{1+v}{v(1-\alpha)}} \\
 i_t &= a_{t+1} - (1-\delta) a_t
 \end{aligned}$$

Normal times

$$\begin{aligned}
 k_t &= a_t \\
 \frac{r_t}{R_t} &= \int_{\bar{p}_t}^1 p \frac{d\mu(p)}{1-\mu(\bar{p}_t)} \\
 \bar{p}_t &= \frac{\rho_t}{R_t} \\
 R_t &= \frac{\rho_t}{\mu^{-1}\left(\frac{\rho_t - \gamma}{\rho_t - (1-\theta)\gamma}\right)} \\
 y_t &= c_t + i_t + (R_t - r_t) a_t
 \end{aligned}$$

Crisis times

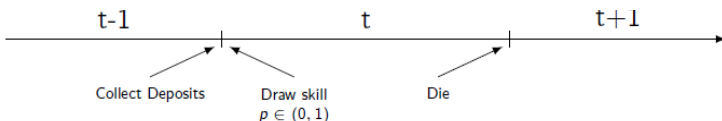
$$\begin{aligned}
 k_t &= a_t - \mu(\gamma/R_t) a_t \\
 \frac{r_t}{R_t} &= \frac{\gamma}{R_t} \mu(\gamma/R_t) + \int_{\gamma/R_t}^1 p d\mu(p) \\
 \bar{p}_t &= \gamma/R_t \\
 \rho_t &= \gamma \\
 y_t &= c_t + i_t + (R_t - r_t) a_t - (R_t - \gamma) (a_t - k_t)
 \end{aligned}$$

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

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

The Banking Sector

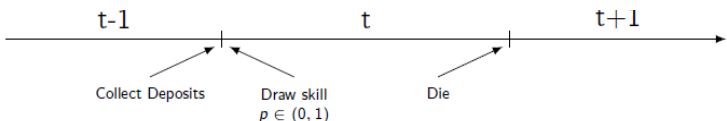
- Banks are atomistic, competitive, and price takers
- Heterogeneous 1-period banks



- 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:

The Banking Sector

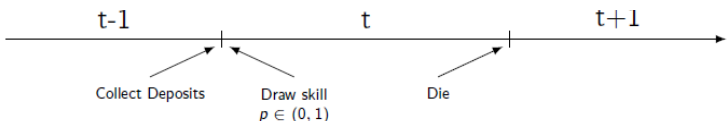
- Banks are atomistic, competitive, and price takers
- Heterogeneous 1-period banks



- 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:
 - **Asymmetric information:** p is private information

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:
 - **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 $\implies \rho_t$
 2. Store goods $\implies \gamma$
 3. Raise funds ϕ_t from market and lend to firm $\implies pR_t(1 + \phi_t)$
 4. Raise funds ϕ_t from market and walk away $\implies \gamma(1 + \theta\phi_t)$
- 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:

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

$$PC: \quad pR_t(1 + \phi_t) - \rho_t\phi_t \geq \rho_t \quad \Rightarrow \quad p \geq \bar{p}_t \equiv \rho_t/R_t$$

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

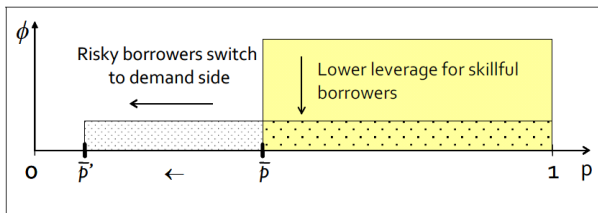
- Profits are fully distributed to household: $r_t \equiv \int_0^1 r_t(p) d\mu(p)$

Interbank Market Equilibrium

Interbank market clearing condition

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

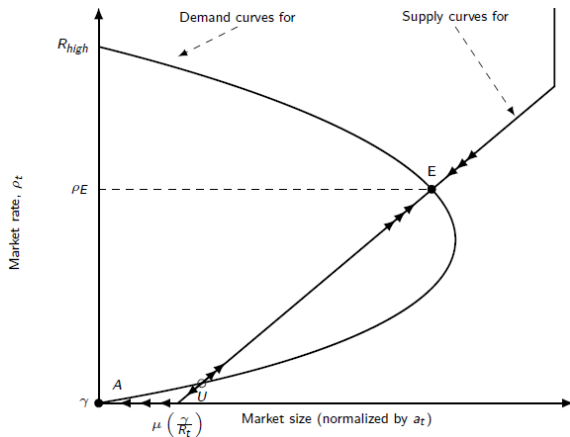
with $\bar{p}_t \equiv \rho_t / R_t$ and $\phi_t = (\rho_t - \gamma) / \theta\gamma$



Two opposite effects on aggregate demand of a decrease in ρ_t

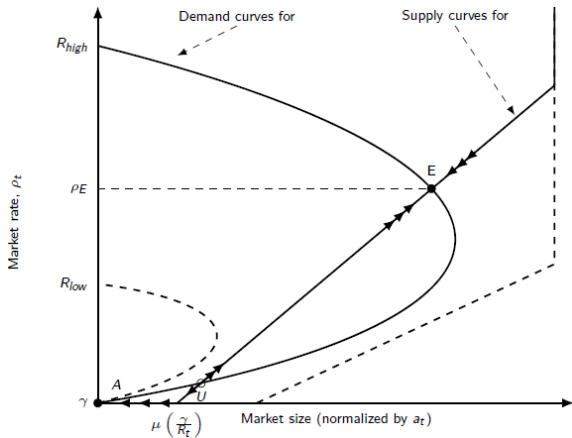
Interbank Market Equilibrium

Trade takes place when the corporate loan rate is high



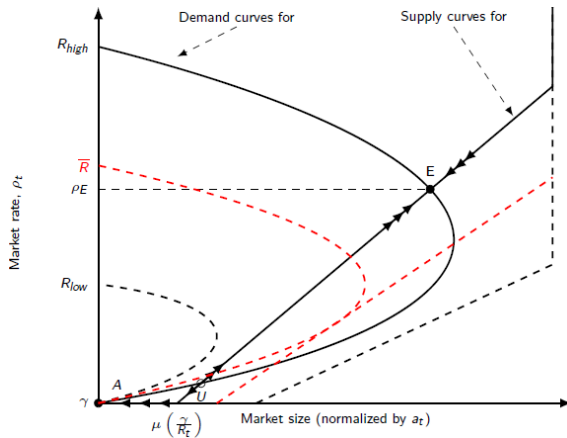
Interbank Market Equilibrium

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:

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

- Corporate loan supply

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

The Banking Sector

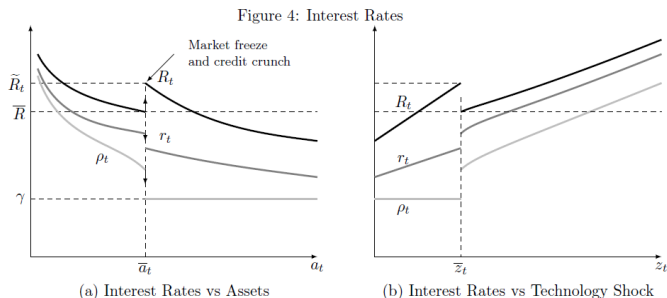
Absorption capacity and financial imbalances

- **Proposition 2 (Interbank loan market freeze):** *The interbank loan market is at work if and only if $a_t \leq \bar{a}_t \equiv f_k^{-1}(\bar{R} + \delta - 1; z_t)$, and freezes otherwise.*
- The interbank market improves efficiency but freezes when $R_t < \bar{R}$
- In general equilibrium, R_t is driven by savings (a_t) and technology (z_t). Hence the interbank market freezes when $a_t > \bar{a}(z_t)$
- **Threshold $\bar{a}(z_t)$ is the banking sector's "absorption capacity"**
- A measure of financial imbalances is $\bar{a}_t(z_t) - a_t$

The Banking Sector

Crisis and credit crunch

- **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 , $\lim_{a_t \searrow \bar{a}_t} R_t/r_t > \lim_{a_t \nearrow \bar{a}_t} R_t/r_t$).*



The Banking Sector

Core and non-core liabilities

Bank balance sheets

<i>Normal times</i>				<i>Crisis times</i>			
A	L	A	L	A	L	A	L
$(1 + \phi_t) a_t$	a_t	a_t	a_t	a_t	a_t	a_t	a_t
$p \geq \bar{p}_t$	$\phi_t a_t$	a_t	$p < \bar{p}_t$	$p \geq \frac{\gamma}{R_t}$	$\frac{\gamma}{R_t}$	$p < \frac{\gamma}{R_t}$	$\frac{\gamma}{R_t}$

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

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 interbank market operates ($R_t^* \geq \bar{R}$)
 - 3 In the negative, solve for R_t^* under a credit crunch

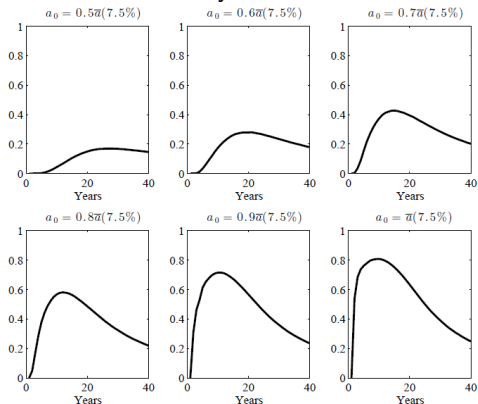
Quantitative Analysis

Solution method

- 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

Sensitivity of the frequency of SBCs to initial conditions

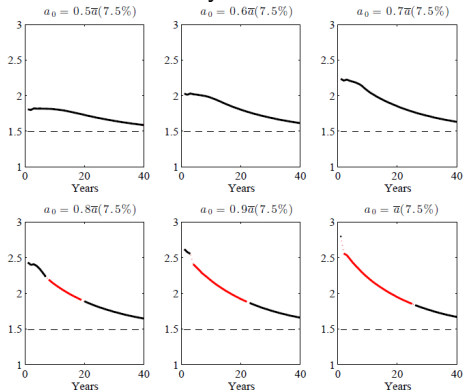
TFP is initially 7.5% above mean



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

Sensitivity of output dynamics to initial conditions

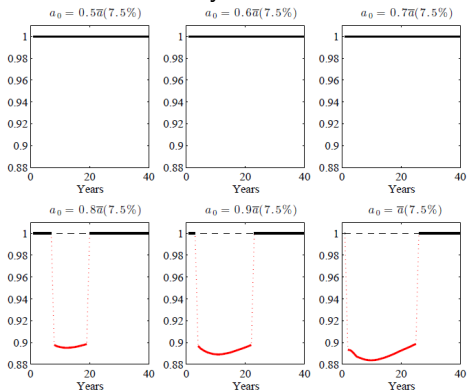
TFP is initially 7.5% above mean



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

Sensitivity of credit dynamics to initial conditions

TFP is initially 7.5% above mean



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

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
\bar{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 undetermined 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

Bank Leverage, Bank Defaults

Typical path to crisis

Leverage and bank default dynamics along typical path

Figure 19: Typical Path: Leverage and Default

