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

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- However, the principles that govern individual prudence do not necessarily apply to systems as a whole.
- 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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- Consider also 40 emerging countries episodes (36 post and 4 pre-WWII).
- Also the US in 2008 for comparison.

Incidence of banking crises

Region or group	Share of years in banking crises since independence or 1800	Number of banking crises
Africa	12.5	1.7
Asia	11.2	3.6
Europe	6.3	5.9
Latin America	4.4	3.6
North America	11.2	10.5
Oceania	4.8	2.0
Advanced economies	7.2	7.2
Emerging economies	8.3	2.8

Table: Reinhart and Rogoff (2009) - Table 10.5

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- Real public debt increases on average by 86% by $t+3$

Capital mobility and banking crises

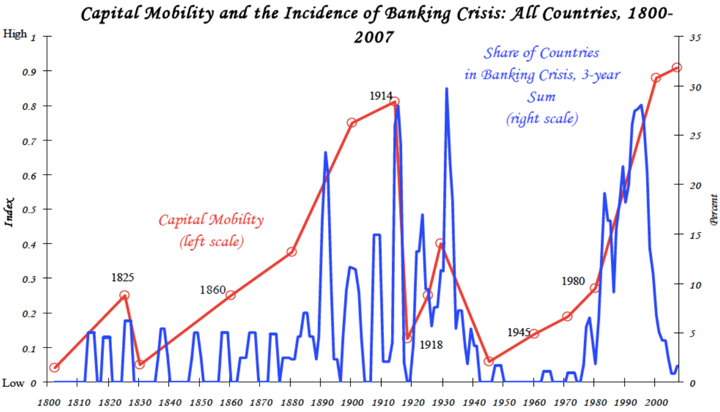

Figure: Reinhart and Rogoff (2009) - Figure 10.1

Current account balance/GDP and banking crises in advanced economies (1945-2008)

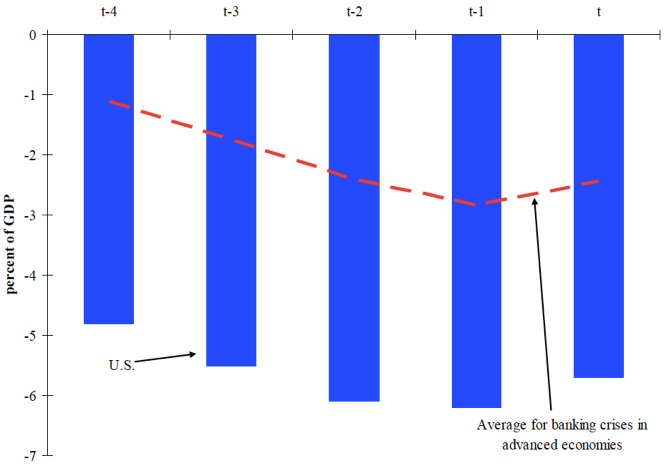

Figure: Reinhart and Rogoff (2009) - Figure 13.5

Real housing prices and banking crises in advanced economies (1945-2008)

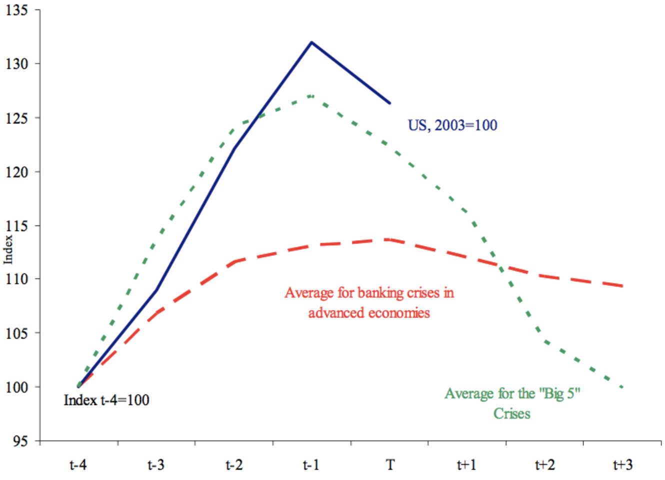

Figure: Reinhart and Rogoff (2009) - Figure 13.3

Equity prices and banking crises in advanced economies (1945-2008)

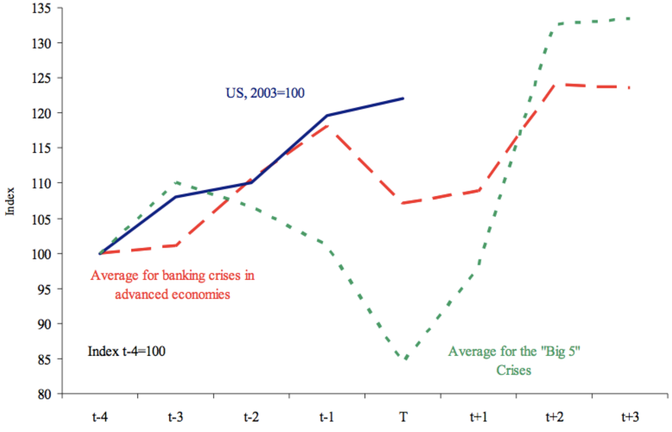

Figure: Reinhart and Rogoff (2009) - Figure 13.4

Growth in real GDP per capita and banking crises in advanced economies (1945-2008)

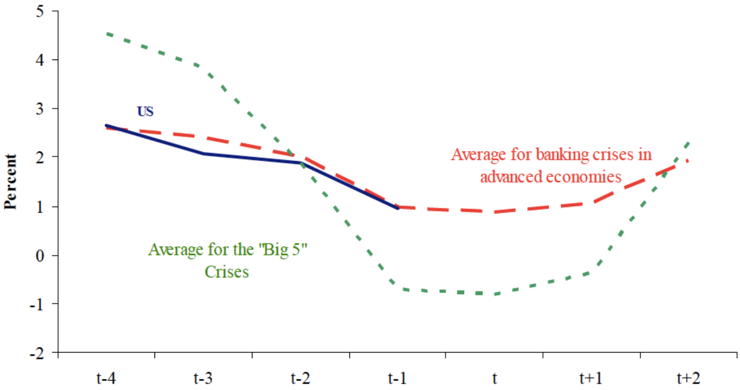

Figure: Figure 13.6 in RR

Central government debt and banking crises in advanced economies (1945-2008)

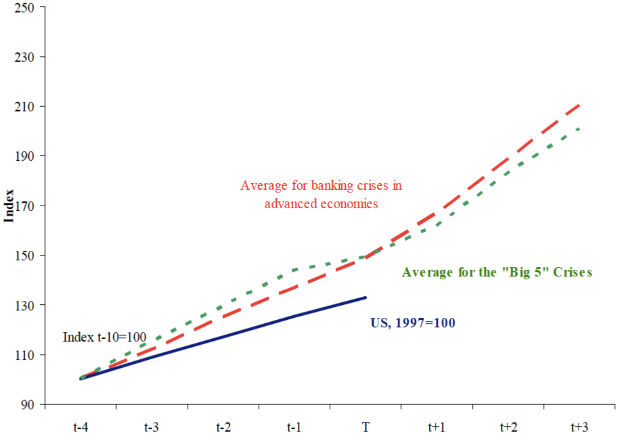

Figure: Reinhart and Rogoff (2009)- Figure 13.7

Dynamic General Equilibrium views

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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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- Equilibrium is just one possible outcome, not assumed a priori.
- 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.

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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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- 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

$$c_1^2 = c_2^1 = 0 \tag{2}$$

$$u'(c_1^1) = Ru'(c_2^2) \tag{3}$$

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

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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

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where $b^i_k \in \{0,1\}$ are Bernoulli random variables and ε^i_k 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

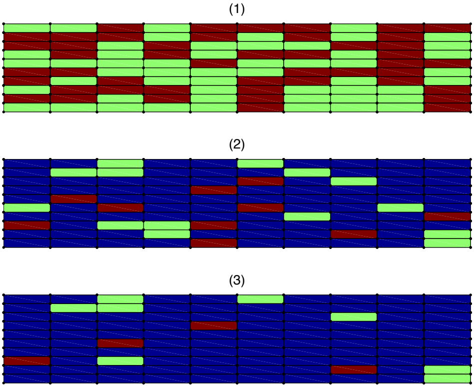

Figure: Society, preference shock, and search for partners.

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  1. Today would be the same as last period.
  2. Today would be the same as two periods ago.
  3. Today would be the same as three periods ago.
  4. Today would be the same as four periods ago.
  5. Today would be the same as five periods ago.
  6. Today would be the same as the mode for the last three periods.

Inductive reasoning

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

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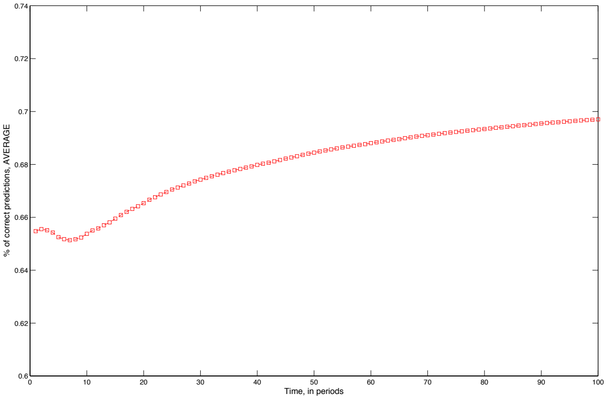
- Depending on the realized outcome, a predictor's strength gets updated by

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

Learning simulation

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



To join or not to join a bank

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	forecast	strength	payoff (join)	payoff (not join)
1	N	-2	c_2	R
2	G	0	c_1	1
3	N	$+1$	c_2	R
4	B	-1	c_1	r
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- The decision is based on the weighted sum of payoffs.

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- Individuals become aware of bank existence only if the bank lies in their neighbourhood
- In addition we give the bank the reach of its new members

Experiment: bank formation

Experiment (continued): established banks

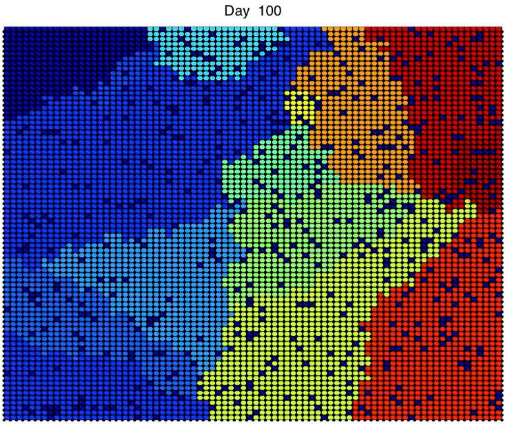
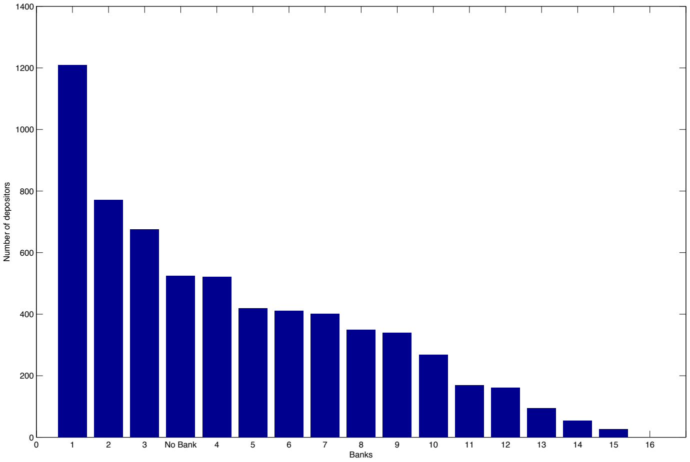


Figure: Banks at T=100 with $c_1 = 1.1$, $c_2 = 1.5$ and $R = 2$

Experiment (continued): number of depositors



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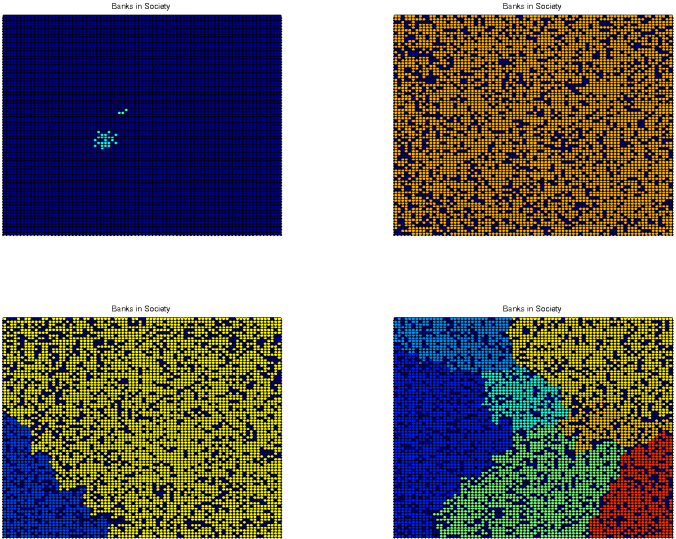
- We say that a bank is subject to a run if late consumers receive less than c_1 at the end of the period.
- If a bank survives at period k, it updates the estimate of early consumers according to

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

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

Experiment: bank formation and runs

Experiment: established banks (with possible runs)



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- In addition, they deem the estimate to be adequate if the fraction of reserves lost in a given period is less than a certain threshold.
- 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

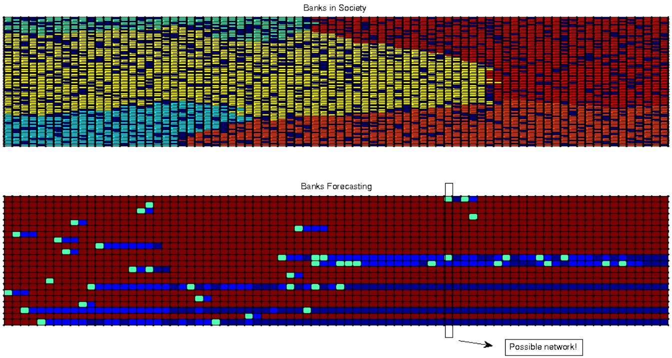


Figure: Banks at T=100 with $c_1 = 1.1$, $c_2 = 1.5$ and $R = 2$ and adequacy of estimates over time.

Experiment: possible network

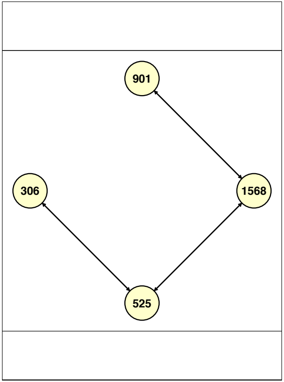
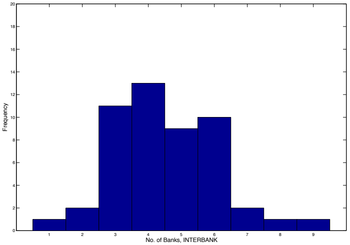
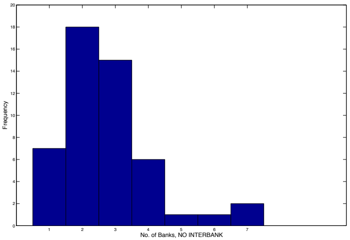


Figure: Snapshot of possible interbank loans

Number of established banks with and without interbank links





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Correlated liquidity shocks

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

Matheus R. Grasselli

Introduction

Banking crises throughout history

DSGE x ABM

The pre-banking society

Bank formation

Bank runs

Interbank networks

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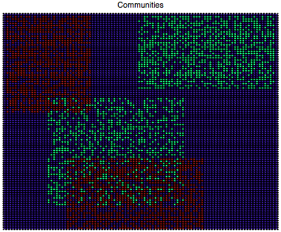
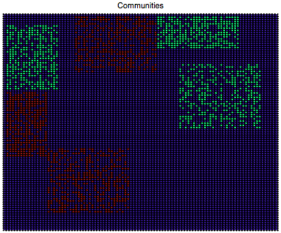
  4. Alter half of the communities to early preferences and half of the communities to late preferences.

Examples of correlated liquidity shocks





Experiment: bank formation and runs with correlated shocks

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

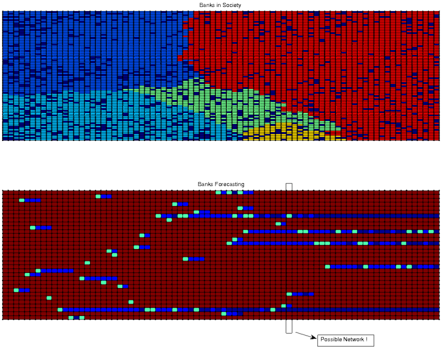
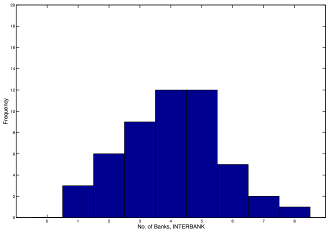
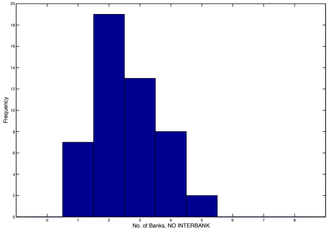


Figure: Banks at T=100 with $c_1 = 1.1$, $c_2 = 1.5$ and $R = 2$ and adequacy of estimates over time.

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.