An agent-based model for bank formation, bank runs and interbank networks

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- Financial innovation and integration leads to highly interconnected, complex and potentially fragile banking systems.
- Systemic crises are essentially stories of contagion, interdependence, interaction and trust - Kirman (2010).

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- Money is neutral in its effect on real variables.
- Largely ignores uncertainty by simply subtracting risk premia from all risky returns and treat them as risk-free.

Voices of discontent

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- R. Solow (2006): "Maybe there is in human nature a deep-seated perverse pleasure in adopting and defending a wholly counterintuitive doctrine that leaves the uninitiated peasant wondering what planet he or she is on."

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- Dynamic reactions can modify both existing interactions and the structure of the links.

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- Sufficiently risk-averse consumers prefer the liquid asset.

Example: Diamond (2007)

- Let $A = (r_1 = 1, r_2 = 2)$ represent an illiquid asset and $B = (r_1 = 1.28, r_2 = 1.813)$ a liquid one.

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- Observe, however, that risk-neutral investors would prefer the illiquid asset, since:

$$E[A] = 1.75 > 1.68 = E[B]$$

Liquidity risk sharing with public information

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Introduction

DSGE x ABM

The pre-banking society

Bank formation

Bank runs

Interbank networks

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- Agents are endowed with one unit of the numeraire at time 0 and must decide either to hold it or to invest in an illiquid asset $(1, R)$.
- Denoting the consumption of agent of type i at time k by c_k^i the optimal risk sharing for *publicly* observed preferences is

$$c_1^2 = c_2^1 = 0 \quad (2)$$

$$u'(c_1^1) = Ru'(c_2^2) \quad (3)$$

$$\omega c_1^1 + (1-\omega)\frac{c_2^2}{R} = 1 \quad (4)$$

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- Denoting by f the total fraction of withdrawers, we see that $r_1 = c_1^1$ and $f = \omega$ is such equilibrium.
- However, it is clear that $f = 1$ (run) is also an equilibrium.

Society

- Consider N heterogeneous agents with liquidity preferences at times t_k given by independent uniform random variables ω^i on $[0, 1]$: if $\omega^i < p$, agent i is said to be of type 1 (impatient), otherwise it is said to be of type 2 (patient).

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where $b_k^i \in \{0,1\}$ are Bernoulli random variables and ε_k^i are uniformly distributed on $[0,1]$. Setting $q = 2p - 1/2$, agent i is then deemed to be impatient if $\widetilde{\omega}^i < q$ and patient otherwise.

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- Because of anticipated shocks, individuals explore the society searching to partners to exchange investments.

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- We use a combination of Von Neumann and Moore neighborhood:

5	1	6
2	X	3
7	4	8

Matching example

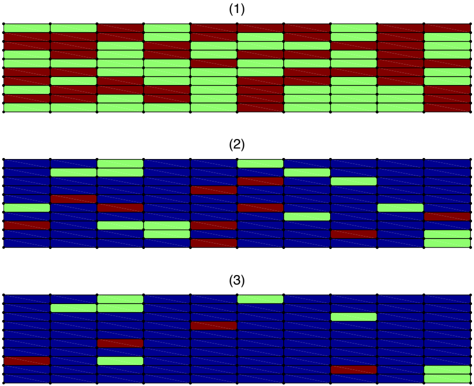

Figure: Society, preference shock, and search for partners.

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  7. Today would be the same as the mode for the last five periods.

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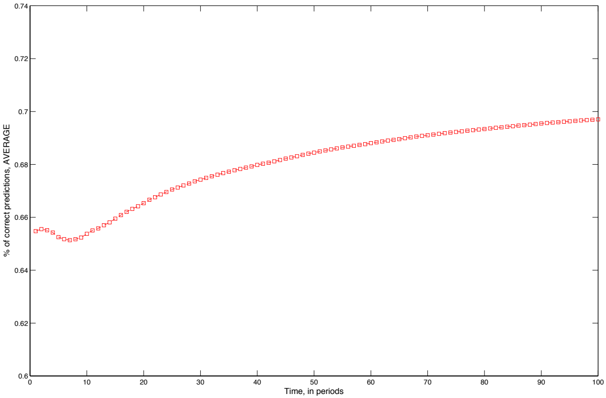
- Depending on the realized outcome, a predictor's strength gets updated by

$$\Delta S = \begin{cases} +1 & \text{if the forecast is correct} \\ -1 & \text{if the forecast is incorrect} \end{cases}$$

Learning simulation

We use 400 persons over a time span of 100 periods in a simulation with 100 realizations:



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	forecast	strength	payoff (join)	payoff (not join)
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- The decision is based on the weighted sum of payoffs.

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- In addition we give the bank the reach of its new members

Experiment: bank formation

Experiment (continued): established banks

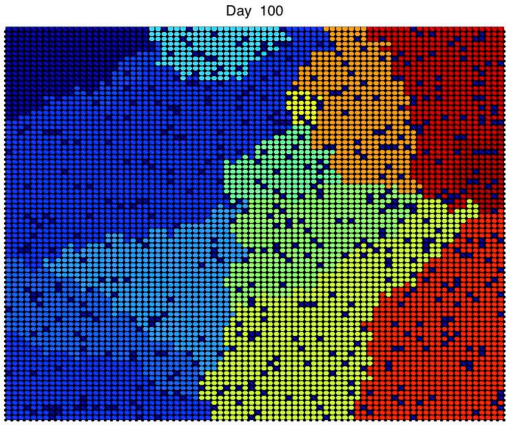
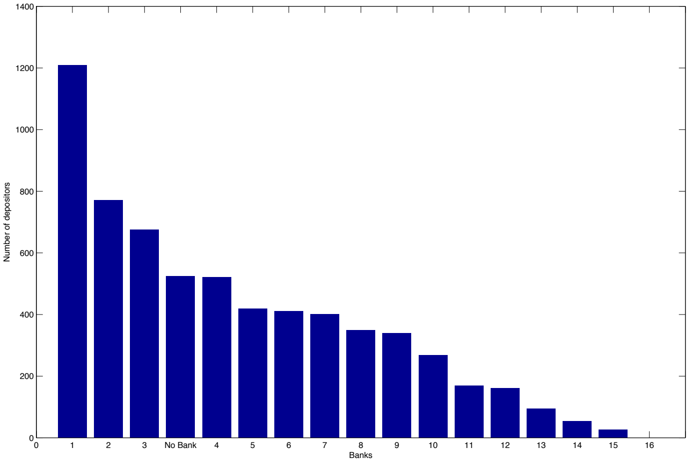


Figure: Banks at T=100 with $c_1 = 1.1$, $c_2 = 1.5$ and $R = 2$

Experiment (continued): number of depositors



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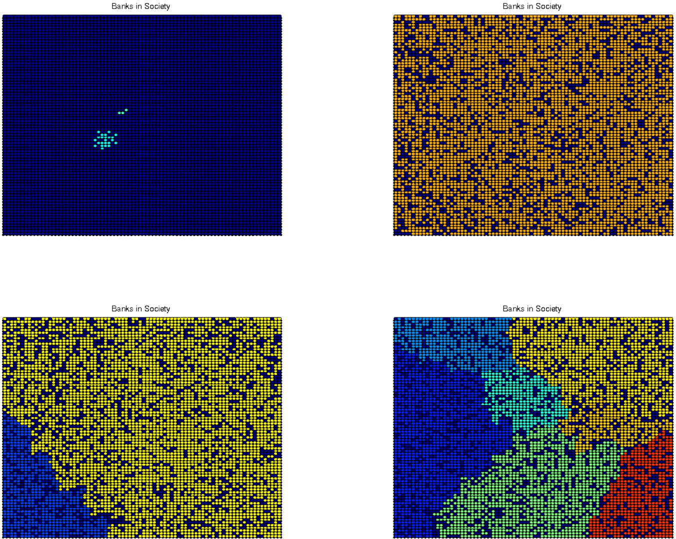
- If a bank survives at period k, it updates the estimate of early consumers according to

$$W_{k+1}^i = W_k^i + \alpha(\overline{W}_k^i - W_k^i) \tag{6}$$

reflecting adaptation through a parameter $\alpha \in (0, 1)$.

Experiment: bank formation and runs

Experiment: established banks (with possible runs)



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- They use the same set of predictors as clients to forecast the adequacy of their estimates as being ‘adequate’, ‘inadequate’ or ‘undetermined’.
- Banks with inadequate or undetermined estimates have an incentive to exchange deposits with other banks and try to protect their reserves.

Experiment: adequacy of estimates through time

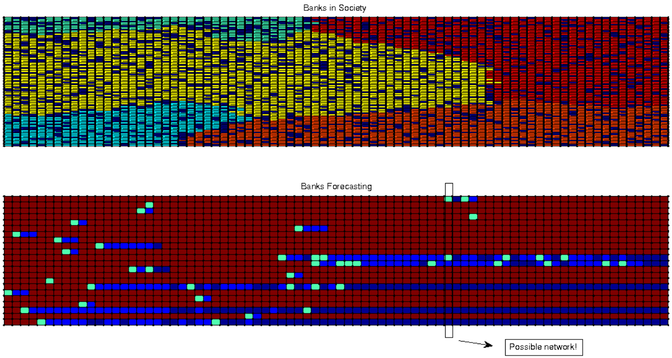


Figure: Banks at T=100 with $c_1 = 1.1$, $c_2 = 1.5$ and $R = 2$ and adequacy of estimates over time.

Experiment: possible network

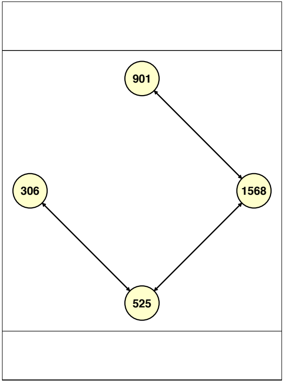
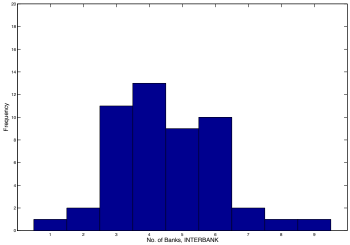
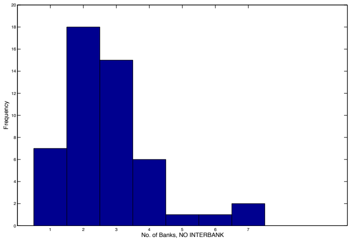


Figure: Snapshot of possible interbank loans

Number of established banks with and without interbank links





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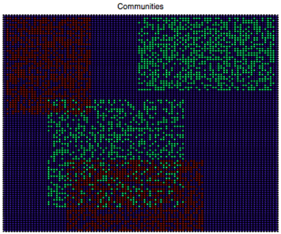
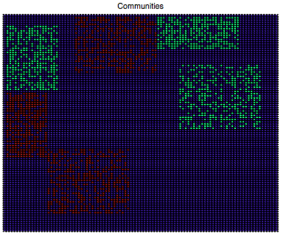
  4. Alter half of the communities to early preferences and half of the communities to late preferences.

Examples of correlated liquidity shocks





Experiment: bank formation and runs with correlated shocks

Experiment: adequacy of estimates through time (with correlated shocks)

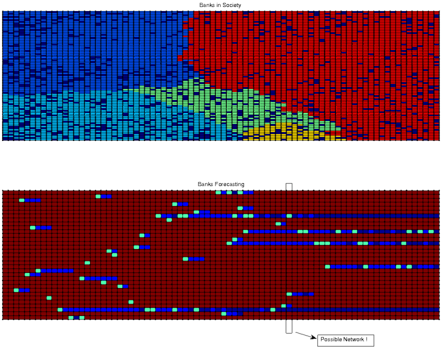
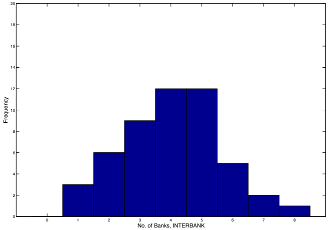
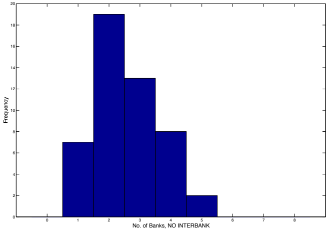


Figure: Banks at T=100 with $c_1 = 1.1$, $c_2 = 1.5$ and $R = 2$ and adequacy of estimates over time.

Number of established banks under correlated shocks





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- Changes in preferences lead agents to search for trading partners.
- Banks arise as providers of liquidity, but are inevitably subject to possible runs.
- Interbank loans redistributed the effect of correlated liquidity shocks across the society.
- Ultimately want to adjust model parameters to reproduced different observed networks and use it as a testbed for policy implications.