Banking crises, sovereign default and macroprudential policy

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Motivation

- Banking crises often happen alongside sovereign debt crises (Reinhart and Rogoff, 2009).
- Examples: Russia 1998, Argentina 2001–2002, European debt crisis 2009–2012 (Greece, Italy, Ireland, Portugal, Spain, etc.).
- Why?
    1. Banks hold government debt.
    2. Bank lending affects economic growth and public finances.
    3. Government may need to bail out banks.
- "Diabolic loop" (Brunnermeier et al., 2016) or "doom loop" (Farhi and Tirole (2017)).
- Pronounced negative effect on the real economy.

The loop

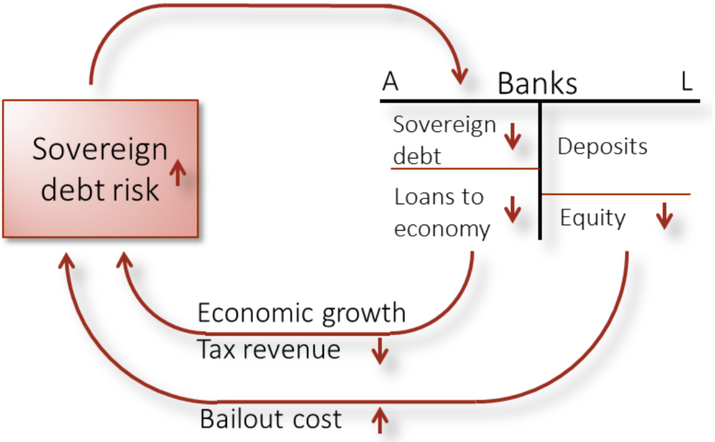

Figure: Diabolic loop

Source: Brunnermeier et al. (2016)

Research question

1. Develop a *quantitative macro model* that can account for the diabolic loop.
2. Study the *optimal macroprudential policy* that can
   - prevent the loop ex-ante,
   - mitigate its impact ex-post.

The striking adverse effects of such financial crises make these questions obviously important.

Literature

- Theoretical "static" models: Livshits and Schoors (2009), Gennaioli, Martin and Rossi (2014), Sandleris (2014), Brunnermeier et al. (2016), Farhi and Tirole (2017).
- Quantitative dynamic models: Boz, D'Erasmo and Durdu (2015), Perez (2015), Bocola (2016), Sosa-Padilla (2018).

Contribution

- The quantitative macro literature tends to abstract from one or more of the following: intertemporal household decisions, bank deposits, endogenous default risk.
- None of the macro papers studied optimal macroprudential policy.
- My contribution is to close this gap.

Methodology

- Gertler and Kiyotaki (2010) + Eaton and Gersovitz (1981).
- Agents:
  - households (workers + bankers),
  - producers (final and capital good),
  - government, including macroprudential authority,
  - foreign lenders.

Agents

- Households consume the final good, (workers) supply labor to final good producers and save through bank deposits.
- Bankers manage banks that intermediate funds between households and final good producers and government subject to an incentive constraint.
- Final good producers need to borrow from banks to purchase physical capital.
- Capital good producers use the final good to build physical capital subject to adjustment cost.
- Government borrows from banks and foreign lenders and collects taxes from households to finance government spending. It lacks commitment to repay its debt, but acts to maximize household welfare.
    - As part of the government decision problem, the macroprudential authority decides on how to regulate the banking sector.

Bankers: balance sheet

- In each household there are $f \in (0,1)$ workers and $1 - f$ bankers.
- Each banker remains a banker next period with the probability $\psi \in (0,1)$.
- The balance sheet of a bank is

$$\sum_{j \in \{B,K\}} (1 + \tau_j(S))Q_j(S)a_j = (1 + \tau_N(S))n + (1 - \tau_P(S))\frac{b'}{R(S)} - t(S),$$

where

  - S is the aggregate state vector,
  - Q_B is the government bond price,
  - Q_K is the price of one unit of equity of final good producers,
  - a_B and a_K are the demanded quantities of government and firm securities,
  - n is the net worth,
  - b is the demanded quantity of deposits to be repaid next period,
  - R is the gross deposit rate,
  - τ_j, $j \in \{B, K, N, P\}$ are tax/subsidy rates,
  - t is the lump-sum tax.

Bankers: net worth

- The next period net worth is

$$n' = \sum_{j \in \{B,K\}} R_j(S', S) Q_j(S) a_j - b',$$

  where R_B and R_K are the gross returns on the banker's assets.
- Combining with the balance sheet,

$$n' = \sum_{j \in \{B,K\}} \left[R_j(S', S) - \widehat{R}_j(S) \right] Q_j(S) a_j + \widehat{R}(S) n - \widehat{t}(S),$$

  where
  - $\widehat{R}_j(S) \equiv \frac{1+\tau_j(S)}{1-\tau_P(S)} R(S)$,
  - $\widehat{R}(S) \equiv \frac{1+\tau_N(S)}{1-\tau_P(S)} R(S)$,
  - $\widehat{t}(S) \equiv \frac{1}{1-\tau_P(S)} R(S) t(S)$.

Bankers: decision problem

- A banker is subject to an incentive constraint that ensures that she will not run away with a fraction $\lambda \in (0,1)$ of her assets.
- A banker's problem is

$$v^b(n;S) = \max_{a_B, a_K} \mathbb{E}_S \left\{ \Lambda(S', S) \left[(1-\psi) n' + \psi v^b(n'; S') \right] \right\}$$

subject to

$$\begin{aligned} n' &= \sum_{j \in \{B,K\}} \left[R_j(S', S) - \widehat{R}_j(S) \right] Q_j(S) a_j + \widehat{R}(S) n - \widehat{t}(S), \\ v^b(n;S) &\geq \lambda \sum_{j \in \{B,K\}} Q_j(S) a_j, \\ S' &= \Gamma(S), \end{aligned}$$

where

- $\Lambda(S', S)$ is the stochastic discount factor of the banker's household,
- Γ is the law of motion of the aggregate state.

Bankers: value function

- The solution to the banker's problem is characterized by the value function $v^b(n; S) = \alpha_1(S)n + \frac{1}{1-f}\alpha_2(S)$ with

$$\alpha_1(S) = \frac{\mathbb{E}_S \left\{ \widehat{\Lambda}(S', S) \right\} \widehat{R}(S)}{1 - \mu(S)}, \tag{1}$$

$$\alpha_2(S) = \frac{\psi \mathbb{E}_S \{ \Lambda(S', S) \alpha_2(S') \} - \mathbb{E}_S \left\{ \widehat{\Lambda}(S', S) \right\} \widehat{T}(S)}{1 - \mu(S)}, \tag{2}$$

  where
  - $\widehat{\Lambda}(S', S) \equiv \Lambda(S', S)[1 - \psi + \psi \alpha_1(S')]$,
  - $\mu(S) \geq 0$ is the Lagrange multiplier on the incentive constraint,
  - $\widehat{T}(S) \equiv (1 - f)\widehat{t}(S)$.
- The Lagrange multiplier satisfies

$$\mu(S) \left[\alpha_1(S)N(S) + \alpha_2(S) - \lambda \sum_{j \in \{B,K\}} Q_j(S)A_j(S) \right] = 0. \tag{3}$$

  where N, A_B and A_K are the net worth, sovereign bond and equity holdings of the banking sector.

Banking sector

- The Euler equations are

$$\mathbb{E}_S\left\{\widehat{\Lambda}(S',S)\left[R_B(S',S)-\widehat{R}_B(S)\right]\right\}=\lambda\mu(S), \tag{4}$$

$$\mathbb{E}_S\left\{\widehat{\Lambda}(S',S)\left[R_K(S',S)-\widehat{R}_K(S)\right]\right\}=\lambda\mu(S). \tag{5}$$

- The balance sheet of the banking sector is

$$\sum_{j\in\{B,K\}} Q_j(S)A_j(S)=N(S)+\frac{P'(S)}{R(S)}, \tag{6}$$

where P are the aggregate deposits.

- The net worth of the banking sector satisfies

$$N(S')=\psi\left[\sum_{j\in\{B,K\}} R_j(S',S)Q_j(S)A_j(S)-P'(S)\right]$$
$$+\omega\sum_{j\in\{B,K\}} Q_j(S')A_j(S), \tag{7}$$

where $\frac{\omega}{1-\psi}\in(0,1)$ is the fraction of assets of exiting bankers transferred to new bankers by households.

Households

- Fraction $f \in (0, 1)$ of workers and $1 - f$ of bankers.
- The problem of a household is

$$v^h(b; S) = \max_{b', c \geq 0, l \in [0,1]} \left\{ u(c, l) + \beta \mathbb{E}_S \left[v^h(b'; S') \right] \right\}$$

subject to

$$c + \frac{b'}{R(S)} \leq W(S)l + \Pi(S) + b + \tau(S),$$
$$S' = \Gamma(S),$$

where b are bank deposits, c is consumption, l is labor, W is wage, Π are net profits, τ are government transfers.

Households

Hence,

$$1 = R(S)\mathbb{E}_S[\Lambda(S', S)], \tag{8}$$

$$W(S) = -\frac{u_l(c, l)}{u_c(c, l)}, \tag{9}$$

where

$$\Lambda(S', S) \equiv \beta \frac{u_c(c', l')}{u_c(c, l)}, \tag{10}$$

$$c \equiv W(S)l + \Pi(S) + b - \tau(S) - \frac{b'}{R(S)}.$$

Final good producers

- Their problem is

$$\max_{k',l}\left(k^{\alpha}(e^{z}l)^{1-\alpha}-W(S)l+\mathbb{E}_S\left\{\Lambda(S',S)\left[k'^{\alpha}(e^{z'}l')^{1-\alpha}+Q_K(S')(1-\delta)k'\right.\right.\right.$$
$$\left.\left.\left.-R_K(S',S)Q_K(S)k'\right]\right\}\right),$$

where k is capital, z is a nonstationary technology process, $\delta \in [0,1]$ is the depreciation rate.

- The technology process is characterized by

$$\Delta z' = (1-\rho_z)\gamma + \rho_z \Delta z + \sigma_z \epsilon_z', \qquad \epsilon_z' \sim \mathcal{N}(0,1).$$

- Let Y and L denote the aggregate output and labor. In equilibrium,

$$Y(S) = K^{\alpha}[e^{z}L(S)]^{1-\alpha}, \tag{11}$$

$$W(S) = (1-\alpha)\frac{Y(S)}{L(S)}, \tag{12}$$

$$R_K(S',S) = \frac{\alpha\frac{Y(S')}{K'(S)} + (1-\delta)Q_K(S')}{Q_K(S)}. \tag{13}$$

Capital good producers

- They solve

$$\max_{i \geq 0} \left[Q_i(S) \Phi \left(\frac{i}{K} \right) K - i \right],$$

where i is the amount of the final good used to produce physical capital, Q_i is the price of the capital good, which must be equal to Q_K by no arbitrage, K is the aggregate capital stock, Φ is a strictly increasing and strictly concave function that satisfies $\Phi(0) > 0$.

- Hence, in equilibrium,

$$Q_K(S) = \left[\Phi' \left(\frac{I(S)}{K} \right) \right]^{-1}, \tag{14}$$

where $I(S)$ is the aggregate investment.

Government: preview

- In the baseline case, the budget of the fiscal authority is described by

$$gY(S) + \mathcal{I}(S)\{\pi + (1-\pi)[\iota + Q_B(S)]\}B + \tau(S) = \mathcal{I}(S)Q_B(S)B'(S), \quad (15)$$

  where
  - g is a stochastic process that determines government spending,
  - $\mathcal{I} = 1$ if the sovereign debt market is open and $\mathcal{I} = 0$ otherwise,
  - $\pi \in [0,1]$ is a share of bonds that mature each period,
  - $\iota \geq 0$ is the coupon rate,
  - B is the stock of government debt,
- The realized return on government bonds is

$$R_B(S', S) = \mathcal{I}(S)\mathcal{I}(S')\frac{\pi + (1-\pi)[\iota + Q_B(S')]}{Q_B(S)}. \quad (16)$$

Foreign lenders

- Foreign lenders are risk neutral and can invest their wealth either in sovereign bonds or a risk-free asset with return r.
- If $\mathcal{I}(S) = 1$, a lender chooses bond holdings a_B^* to solve

$$\max_{a_B^*} \left\{ -Q_B(S)a_B^* + \frac{1}{1+r}\mathbb{E}_S \left\{ \mathcal{I}(S')[\pi + (1-\pi)(\iota + Q_B(S'))]a_B^* \right\} \right\}.$$

- Hence,

$$Q_B(S) = \frac{1}{1+r}\mathbb{E}_S \left\{ \mathcal{I}(S')[\pi + (1-\pi)(\iota + Q_B(S'))] \right\}, \qquad (17)$$

which implies $\mathbb{E}_S\{R_B(S', S)\} = \mathcal{I}(S)(1+r)$.

Diabolic/doom loop

- Default happens ($\mathcal{I} = 0$) $\Rightarrow R_B \downarrow \Rightarrow N \downarrow \Rightarrow \mu \uparrow$ (incentive constraint binds) $\Rightarrow Q_B, Q_K, A_B, A_K \downarrow \Rightarrow \mu \uparrow \Rightarrow \ldots \Rightarrow Y \downarrow \Rightarrow$ more likely to default in the future.
- Bank bailouts can be introduced into the picture.
- How to break the loop?

Macroprudential policy

- Presumably, macroprudential policy could mitigate the effect of sovereign default on banks' net worth and break the doom loop.
- Moreover, the overborrowing story of Jeanne and Korinek (2010), Bianchi (2011) and Bianchi and Mendoza (2018) is also relevant.
- In the baseline case, the macroprudential authority maintains the balanced budget:

$$\sum_{j \in \{B,K\}} \tau_j(S) Q_j(S) A_j(S) = \tau_N(S) N(S) - \tau_P(S) \frac{P'(S)}{R(S)} - T(S). \tag{18}$$

- An alternative arrangement specifies a consolidated budget constraint for fiscal and macroprudential authorities.

Equilibrium, given government policy

- The aggregate state is $S \equiv \left\{K, B, \overline{A}_B^*, P, \Delta z, g\right\}$.
- The government policy is $\{\mathcal{I}, B', \tau_B, \tau_K, \tau_N, \tau_P\}$.
- Market clearing requires

$$
\begin{aligned}
A_B(S) + A_B^*(S) &= B'(S), && (19)\\
A_K(S) &= K'(S), && (20)\\
K'(S) - (1-\delta)K &= \Phi\left(\frac{I(S)}{K}\right)K, && (21)\\
(1-g)Y(S) &= C(S) + I(S) + \mathcal{I}(S)[\pi + (1-\pi)(\iota + Q_B(S))]\overline{A}_B^* \\
&\quad - \mathcal{I}(S)Q_B(S)A_B^*(S). && (22)
\end{aligned}
$$

- Given government policy, price functions and the aggregate law of motion, the individual agents' value and policy functions solve their problems.
- Price functions are such that markets clear.
- The aggregate law of motion is consistent with agents' optimization.

Government policy

- Let $\widetilde{S} \equiv S \setminus \left\{B, \overline{A}_B^*\right\}$.
- The government's value function is

$$V(S) = \max\left\{V^R(S), V^D\left(\widetilde{S}\right)\right\},$$

where V^R is the value of repaying the debt, and V^D is the value of default.

- The value of repayment satisfies

$$V^R(S) = \max_{\mathcal{C}^R}\left\{U(C, L) + \beta \mathbb{E}_S\left\{V\left(S'\right)\right\}\right\},$$

where $\mathcal{C}^R \supset \{B', \tau_B, \tau_K, \tau_N, \tau_P\}$ is the set of relevant control variables, and the maximization is subject to (1)–(22) with $\mathcal{I}(S) = 1$.

- The value of default is

$$V^D\left(\widetilde{S}\right) = \max_{\mathcal{C}^D}\left\{U(C, L) + \beta \mathbb{E}_{\widetilde{S}}\left\{\theta_g V\left(\widetilde{S}' \cup \{0, 0\}\right) + (1 - \theta_g) V^D\left(\widetilde{S}'\right)\right\}\right\},$$

where $\mathcal{C}^D \supset \{\tau_B, \tau_K, \tau_N, \tau_P\}$ is the set of relevant control variables, and the maximization is subject to (1)–(22) with $\mathcal{I}(S) = 0$.

Markov perfect equilibrium

- The current government policy solves the Ramsey problem, given the future government policies.
- Current and future government policies coincide.

Deterministic steady state

- When there is no uncertainty, the detrended model admits one of the two possible steady states:
  - Unconstrained: the incentive constraint is not binding.
  - Constrained: the incentive constraint is binding.
- A sufficient condition for the steady state to be unconstrained is

$$\frac{\psi R\left(\frac{1+\tau_j}{1-\tau_P}-1\right)+\omega}{e^{\gamma}-\psi R}\left[1-\tau_P-\psi\beta(1+\tau_N)\right]+\tau_j+\tau_P$$
$$>\frac{\lambda(1-\psi\beta)[1-\tau_P-\psi(1+\tau_N)]}{1-\psi}$$

  for $j \in \{B, K\}$.
- If $\tau_B = \tau_K$, then it is also a necessary condition. If $\tau_B = \tau_K = \tau_N = \tau_P = 0$, then it simplifies to

$$\beta\left(1-\frac{\omega}{e^{\gamma}\lambda}\right)<\psi<\beta.$$

What needs to be done

- The theoretical model has been developed.
- The approximate solution of a model with no default risk can be characterized in a neighborhood of an unconstrained or constrained steady state using the "piecewise linear perturbation" of Guerrieri and Iacoviello (2015).
- The global solution method must be applied to the complete model.
- The optimal policy must be characterized.
- The impact of the optimal policy must be studied and explained.