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)
- A few features are common to SBCs (e.g. Reinhart and Rogoff 2009; Jordà et al., 2011; Claessens et al., 2011; Schularick and Taylor, 2012):
  - Fact #1: SBCs are *rare events*
Better understand the joint dynamics of regular business cycles and systemic banking crises (SBCs)

A few features are common to SBCs (e.g. Reinhart and Rogoff 2009; Jordà et al., 2011; Claessens et al., 2011; Schularick and Taylor, 2012):

- Fact #1: SBCs are rare events
- Fact #2: Recessions that follow SBCs are deeper and last longer
**Stylized facts**

SBCs are rare and bring about deep and long recessions

### Frequency, magnitude, and duration of systemic banking crises

<table>
<thead>
<tr>
<th></th>
<th>Frequency (%)</th>
<th>Magnitude (%)</th>
<th>Duration (Years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Systemic Banking Crises (SBC)</td>
<td>2.42</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Financial recessions (with SBC)</td>
<td>6.74</td>
<td>2.59</td>
<td></td>
</tr>
<tr>
<td>Other recessions (w/o SBC)</td>
<td>4.27</td>
<td>1.61</td>
<td></td>
</tr>
</tbody>
</table>

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

Crises defined as in Laeven and Valencia (2008)
Motivation/Objective

Better understand the joint dynamics of regular business cycles and systemic banking crises (SBCs)

A few features are common to SBCs (e.g. Claessens et al., 2011):

- Fact #1: SBCs are rare events
- Fact #2: Recessions that follow SBCs are deeper and last longer
- Fact #3: SBCs are "credit booms gone wrong"
Stylized facts
SBCs follow credit booms

Distribution of GDP and credit gaps on average (red line) and around SBCs (bars)
Stylized facts
Financial recessions are different from other severe recessions

Prediction of financial recessions

<table>
<thead>
<tr>
<th></th>
<th>Banking crisis</th>
<th>all</th>
<th>Recession financial</th>
<th>Recession severe</th>
</tr>
</thead>
<tbody>
<tr>
<td>$L.\Delta \log (\text{loans/P})$</td>
<td>1.544 (2.081)</td>
<td>-3.963** (1.606)</td>
<td>-2.253 (2.975)</td>
<td>-2.901 (2.780)</td>
</tr>
<tr>
<td>$L2.\Delta \log (\text{loans/P})$</td>
<td>8.571*** (2.403)</td>
<td>2.568 (1.608)</td>
<td>10.363*** (2.413)</td>
<td>0.439 (2.900)</td>
</tr>
<tr>
<td>$L3.\Delta \log (\text{loans/P})$</td>
<td>3.114 (2.347)</td>
<td>1.527 (1.583)</td>
<td>5.428** (2.382)</td>
<td>3.020 (2.854)</td>
</tr>
<tr>
<td>$L4.\Delta \log (\text{loans/P})$</td>
<td>2.555* (1.441)</td>
<td>3.772** (1.770)</td>
<td>0.748 (2.466)</td>
<td>3.751 (2.910)</td>
</tr>
<tr>
<td>$L5.\Delta \log (\text{loans/P})$</td>
<td>3.539** (1.555)</td>
<td>-3.696*** (1.372)</td>
<td>1.105 (2.306)</td>
<td>-6.976** (2.753)</td>
</tr>
<tr>
<td>$L1/5.\Delta \log (\text{GDP/P})$</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Country fixed effects</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>N. obs</td>
<td>1,272</td>
<td>1,272</td>
<td>1,272</td>
<td>1,078</td>
</tr>
<tr>
<td>N. groups</td>
<td>14</td>
<td>14</td>
<td>14</td>
<td>12</td>
</tr>
<tr>
<td>N. events</td>
<td>78</td>
<td>196</td>
<td>41</td>
<td>58</td>
</tr>
<tr>
<td>Sum of lag coefficients</td>
<td>19.322***</td>
<td>0.208</td>
<td>15.391***</td>
<td>-2.668</td>
</tr>
<tr>
<td>Standard error</td>
<td>4.329</td>
<td>3.057</td>
<td>5.736</td>
<td>5.420</td>
</tr>
<tr>
<td>Pseudo $R^2$</td>
<td>0.123</td>
<td>0.053</td>
<td>0.127</td>
<td>0.099</td>
</tr>
</tbody>
</table>
In most DSGE models with financial frictions banking crises are big negative shocks amplified

- Can explain Facts #1 & #2
- **Cannot explain Key Fact #3** → SBCs are not random

To explain Fact #3 one needs to model the dynamics leading to SBCs
Our Framework

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

1. Normal times feature productivity–driven business cycles with a small financial accelerator; model calibrated to generate SBCs every 40 years.

2. The typical banking crisis follows an unusually long sequence of small, positive, transitory productivity shocks. No need for a large negative financial shock: crises may even occur without a shock happening at the same time.

3. High productivity generates a credit boom and a ballooning banking sector; as productivity peters out, a savings glut arises; interest rates fall, bank risk-taking and counterparty fears rise, which may lead to a freeze of the interbank market.

4. Financial imbalances (size of the banking sector relative to GDP) predict SBCs.

5. SBCs bring about deeper and longer lasting recessions because of a credit crunch.
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Related literature

  - 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
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:**

\[
\max \left\{ a_{t+1}, c_{t+1}, h_{t+1} \right\}_t \to^\infty \mathbb{E}_t \sum_{\tau=0}^\infty \beta^\tau u(c_{t+\tau}, h_{t+\tau})
\]

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)
Banks are atomistic, competitive, and price takers

Continuum of heterogeneous 1–period banks \( p \), with cdf \( \mu(p) \) over \((0, 1)\)

Bank \( p \)'s net return per unit of corporate loan is \( pR_t \)

It is beneficial to relocate funds, but relocation is impaired due to:

- Asymmetric information: \( p \) is private information
- Moral hazard: bank \( p \) may borrow \( \phi_t \) and walk away (“diversion”)
The Banking Sector

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  - **Asymmetric information**: \( p \) is private information
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The Banking Sector

- Bank $p$ has 4 options:
  1. Lend to other banks on the interbank market $\implies \rho_t$
  2. Store goods $\implies \gamma$
  3. Raise funds $\phi_t$ from interbank market and lend to firm $\implies pR_t (1 + \phi_t) - \rho_t \phi_t$
  4. Raise funds $\phi_t$ from interbank market and walk away $\implies \gamma (1 + \theta \phi_t)$

Incentives to divert depend on the corporate loan rate: the lower $R_t$, the higher these incentives, and the more counterparty fears on the interbank market.
Borrowing bank $p$ solves:

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

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

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

- 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

Supply ($+$)

\[ \mu(\bar{p}_t) = \frac{(1 - \mu(\bar{p}_t))}{\phi_t} \]

Demand bends backward ($+$ or $-$)

"extensive margin" ($-$)  "intensive margin" ($+$)

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

The interbank market freezes when the retail corporate loan rate is below a threshold.
Interbank Market Equilibrium
The interbank market freezes when the retail corporate loan rate is below a threshold.
Interbank Market Equilibrium

The interbank market freezes when the retail corporate loan rate is below a threshold.
Return on Deposits and Corporate Loan Supply

- Return on deposits:

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

- Corporate loan supply

\[
k_t^s = \begin{cases} 
a_t, & \text{if an equilibrium with trade exists} \\
\left( 1 - \mu \left( \frac{\gamma}{R_t} \right) \right) a_t, & \text{otherwise}
\end{cases}
\]
Proposition 2 (Interbank loan market freeze): The interbank trades exist if and only if \( a_t \leq \bar{a}_t \equiv f_k^{-1}(\bar{R} + \delta - 1; z_t) \); the interbank market 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 \( \bar{a}_t(z_t) - a_t \)
Calibration of the real side is most standard.

Financial sector ($\gamma$, $\theta$, $\mu(.)$) is calibrated so that:
- Crisis probability is 2.5%.
- Average interest rate spread is 1.71%.
- Average corporate loan rate of 4.35%.

The model is solved numerically by a collocation method.
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

Typical (median) path

- **TFP Level (Log.)**
  - Dynamics in normal times,
  - Dynamics in a systemic banking crisis,
  - Dynamics of $\bar{a}_t$,
  - Long-run average,
  - Dynamics in the constrained efficient Central Planner Allocation,
  - 66% Confidence Band.

- **Assets**

- **Saving Rate**
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 threshold $\bar{R}$
Selected dynamics along the typical path

- Output
- Hours Worked
- Consumption
- Investment
Selected dynamics along the typical path
Quantitative Assessment

SBCs are rare and bring about deep and long recessions

Frequency, magnitude, and duration of systemic banking crises

<table>
<thead>
<tr>
<th></th>
<th>Frequency (%)</th>
<th>Magnitude (%) from peak to trough</th>
<th>Duration (Years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Systemic Banking Crises (SBC)</td>
<td>2.69</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Recessions with SBC</td>
<td>17.87</td>
<td></td>
<td>2.62</td>
</tr>
<tr>
<td>Recessions w/o SBC</td>
<td>10.04</td>
<td></td>
<td>1.90</td>
</tr>
</tbody>
</table>
Quantitative Assessment
SBCs follow credit booms

Distribution of GDP and Credit gaps on average (red line) and around SBCs (bars)

Before a SBC, Full sample, Mean (Before a SBC), Mean (Full Sample)
Concluding Remarks

- Simple DSGE model with SBCs, where SBCs are not caused by large, negative, financial shocks but rather by long sequences of small, positive, productivity shocks.
- Not all credit booms lead to crises; only supply–driven credit booms do.
- Highlight the role in the build-up of financial imbalances of:
  - savings gluts; here consumption smoothing and precautionary savings
  - the size of the banking sector relative to the real economy (≈ "hidden" leverage)
- From a policy making perspective:
  - Framework for both crisis management and crisis prevention
  - DSGE-based probability of a crisis
THANK YOU
Stylized facts
SBCs follow credit booms; they last longer

![Graphs showing output and credit deviation during recessions with and without financial crises.](image-url)
Quantitative Assessment

SBCs follow credit booms; they last longer

![Graphs showing output and credit deviations](image-url)
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 $z_t$, $\lim_{a_t \to a_t} k_t^s < \lim_{a_t \to a_t} k_t^s$), as well as by a sudden increase in the interest rate spread $R_t / r_t$ (i.e. given $z_t$, $\lim_{a_t \to a_t} R_t / r_t > \lim_{a_t \to a_t} R_t / r_t$).
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 is solved taking these interactions into account.
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: \( u(c_t, h_t) = \frac{1}{1-\sigma} \left( c_t - \theta \frac{h_t^{1+v}}{1+v} \right)^{1-\sigma} \)
- 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

**Table 1: Calibration**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Growth Adj. Discount factor</td>
<td>$\beta$ 1/1.03</td>
</tr>
<tr>
<td>Inverse of Frish elasticity</td>
<td>$\nu$ 0.500</td>
</tr>
<tr>
<td>Labor disutility</td>
<td>$\vartheta$ 0.944z</td>
</tr>
<tr>
<td>Risk aversion</td>
<td>$\sigma$ 4.500</td>
</tr>
<tr>
<td>Capital elasticity</td>
<td>$\alpha$ 0.300</td>
</tr>
<tr>
<td>Capital depreciation rate</td>
<td>$\delta$ 0.100</td>
</tr>
<tr>
<td>Growth Factor</td>
<td>$\psi$ 1.012</td>
</tr>
<tr>
<td>Standard dev. productivity shock</td>
<td>$\sigma_z$ 0.0177</td>
</tr>
<tr>
<td>Persistence of productivity shock</td>
<td>$\rho_z$ 0.900</td>
</tr>
<tr>
<td>Bank distribution; $\mu(p) = p^\lambda$</td>
<td>$\lambda$ 25.000</td>
</tr>
<tr>
<td>Diversion cost</td>
<td>$\theta$ 0.100</td>
</tr>
<tr>
<td>Storage technology</td>
<td>$\gamma$ 0.939</td>
</tr>
</tbody>
</table>
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.
IRF to a one-standard deviation TFP shock
Quantitative Analysis

Exogenous versus endogenous factors?

Distributions of percentage deviations before a SBC

Note: The figure above shows ergodic cumulative distributions. Panels (a) and (b) show $P(\Delta x_{T-k} \geq \zeta)$ in the case of positive percentage deviations $\zeta$ (x-axis, right hand side) from average steady state, and $P(\Delta x_{T-k} \leq -\zeta)$ in the case of negative deviations $-\zeta$ (x-axis, left hand side), where $\Delta x_{T-k} = \log(x_{T-k}) - \log(\bar{x})$, $T$ is the date of the crisis, $\bar{x}$ is the average steady state of variable $x$ calculated over our 500,000 simulations, and $x$ is the logarithm of TFP or credit/output ratio. Panel (c) shows the probability that the level of assets $k$ periods before the crisis be less than $\zeta$% away from the absorption capacity of the banking sector, $P(\Delta a_{T-k} \leq \zeta)$, with $\Delta a_{T-k} = \log(\bar{a}_{T-k}) - \log(a_{T-k})$. 

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Boissay - Collard - Smets
Booms and Systemic Banking Crises
ESSIM2013
Typical path to crisis with a constant savings rate (Solow)

- Dynamics in normal times,
- Dynamics in a systemic banking crisis,
- Dynamics of $\bar{a}_t$, long-run average,
- 66% Confidence Band.
Quantitative Analysis
The role of savings behavior

Saving rates: Consumption smoothing versus precautionary motives
Quantitative Assessment
Early Warning Signals

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

<table>
<thead>
<tr>
<th>Benchmark</th>
<th>( \sigma ) (2)</th>
<th>( \nu ) (10)</th>
<th>( \nu ) (0.25)</th>
<th>( \nu ) (1)</th>
<th>( \theta ) (0.20)</th>
<th>( \lambda ) (35)</th>
<th>( \sigma_z ) (0.02)</th>
<th>( \rho_z ) (0.95)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Returns:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interbank (( \rho ))</td>
<td>0.86</td>
<td>1.04</td>
<td>0.23</td>
<td>0.84</td>
<td>0.83</td>
<td>0.40</td>
<td>1.34</td>
<td>0.89</td>
</tr>
<tr>
<td>Corporate (( R ))</td>
<td>4.35</td>
<td>4.55</td>
<td>3.70</td>
<td>4.28</td>
<td>4.41</td>
<td>5.50</td>
<td>3.70</td>
<td>4.32</td>
</tr>
<tr>
<td>deposit/equity (( r ))</td>
<td>2.64</td>
<td>2.96</td>
<td>1.61</td>
<td>2.52</td>
<td>2.80</td>
<td>2.61</td>
<td>2.67</td>
<td>2.55</td>
</tr>
<tr>
<td>Spread (( R - r ))</td>
<td>1.71</td>
<td>1.59</td>
<td>2.09</td>
<td>1.77</td>
<td>1.60</td>
<td>7.289</td>
<td>1.03</td>
<td>1.77</td>
</tr>
<tr>
<td>( \bar{R} )</td>
<td>2.43</td>
<td>2.43</td>
<td>2.43</td>
<td>2.43</td>
<td>2.43</td>
<td>4.83</td>
<td>0.41</td>
<td>2.43</td>
</tr>
<tr>
<td><strong>Crises:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Probability</td>
<td>2.69</td>
<td>1.20</td>
<td>5.43</td>
<td>3.31</td>
<td>0.99</td>
<td>7.34</td>
<td>0.16</td>
<td>3.35</td>
</tr>
<tr>
<td>Duration</td>
<td>2.62</td>
<td>1.89</td>
<td>4.08</td>
<td>2.90</td>
<td>1.97</td>
<td>5.06</td>
<td>1.87</td>
<td>2.82</td>
</tr>
<tr>
<td>Amplitude</td>
<td>17.87</td>
<td>17.30</td>
<td>19.00</td>
<td>19.94</td>
<td>11.96</td>
<td>16.90</td>
<td>15.80</td>
<td>19.36</td>
</tr>
</tbody>
</table>

*Note: All numbers are averages over a long simulation of 500,000 periods and, except for durations, are expressed in percents. In the case where the persistence of the technology shock is raised to \( \rho_z = 0.95 \), the standard deviation of the innovation was rescaled so as to maintain constant the volatility of TFP.*
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
Leverage and bank default dynamics along typical path
### Bank balance sheets

<table>
<thead>
<tr>
<th>Normal times</th>
<th>Crisis times</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>L</td>
</tr>
<tr>
<td>(1 + ( \phi_t )) ( a_t )</td>
<td>( a_t )</td>
</tr>
<tr>
<td>( \phi_t a_t )</td>
<td>( \phi_t a_t )</td>
</tr>
<tr>
<td>( p \geq \bar{p}_t )</td>
<td>( p &lt; \bar{p}_t )</td>
</tr>
</tbody>
</table>

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