On the Instability of Banks and other Financial Intermediaries

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Introduction

- Why do banks and other financial intermediaries exist? What are their roles? Do they engender instability?
- A venerable view: these institutions are inherently fragile and excessively volatile.
  - even the staunchest defenders of laissez-faire (eg, Friedman) advocated bank regulation.
- We study this in several models of financial intermediation.

The many functions of financial intermediaries

- Provide liquidity insurance and maturity transformation.
- Find, screen and monitor opportunities to make investments on behalf of depositors.
- Act as middlemen between asset buyers and asset sellers.
- Their liabilities are used as safe payment instruments.
- Maintain privacy about their customers or assets.

This paper

- As there is no all-encompassing model of these activities, we consider four distinct setups:
  - Diamond-Dybvig with reputational concerns as in Gu et al
  - Delegated monitoring as in Diamond or Huang
  - Rubinstein-Wolinsky middlemen in a Duffie et al asset market
  - Bank liabilities as payment instruments as in He et al
- In each case financial intermediation engenders instability by making it more likely that there will be:
  - multiple steady states, or
  - cyclic, chaotic and stochastic dynamics

Model 1: Banking and insurance

- Diamond-Dybvig with infinite horizon as in Gu et al
- Each period in discrete time has two subperiods.
- Agents:
  - Many one-period-lived households born at each t
  - Some infinitely-lived candidate bankers
- Preferences:
  - Households: $u_1(c_1)$ with prob π, $u_2(c_2)$ with prob $1-\pi$.
  - Candidate bankers: $u_0(c_2)$
- Households endowed with 1 unit of c, bankers with 0.
- Technology: storage or $x \longrightarrow \begin{cases} x & \text{in subperiod 1} \\ Rx & \text{in subperiod 2} \end{cases}$

Friction 1 – private information

- Preference types are unobservable.
- Incentive compatible contract among households:

$$\max_{c_1, c_2} \pi u_1(c_1) + (1-\pi) u_2(c_2)$$
$$\text{st} \ \ (1-\pi) c_2 = (1-\pi c_1) R$$
$$c_2 \geq c_1$$

- Standard assumptions imply the efficient arrangement is incentive feasible with $1 < c_1^* < c_2^* < R$.

Friction 2 – limited commitment

- Patient agents have no incentive to deliver the goods to impatient
  - Households: finite lives imply no punishment available
  - Bankers: reputation can sustain some credibility
- Hence households might deposit some endowment with a banker, who invests on their behalf.

Deposit banking

- Banker at time t:
  - accepts deposits d_t
  - gets $b_t R$ at the end of period
  - can abscond with d_t for opportunistic payoff λd_t
  - misbehavior is detected/communicated to next gen with prob μ and punished with autarky
- The key incentive constraint:

$$u_0 (b_t R) + \beta V_{t+1} \geq \lambda d_t + \beta (1 - \mu) V_{t+1}$$
$$\iff \lambda d_t - u_0 (b_t R) \leq \beta \mu V_{t+1} \equiv \phi_t$$

where ϕ_t is bank's franchise value.

Bank contract problem

$$\max_{d, r_1, r_2, b} \pi u_1 \left(d r_1 + 1 - d \right) + \left(1 - \pi \right) u_2 \left(d r_2 + \left(1 - d \right) R \right)$$

$$\text{st} \;\; \left(1 - \pi \right) d r_2 = \left(d - b - \pi d r_1 \right) R$$

$$r_2 \geq r_1$$

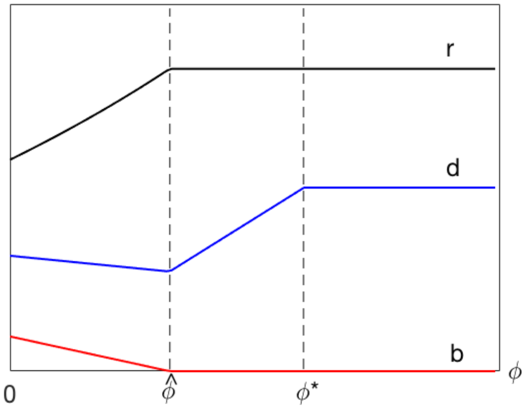
$$\phi \geq \lambda d - u_0 \left(b R \right)$$

Solution: three cases

$\exists\ \hat{\phi}$ and $\phi^* > \hat{\phi}$ such that:

1. $\phi > \phi^* \implies$ IC loose $\implies d = d^*,\ b = 0$ is a solution;
2. $\hat{\phi} \leq \phi < \phi^* \implies$ IC medium $\implies d < d^*,\ b = 0$;
3. $\phi < \hat{\phi} \implies$ IC tight $\implies d < d^*,\ b > 0$.

Static partial equilibrium



(d, r, b) vs ϕ

Dynamic general equilibrium

- Banker's value equation

$$V_t = u_0 (b_t R) + \beta V_{t+1}$$

- Use $\phi_t \equiv \beta \mu V_{t+1}$ to get

$$\phi_{t-1} = f(\phi_t) \equiv \beta \mu u_0 [b(\phi_t) R] + \beta \phi_t.$$

- **Def'n**: An equilibrium is a bounded, nonnegative solution to $\phi_{t-1} = f(\phi_t)$.

Prop: $\exists!$ stationary equil $\bar{\phi} = f(\bar{\phi})$.

- $\tilde{\phi} > 0 \implies$ stationary equil has banking and $\bar{\phi} \in (0, \hat{\phi})$.
- $\tilde{\phi} < 0 \implies$ stationary equil has no banking
- Outcome is obviously unique with no banking; specification is designed to get unique stationary equil with banking. But...

Prop: For some parameters, there are many nonstationary equil with banking.

Examples

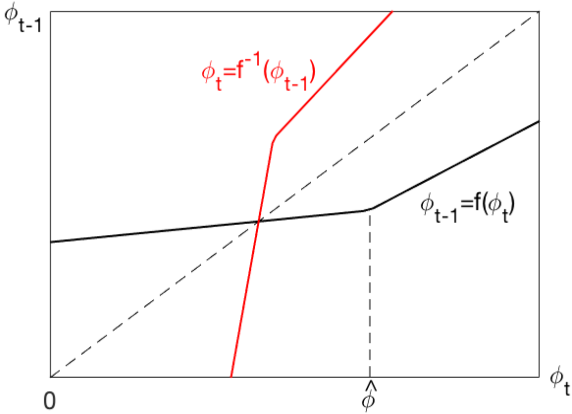
- Utility functions:
  - $u_0(c) = A_0 c$
  - $u_1(c) = A_1 \frac{(c+\varepsilon)^{1-\sigma_1} - \varepsilon^{1-\sigma_1}}{1-\sigma_1}$

    $u_2(c) = A_2 \frac{(c+\varepsilon)^{1-\sigma_2} - \varepsilon^{1-\sigma_2}}{1-\sigma_2}$
- Parameter values:

  $A_0 = 0.95$, $A_1 = 1$, $A_2 = 0.1$, $\sigma_1 = \sigma_2 = 2$, $\varepsilon = 0.01$,

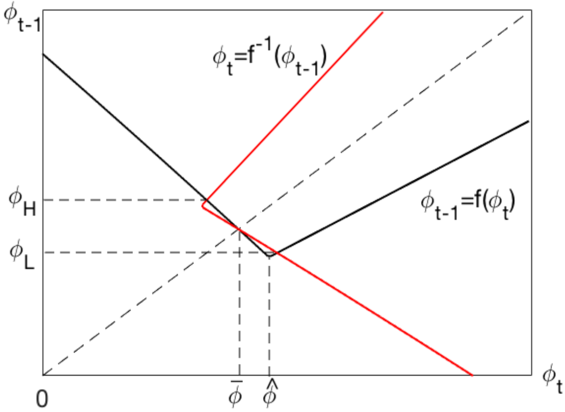
  $R = 2.1$, $\pi = 0.25$, $\lambda = 0.6$, $\beta = 0.99$, $\mu = 0.7$.
- Vary σ's for different examples.

Example with unique equilibrium



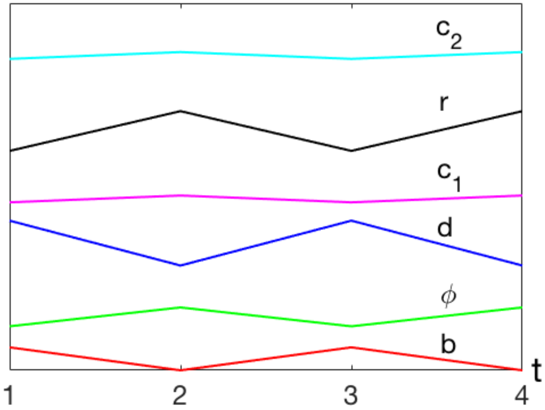
monotone f

Example with two-cycles and sunspot equil

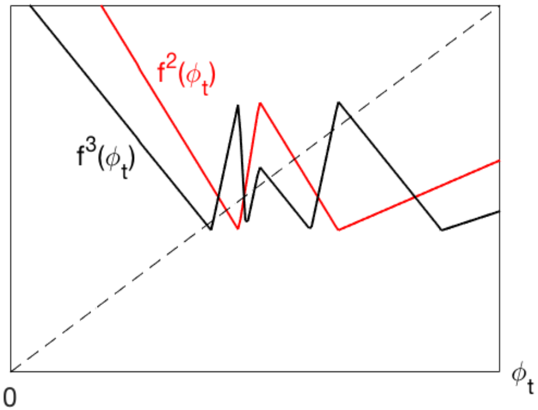


nonmonotone f

Banking activity over the two-cycle



Example with three-cycles and chaos



cycles

Summary

Message:

- Banking is essential: if it is eliminated payoffs go down.
- But does engender instability: the equil set with (without) banking does (does not) admit cycles, chaos and sunspots.

Intuition:

- If bank franchise value ϕ_t is high his current salary b_t can be low and still satisfy IC thus making ϕ_{t-1} low.
- This can yield nonmonotone dynamics if it dominates the linear term in $\phi_{t-1} = \beta \mu u_0 [b(\phi_t) R] + \beta \phi_t$.

Model 2: Delegated Investment

- Based on Diamond and recent work by Huang.
- Time is discrete and all agents live forever.
- A large number of distinct locations (islands) and we randomly relocated agents every t.
- Agents can pay a fixed cost κ to find, evaluate, screen or monitor a project that pays R at the end of the period.
- Utility: $u(x) - c(d)$, where x is consumption and d is investment

Autarky

- If an agent invests on his own, his payoff is

$$\tilde{W} = \max_{x,d} \left\{ u\left(x\right) - c\left(d\right) \right\} \text{ st } x = Rd - \kappa.$$

- If an agent does not invest, his payoff is $u\left(0\right) - c\left(0\right) = 0$.
- For the sake of illustration, assume κ is big so that agents do not invest on their own.

Coalition

- Some agents (depositors, measure $1-\omega$) delegate their investment to others (bankers, measure ω) to save on fixed cost.
- But bankers lack commitment.
- The key IC constraint is

$$\beta V_{t+1} \geq \frac{\lambda\left(1-\omega_t\right)}{\omega_t} x_t + (1-\mu)\beta V_{t+1}$$

or

$$\frac{1-\omega_t}{\omega_t} x_t \leq \phi_t \equiv \frac{\beta\mu}{\lambda} V_{t+1},$$

Contract

$$W(\phi) = \max_{\omega, X, D, x, d} \left\{ \omega \left[u(X) - c(D) \right] + (1 - \omega) \left[u(x) - c(d) \right] \right\}$$

$$\text{st } \omega X + (1 - \omega) x = R \left[\omega D + (1 - \omega) d \right] - \kappa \omega$$

$$u(x) - c(d) \geq 0$$

$$\frac{1 - \omega_t}{\omega_t} x_t \leq \phi_t$$

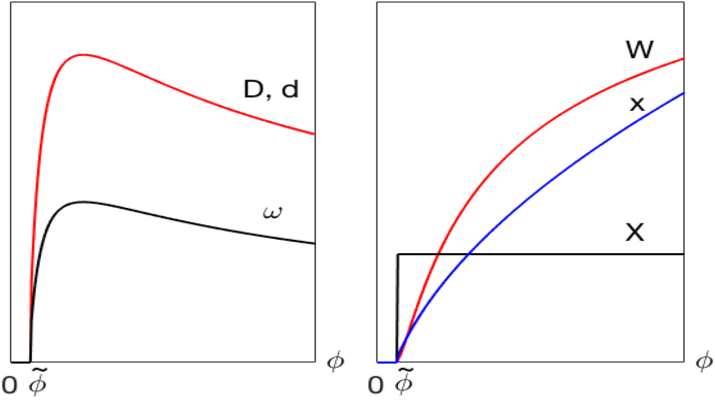
Example

- Functions:
  - $u(x) = A\frac{(x+b)^{1-\sigma} - b^{1-\sigma}}{1-\sigma}$
  - $c(d) = Bd$
- Parameter values:

  $A = b = 0.001,\ \sigma = 2,\ B = 0.1$

  $\kappa = 230, R = 1.2.$

Static Partial Equilibrium



Bank contract vs ϕ

Dynamic general equilibrium

- Agent's value equation

$$V_t = \max\left\{W\left(\phi_t\right), 0\right\} + \beta V_{t+1}.$$

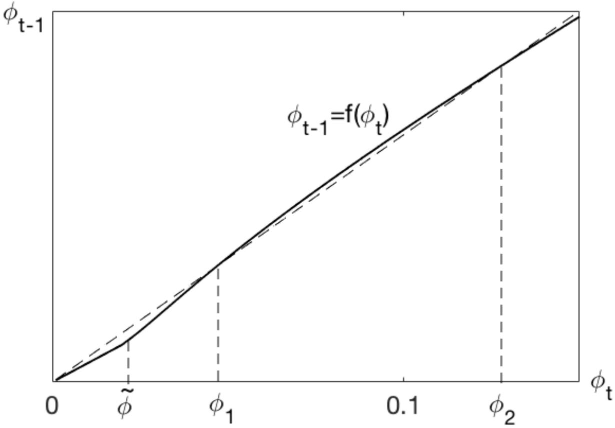
- Use $\phi_t \equiv \beta\mu V_{t+1}/\lambda$ to get

$$\phi_{t-1} = f\left(\phi_t\right) \equiv \frac{\beta\mu}{\lambda}\max\left\{W\left(\phi_t\right), 0\right\} + \beta\phi_t.$$

Prop: There is generically and odd number of stationary equil, one of which is $\bar{\phi} = 0$.

Prop: If there is a stationary equil with $\bar{\phi} > 0$ then there are sunspot equil.

Example of Sunspot Equilibrium



Monotone f with multiple steady states

Variation

- Note that this is not the same as the endogenous dynamics in Gu et al, which relies on Nash bargaining with $0 < \theta < 1$.
- That is not in the above models, but we can add it.
- Agents:
  - A one-period lived agent born at every date (depositor)
  - An infinitely lived agent (banker)
- Nash bargaining

Nash Bargaining

$$W(\phi) = \max_{X,x,D,d} [U(X) - C(D)]^{\theta} [u(x) - c(d)]^{1-\theta}$$

$$\text{st } X + x = R(D + d) - \kappa$$

$$u(x) - c(d) \geq 0$$

$$x_t \leq \phi_t$$

Solution

1. If κ is too big there is no banking.
2. Otherwise $\exists\ \tilde{\phi} < \phi^*$ such that:
   a. $\phi > \phi^* \implies$ IC loose $\implies x = x^*$ is a solution
   b. $\tilde{\phi} \leq \phi < \phi^* \implies$ IC medium $\implies x = \phi$.
   c. $\phi < \tilde{\phi} \implies$ IC tight $\implies d = x = 0$.

Dynamic general equilibrium

- The banker's value function is

$$V_t = U(X_t) - C(D_t) + \beta V_{t+1}$$

- Use $\phi_t = \beta\mu V_{t+1}/\lambda$ to get

$$\phi_{t-1} = \begin{cases} \beta\phi_t & \text{if } \phi_t < \tilde{\phi} \\ \frac{\beta\mu}{\lambda}[U \circ X(\phi_t) - C \circ D(\phi_t)] + \beta\phi_t & \text{if } \tilde{\phi} \leq \phi_t < \phi^* \\ \frac{\beta\mu}{\lambda}[U(X^*) - C(D^*)] + \beta\phi_t. & \text{if } \phi_t \geq \phi^* \end{cases}$$

Proposition: There are odd number of steady states, one of which is $\bar{\phi} = 0$.

Proposition: If there is more than 1 steady state, there are sunspot equilibria.

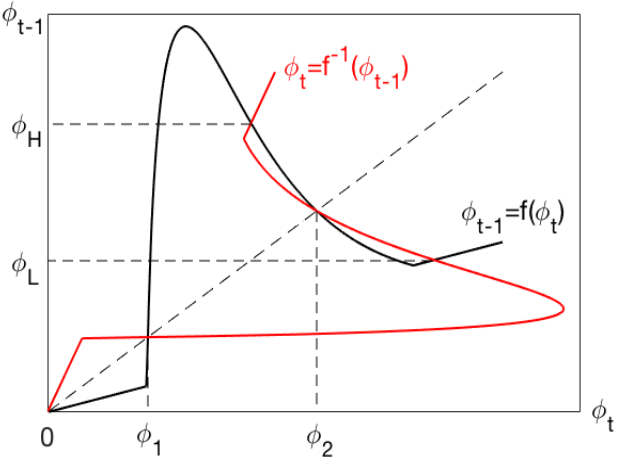
Example

- Utility functions:
  - $U(x) = u(x) = Ax$
  - $C(d) = c(d) = Bd^{\gamma}/\gamma$
- Parameter values:

  $A = 1,\ B = 0.5,\ \gamma = 5.$

  $R = 2,\ k = 1.5,\ \theta = 0.01,\ \lambda = 0.01,\ \mu = 1,\ \beta = 0.35$

Example of Deterministic and Stochastic Cycles



Delegated investment – Nash bargaining

Summary

Message:

- Banking is essential – it saves fixed cost.
- But it engender instability: the equilibrium set with (without) banking does (does not) admit cycles, chaos and sunspots.

Intuition:

- Adding fixed cost generates a stable steady state, which supports a continuum of equilibria around it.
- In Nash bargaining, one's payoff does not necessarily increase with the expansion of the bargaining set. In particular, $\partial \left[U\left(X\right) - C\left(D\right)\right] / \partial\phi|_{\phi\rightarrow\phi^*} < 0$.

Model 3: Asset Market Intermediation

- Based on RW (1987), DGP (2005) and NWW (2017)
- Time is discrete and infinite.
- Agents
  - Buyers and sellers: one-period lived, replaced by "clones"
  - Middlemen: infinitely lived
- Sellers are endowed with 1 unit of investment good.
- Buyers can transform the investment good into π, which is random with cdf $F(\pi)$, units of consumption good.
- Preferences: linear utility of consumption, and transferable utility for payments.
- Agents meet bilaterally.
- Entry by sellers or buyers or middlemen.

Agent's problem

Let $\Delta_t \equiv V_{1,t} - V_{0,t}$ and $R_t \equiv (1-\delta)\,\beta\Delta_{t+1}$

- Buyer:

$$V_{b,t}(\pi) = \frac{\alpha n_{s,t}}{N_t}\theta_{bs}\pi + \frac{\alpha n_t}{N_t}\tau(\pi, R_t)\,\theta_{bm}\left[\pi - (1-\delta)\,\beta\Delta_{t+1}\right]$$

- Seller:

$$V_{s,t} = \frac{\alpha n_b}{N_t}\theta_{sb}\mathbb{E}\pi + \frac{\alpha(n_m - n_t)}{N_t}\theta_{sm}(1-\delta)\,\beta\Delta_{t+1}$$

- Middleman:

$$\begin{aligned} V_{0,t} &= \frac{\alpha n_{s,t}}{N_t}\theta_{ms}R_t + \beta V_{0,t+1} \\ V_{1,t} &= \rho + \frac{\alpha n_b}{N_t}\theta_{mb}\int_{R_t}^{\infty}(\pi - R_t)\,dF(\pi) \\ &\quad + (1-\delta)\beta V_{1,t+1} + \delta\beta V_{0,t+1}. \end{aligned}$$

Equilibrium

- The value functions reduce to

$$R_{t-1} = (1-\delta)\,\beta\left\{\rho + R_t + \frac{\alpha n_b \theta_{mb}}{N_t}\int_{R_t}^{\infty}\left[1 - F(\pi)\right]d\pi - \frac{\alpha n_{s,t}\theta_{ms}}{N_t}R_t\right\}$$

- Law of motion of middlemen with inventory:

$$n_{t+1} = g(n_t, N_t, R_t)$$

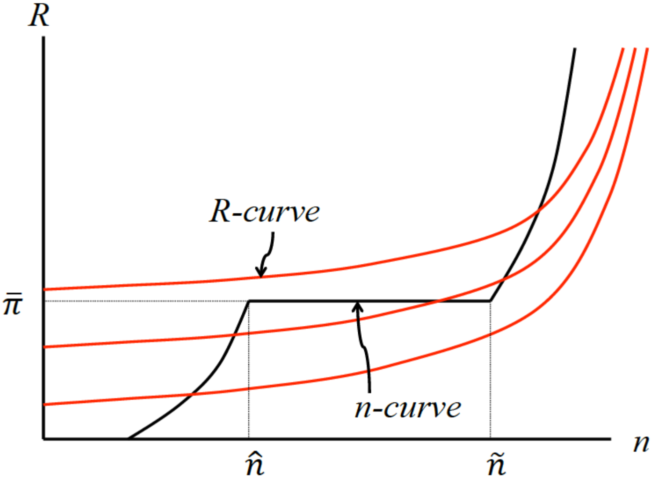
- Free entry

$$n_{s,t} = h(n_t, R_t)$$

- Equilibrium is a two-dimensional dynamical system,

$$\begin{bmatrix} n_{t+1} \\ R_{t-1} \end{bmatrix} = \begin{bmatrix} f(n_t, R_t) \\ g(n_t, R_t) \end{bmatrix}$$

Steady states – degenerate distribution



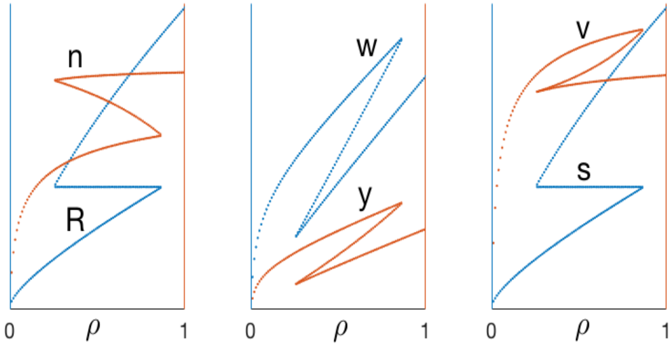
The n-curve and R-curve for different ρ

Steady state

Proposition: Consider entry by type S and $\pi = \bar{\pi}$. There exist $\tilde{\rho} > 0$ and $\hat{\rho} > \tilde{\rho}$ such that:

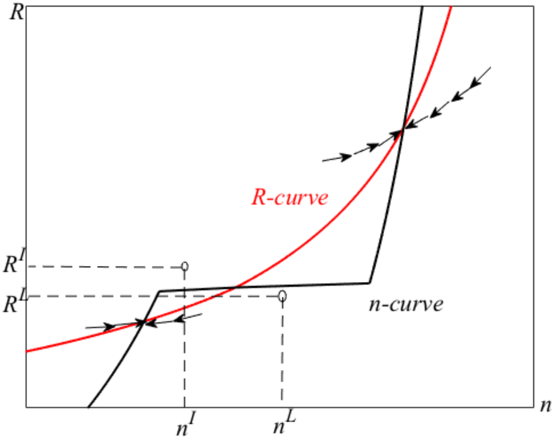
1. $\rho \in [0, \tilde{\rho})$ implies there is a unique steady state and it entails $R < \bar{\pi}$;
2. $\rho \in (\hat{\rho}, \infty)$ there is a unique steady state and it entails $R > \bar{\pi}$; and
3. $\rho \in (\tilde{\rho}, \hat{\rho})$ implies there are three steady states, one with $R < \bar{\pi}$, one with $R > \bar{\pi}$, and one with $R = \bar{\pi}$.

Steady state



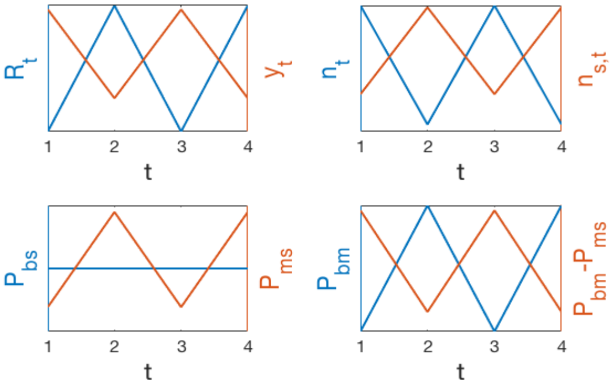
The equilibrium correspondence

Cycles



Phase plane with entry by S, including a two-cycle

Cycles



Time series for a two-period cycle with entry by S

Summary

Proposition: For some parameter values, financial intermediation is essential. The equilibrium set admits multiple steady states, cycles and sunspots.

Interpretation:

- There is strategic complementarity between M and S.
- Asset market intermediation is a useful institution but is prone to multiplicity and excess volatility or instability.

Model 4: Safety and Liquidity

- Based on the version of LW (2005) in HHW (2005) (also see BCW 2007, SW 2010)
- Continuum of infinitely-lived buyers b and sellers s.
- Each period has two markets convene:
  - DM: s agents sell q and b agents buy q
  - CM: all trade (x, ℓ), adjust portfolios, settle debts
- Utility: $U(x) - \ell + u(q)$ & $U(x) - \ell - c(q)$
- An asset in fixed supply (Lucas tree) can be held in two ways:
  - a_1 : safe but illiquid,
  - a_2 : less safe but liquid

CM problem

- Let $A = (\phi + \rho)(a_1 + a_2)$.

$$\begin{aligned} W_t(A_t) &= \max_{x_t, \ell_t, \hat{\mathbf{a}}_t} \{U(x_t) - \ell_t + \beta V_t(\hat{\mathbf{a}}_t)\} \\ \text{st } x_t &= A_t + \ell_t - \phi_t(\hat{a}_{1,t} + \hat{a}_{2,t}) \end{aligned}$$

- Standard results: $W_t(A_t)$ linear.
- FOC for demand for $\hat{a}_{j,t+1}$:

$$\hat{a}_{j,t+1}\left[-\phi_t + \beta \frac{\partial V_{t+1}(\hat{\mathbf{a}}_{t+1})}{\partial \hat{a}_{j,t+1}}\right] = 0$$

DM problem

- A general trading mechanism $p = v(q)$, where $p \leq (\phi + \rho)\, a_2$

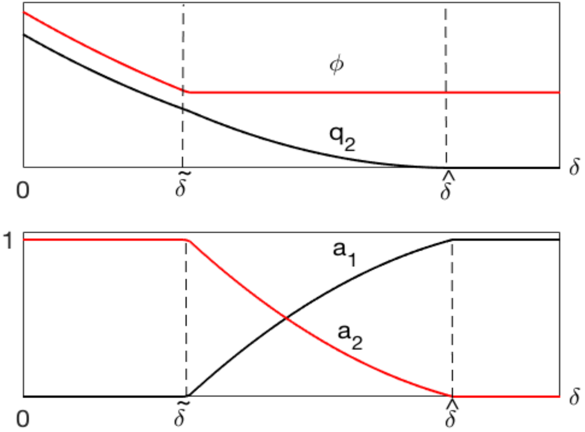
$$
\begin{aligned}
V_t(\hat{\mathbf{a}}_t) &= (1-\delta)\left\{W_t(A_t) + \alpha\left[u(q_t) - v(q_t)\right]\right\} \\
&\quad + \delta W_{t+1}\left[(\phi_t + \rho)\, \hat{a}_{1,t}\right]
\end{aligned}
$$

- Euler equations:

$$
\begin{aligned}
0 &= \hat{a}_{1,t}\left[\beta\left(\phi_{t+1} + \rho\right) - \phi_t\right] \\
0 &= \hat{a}_{2,t}\left\{\beta\left(\phi_{t+1} + \rho\right)(1-\delta)\left[1 + \alpha\lambda(q_{t+1})\right] - \phi_t\right\}
\end{aligned}
$$

where $\lambda(q) = u'(q)/v'(q) - 1$.

Steady states



Steady State Regimes

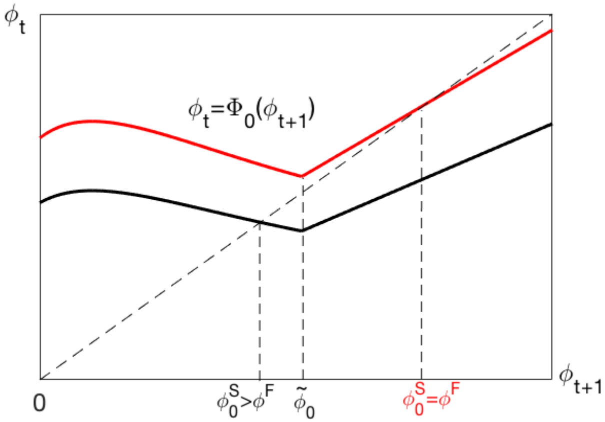
Equilibrium without banking

Suppose $\delta < \hat{\delta}$. The dynamic system is

$$\phi_{t-1} = \begin{cases} \beta\left(\phi_t + \rho\right)\left(1-\delta\right)\left[1 + \alpha\lambda \circ v^{-1}\left(\phi_t + \rho\right)\right] & \text{if } \phi_t < \tilde{\phi}_0 \\ \beta\left(\phi_t + \rho\right) & \text{if } \phi_t \geq \tilde{\phi}_0 \end{cases}$$

where $\alpha\lambda \circ v^{-1}\left(\tilde{\phi}_0 + \rho\right) = \delta / \left(1 - \delta\right)$

Equilibrium without banking



Dynamic equilibrium

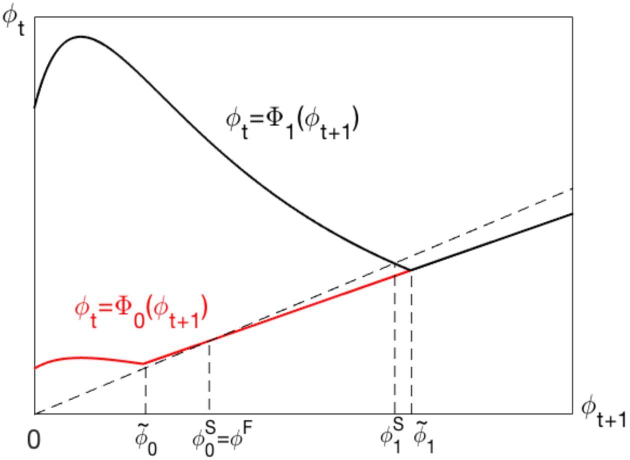
Banking

- Asset can be deposited at a bank with return ρ and $\delta = 0$.
- Equilibrium:

$$\phi_{t-1} = \begin{cases} \beta(\phi_t + \rho)\left[1 + \alpha\lambda \circ v^{-1}(\phi_t + \rho)\right] & \text{if } \phi_t < \tilde{\phi}_1 \\ \beta(\phi_t + \rho) & \text{if } \phi_t \geq \tilde{\phi}_1 \end{cases}$$

where $\lambda \circ v^{-1}(\tilde{\phi}_1 + \rho) = 0$

Equilibrium with banking



Equilibrium with banking

Summary

Proposition: Banking is essential. But it can introduce new nonstationary equilibria including cycles, sunspots and chaos. If banking is stable, the economy without banking is stable.

Interpretation:

- Liquidity premium is amplified if the asset is safer.
- Banking for safekeeping and liquidity provision is a useful institution but is prone to multiplicity and excess volatility or instability.

Conclusion

- Banks, as several banking crisis throughout history have demonstrated, are fragile institutions. This is to a large extent unavoidable and is the direct result of the core functions they perform in the economy. *Finance Market Watch Program @ Re-Define.*
- We study this idea by building four models of financial intermediation that are explicit about their core functions – i.e., they are models of these institutions, not just models with these institutions.
- The results show these are socially useful institutions but are indeed prone to excess volatility or multiplicity.