Endogenous Banks' Networks, Cascades and Systemic Risk

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Motivation

During recent financial crisis numerous prudential policy measures to counter **systemic risk** have been proposed.

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In this paper we:

- develop a **network model** in which banks choose their optimal portfolio via maximizing profit subject to regulatory constraints;
- allow for an **endogenously evolving** financial system/interbank market structure;
- can use the model to investigate **systemic risk**.

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- allow for an **endogenously evolving** financial system/interbank market structure;
- can use the model to investigate **systemic risk**.

Question investigated:

What are the effects of regulatory taxation on the financial system structure and systemic risk?

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1. Model
2. Regulatory Taxation and Systemic Risk
3. Conclusion and Outlook

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Network Model of Heterogenous Banks: Portfolio Optimization

- Model consists of N bank balance sheets:

Assets	Liabilities
Cash	Deposits
Bank lending	Bank borrowing
Non-liquid assets (nla)	Equity

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$\Rightarrow$ How to generate and analyze financial system from microfounded decisions?

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Stage 1: Establish **financial system matrix**
$\rightarrow$ Determine **optimal portfolio** for each bank

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Stage 3: Investigate financial system after shock is absorbed
$\rightarrow$ Compute **systemic risk** and **banks' contribution**

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- **Risk charges** affect **banks' expected profit**:

$$max \quad E(\pi^i) = E(\pi^{lending^i}) + E(\pi^{nla^i} - F(\beta_1)) - E(cost^{borrowing^i} + F(\beta_2))$$

where β_1 and β_2 are risk charges on non-liquid asset investments and banks' interconnectedness, respectively.

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$\Rightarrow$What are the effects of regulatory taxation on financial system structure and stability?

Regulatory Taxation and Systemic Risk

- Effect of risk charge on **non-liquid assets**:
  System becomes **more heterogenous and interconnected**;
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- Effect of risk charge on **interconnectedness**:
  System becomes **less interconnected and heterogenous**;

- Both charges incentivize **banks to lower contribution** to systemic risk, causing overall systemic risk to go down.

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Conclusion and Outlook

- Microfounded network model allows for investigating systemic risk in endogenously evolving financial system;
- Risk charges incentivize banks to lower contribution to systemic risk and therefore lower overall systemic risk;
- Several model extensions under construction (central bank, different shocks, multiperiod, robustness etc.).

References

Cifuentes, R., G. Ferrucci, and H.S. Shin (2005): Liquidity Risk and Contagion, *Journal of the European Economic Association*, 3, 556-566.

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Eisenberg, L. and T. H. Noe (2001): Liquidity Risk and Contagion, *Management Science*, 47, 236-249.

Financial Stability Board, International Monetary Fund, and Bank for International Settlements (2009): Guidance to Assess the Systemic Importance of Financial Institutions, Markets and Instruments: Initial considerations, *Report to the G-20 Finance Ministers and Central Bank Governors*.

Financial System Matrix

	Bank 1	Bank 2	...	R.O.W.	
				NLA	C
Bank 1					
Bank 2					
⋮					
R.O.W.					

Financial System Matrix Found via Iterative Algorithm

1. Banks **optimize** portfolios for given **parameters**[1] and interbank rates $r^i = r^i\left(r^{rf}, r^{rp}\left(PD^i\right)\right)$;
   $\rightarrow$ Obtain aggregate demand and supply on interbank market;

[1] Deposits, equity^i, return on non-liquid assets, and regulatory constraints.

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3. For given market equilibrium, interbank fund allocation found via **counterparty matching**;

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5. **Iterate** over steps 1 to 4 until PDs converge.

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Shock Absorption

- Shock absorption similar to Cifuentes, Ferruci, and Shin (2005), using an iterative clearing algorithm based on Eisenberg and Noe (2001);

- Contagion (banks' negative externality) occurs via

  $\Rightarrow$ interbank market exposure, and

  $\Rightarrow$ firesales (marking-to-market mechanism).

Analyzing Systemic Risk in the Model

Systemic risk is defined as

"a risk of disruption to financial services that is (i) caused by an impairment of all or parts of the financial system and (ii) has the potential to have serious negative consequences for the real economy." (FSB, IMF, and BIS; 2009)

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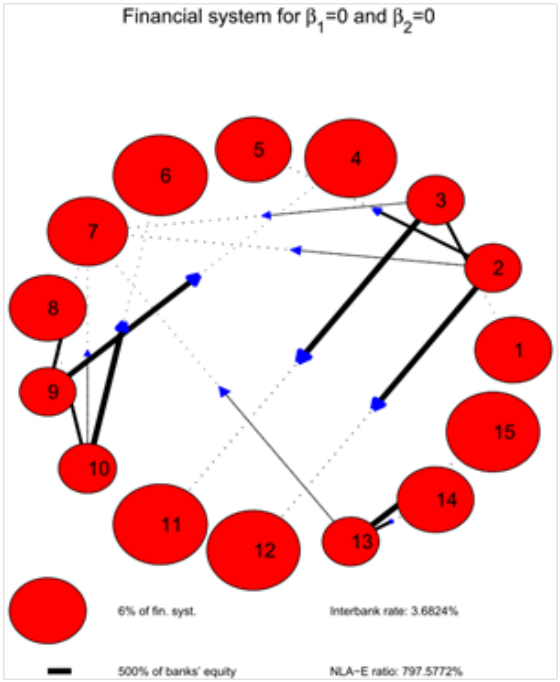
To measure contribution to systemic risk we use an approximated **Shaply value**:
$\hat{\phi}_i(v) = \frac{1}{I} \sum_{K_I \ni i; K_I \subset I} v(K) - v(K - \{i\})$.

Risk Charge on Non-Liquid Asset Investments



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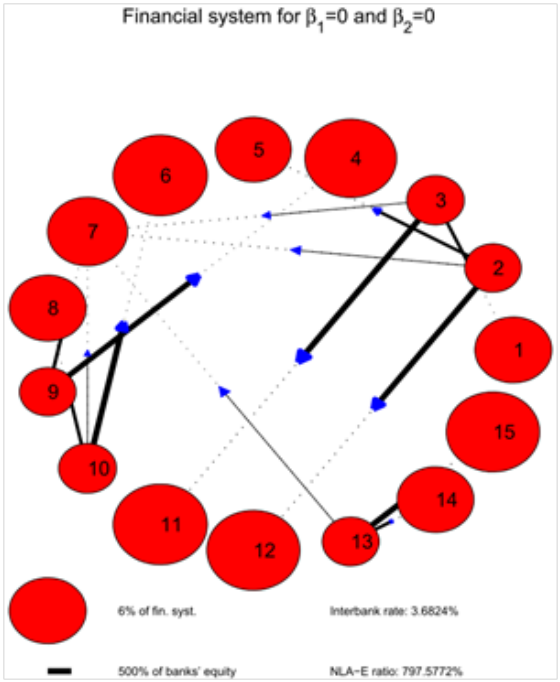

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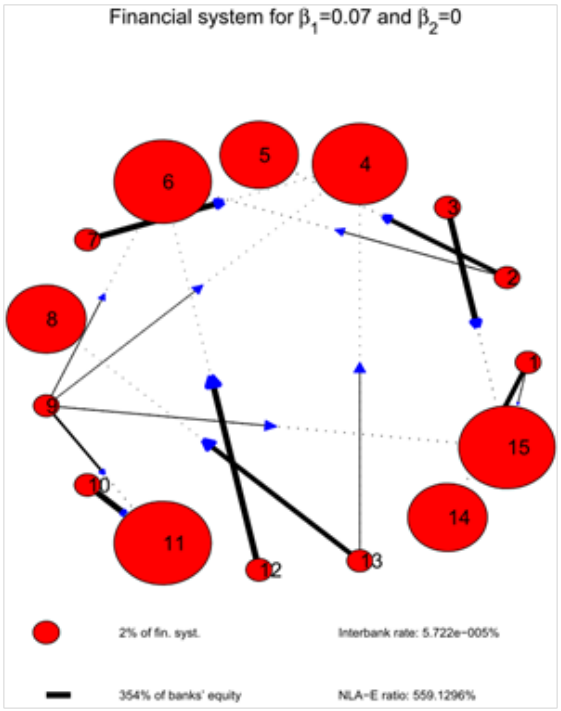

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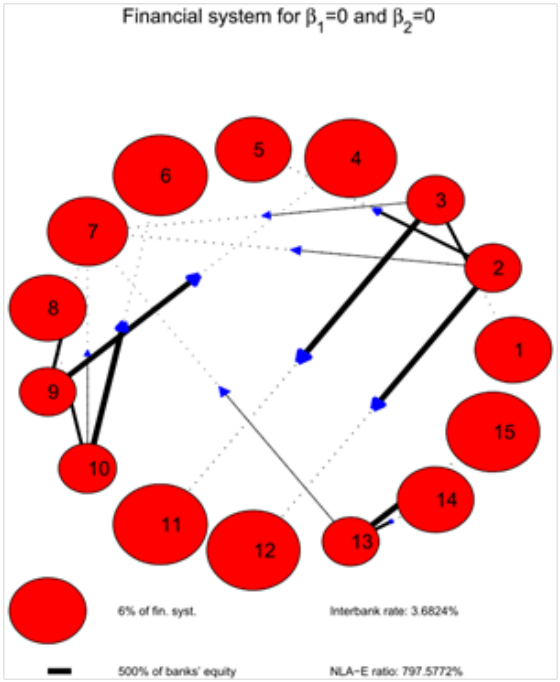

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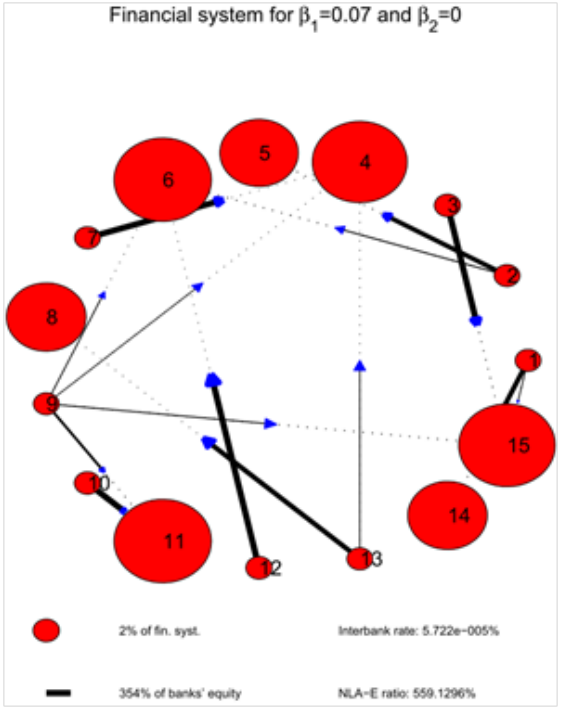

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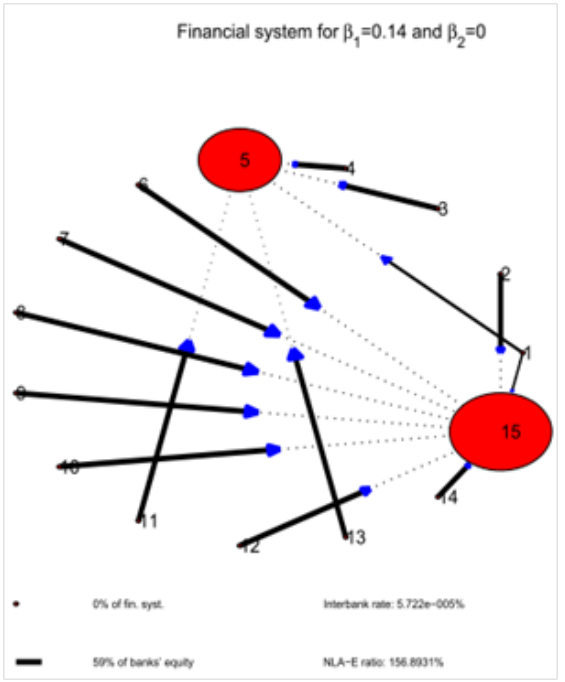

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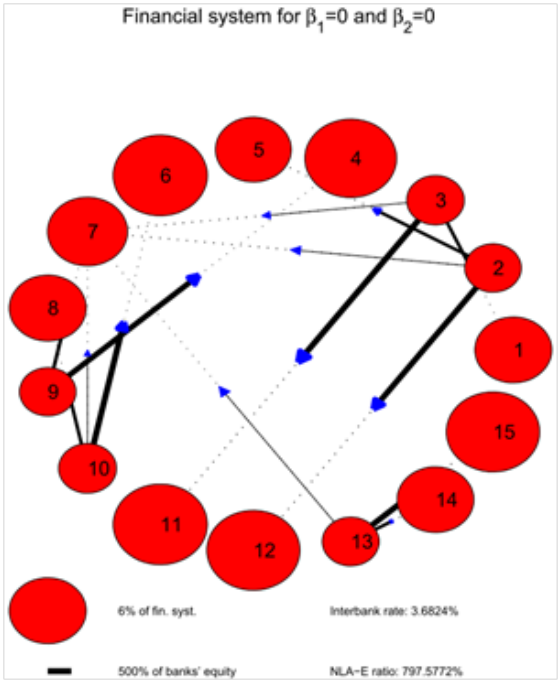

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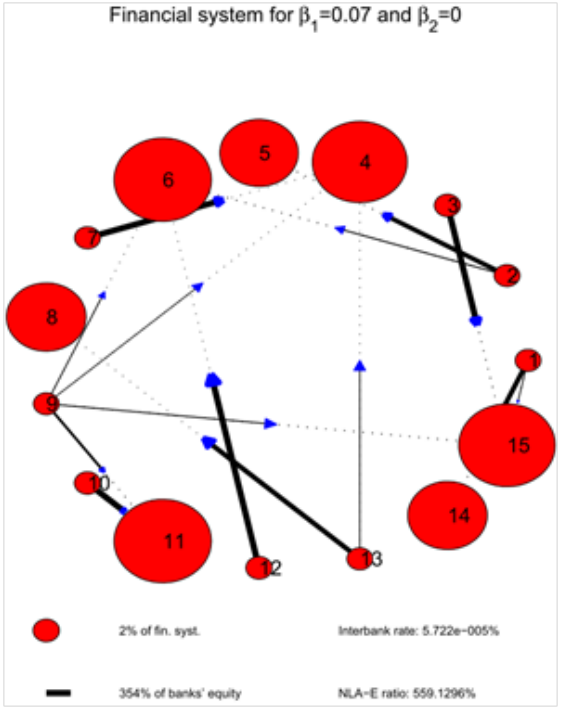

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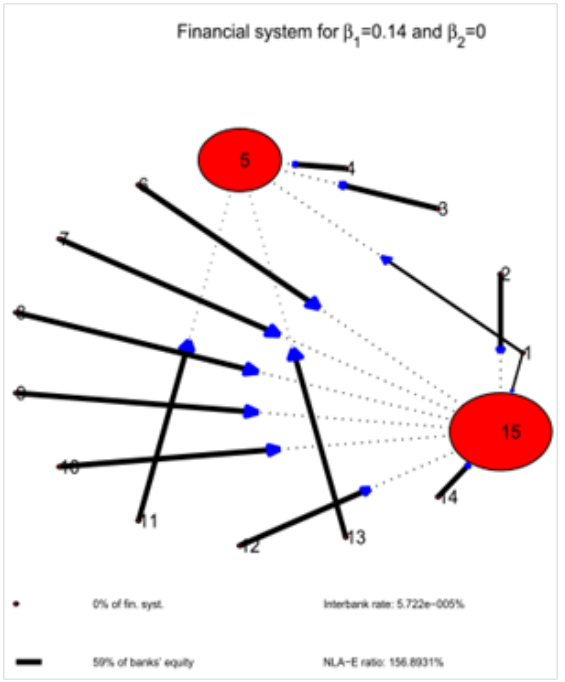

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- Risk charge on nla↑

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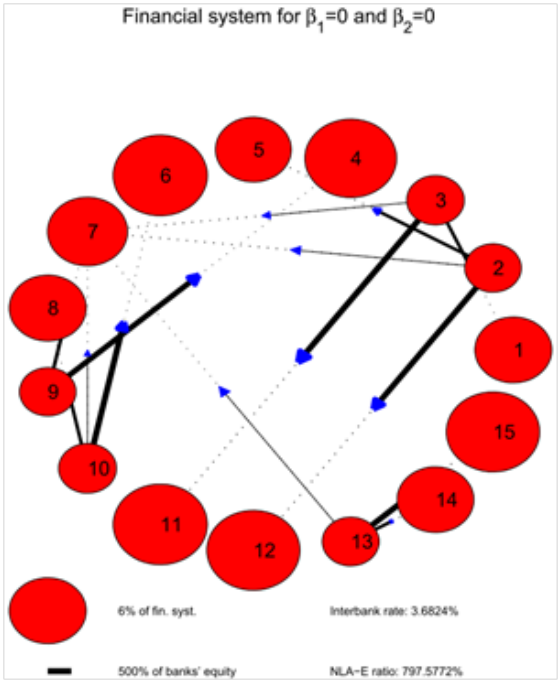

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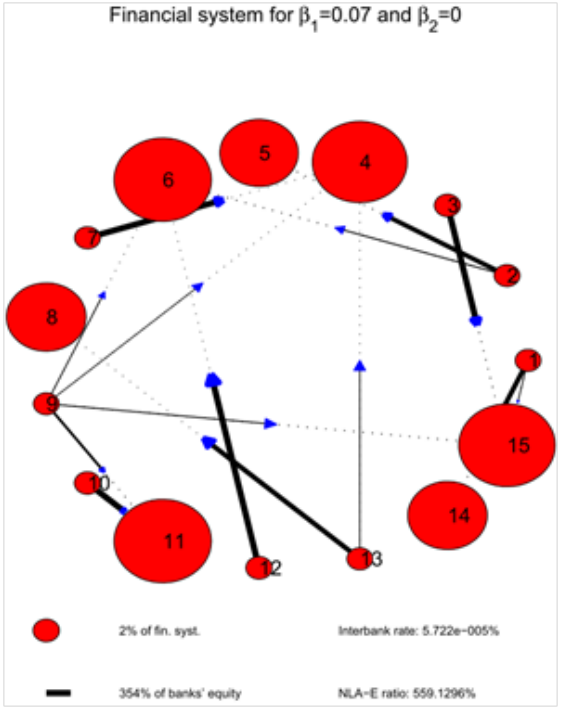

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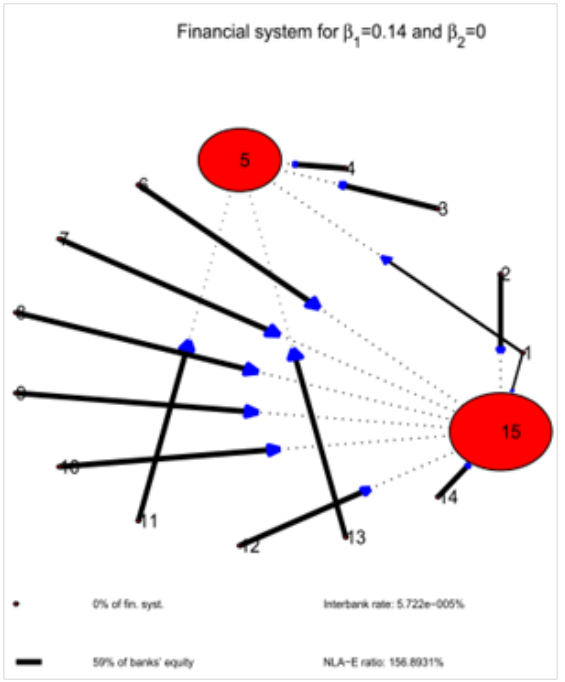

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- Risk charge on nla$\uparrow \Rightarrow$yield on nla$\downarrow$

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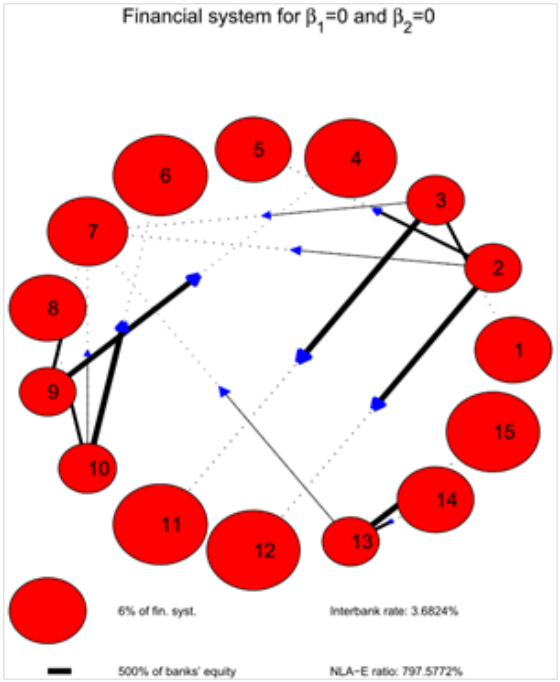

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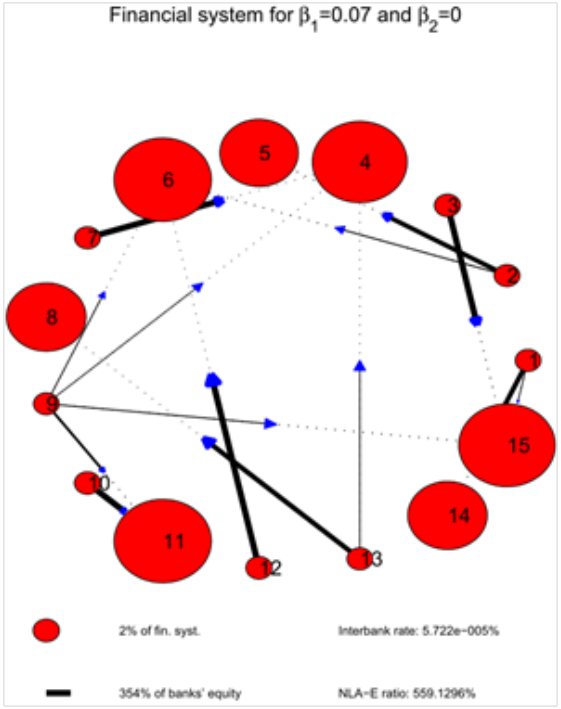

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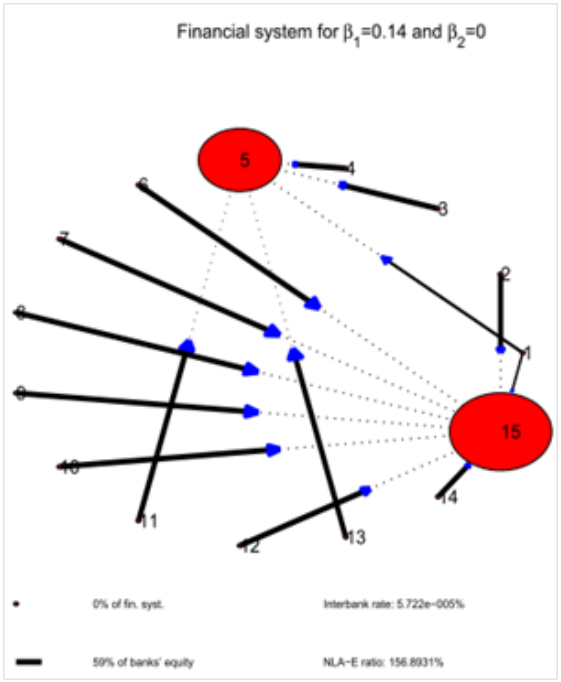

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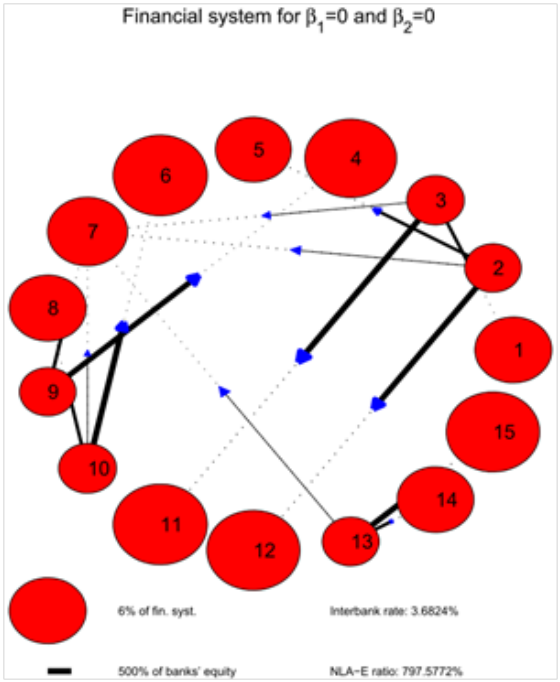

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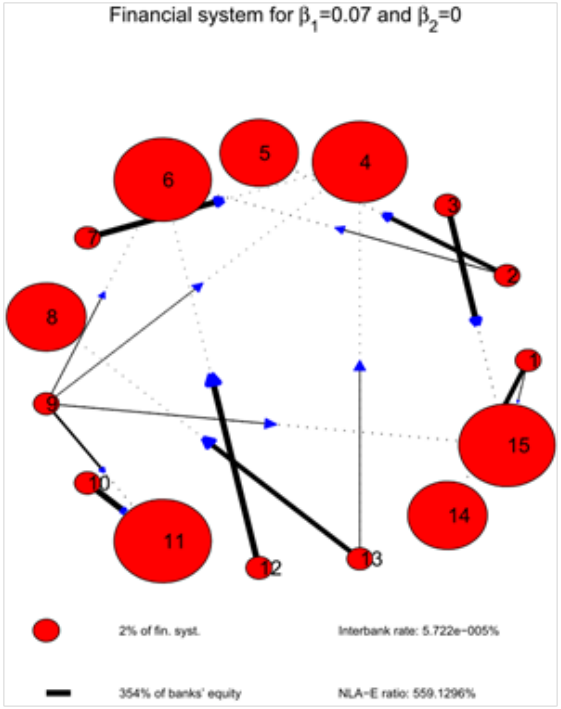

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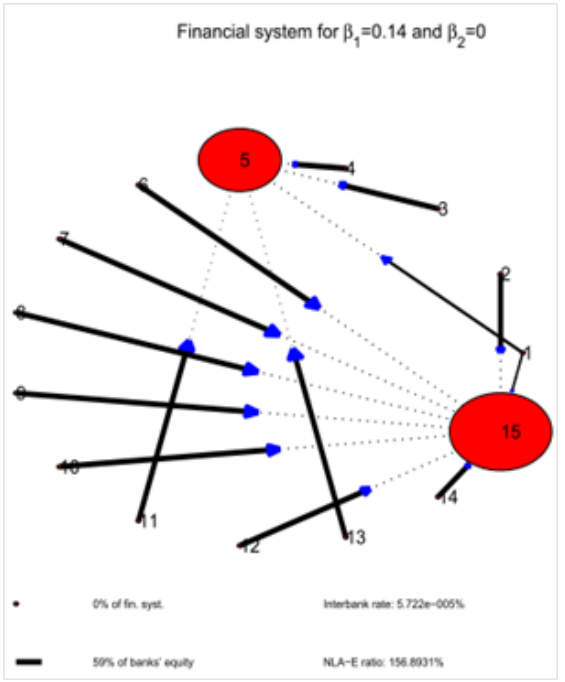

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- Results: interbank market rates ↓; financial system heterogeneity and interonnectedness ↑; overall investment in nla ↓.

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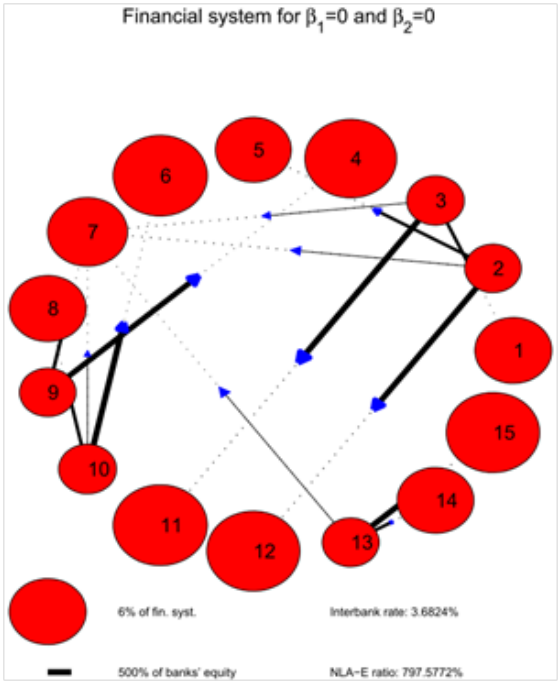

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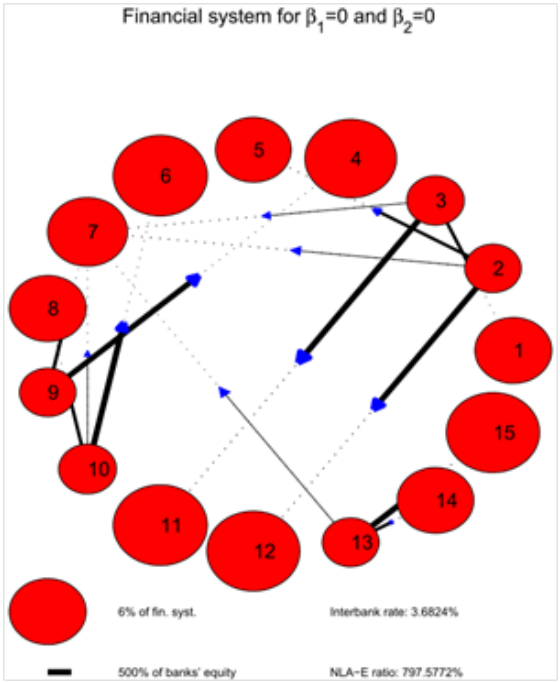

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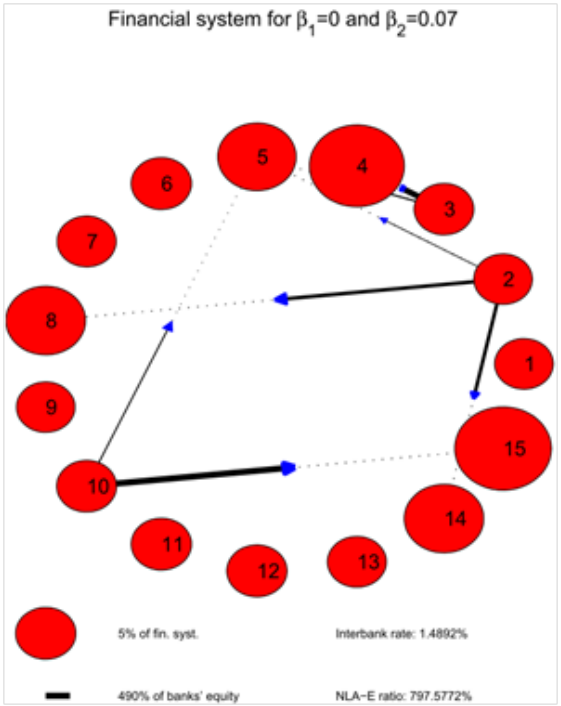

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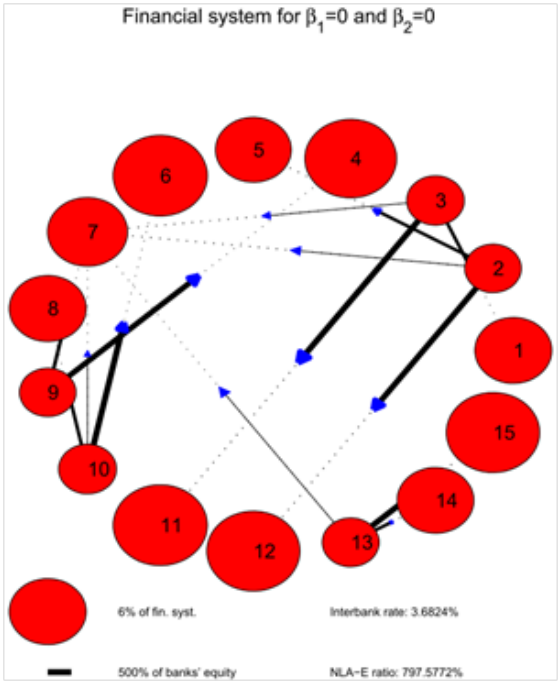

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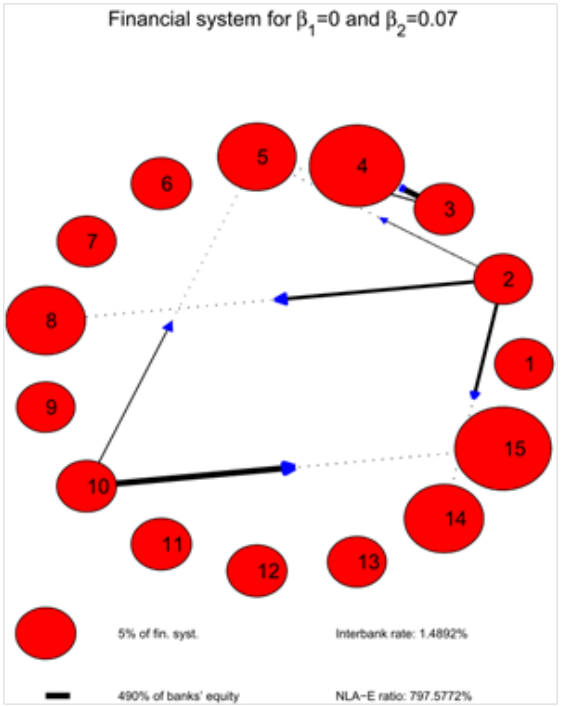

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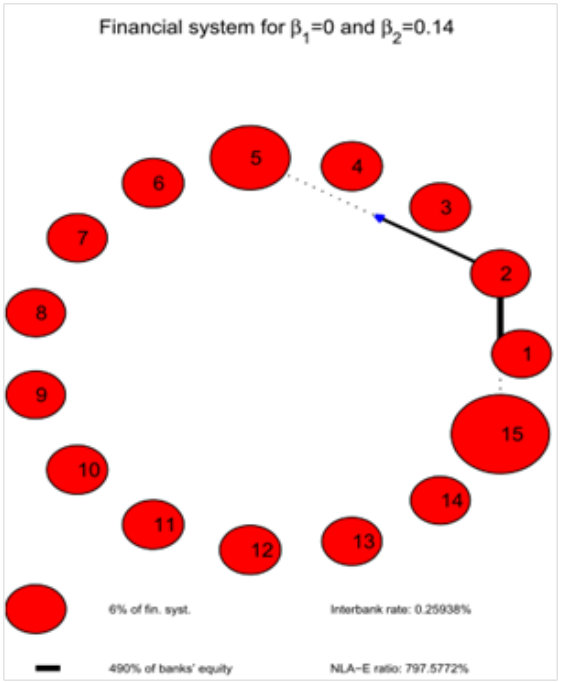

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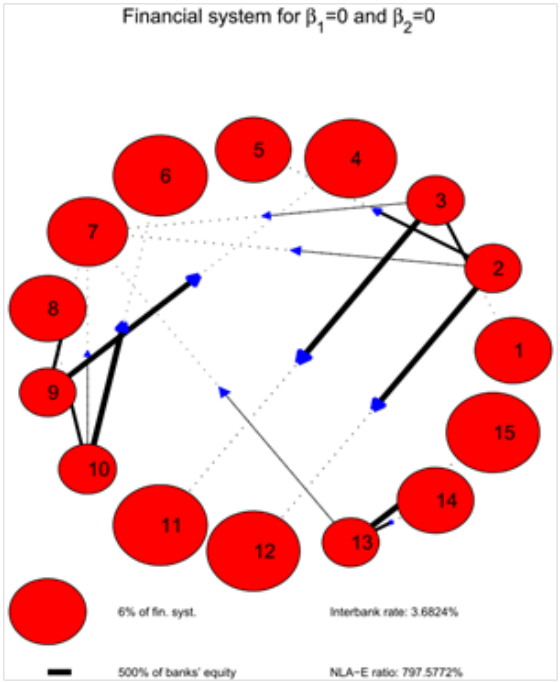

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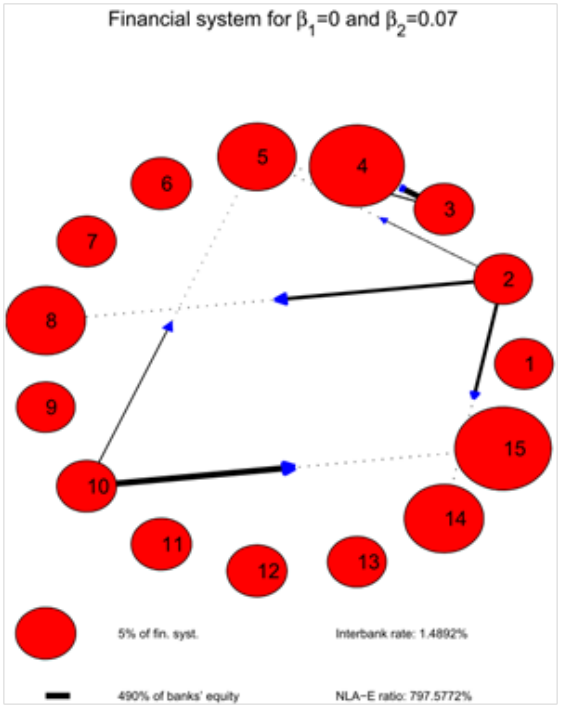

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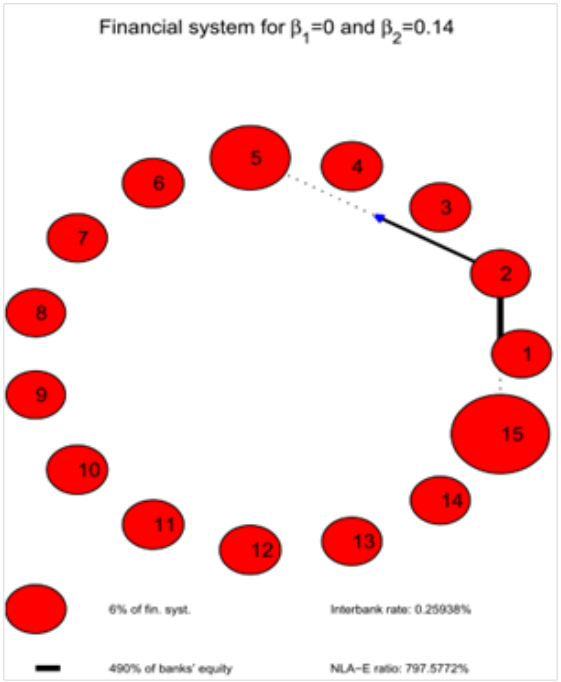

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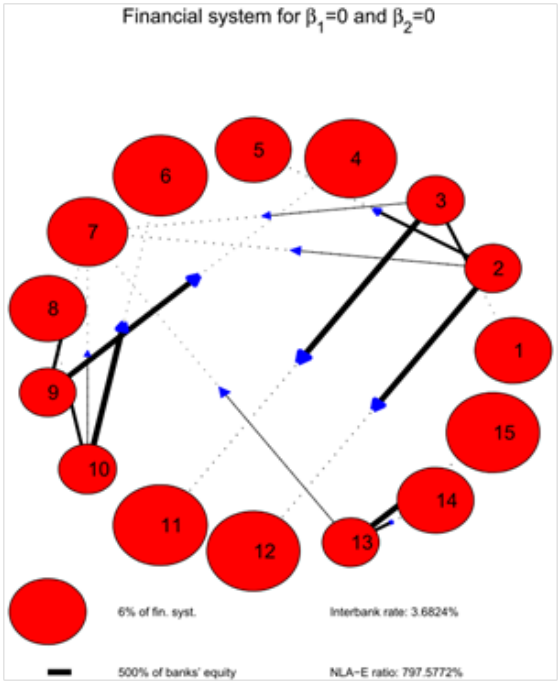

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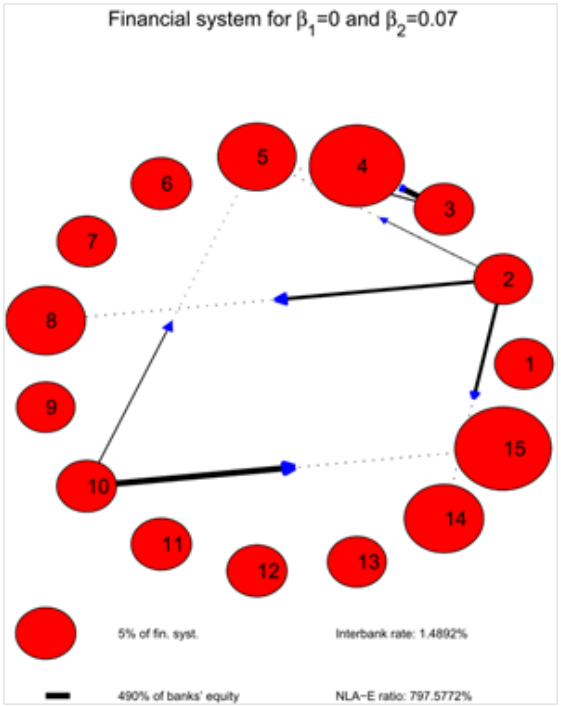

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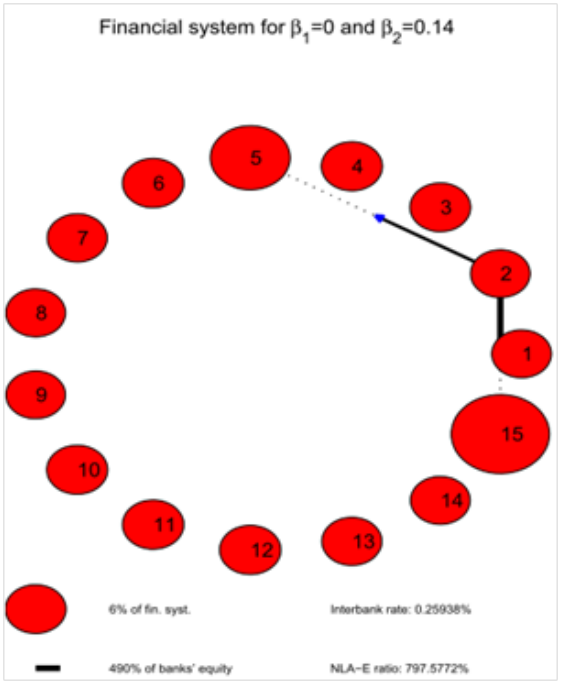

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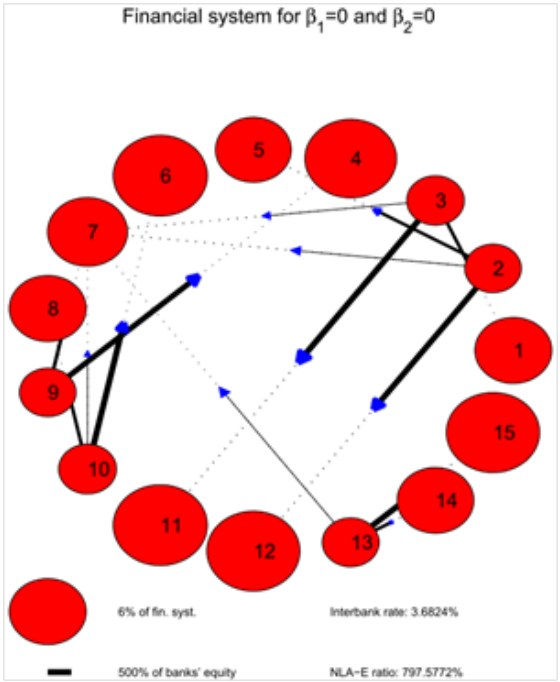

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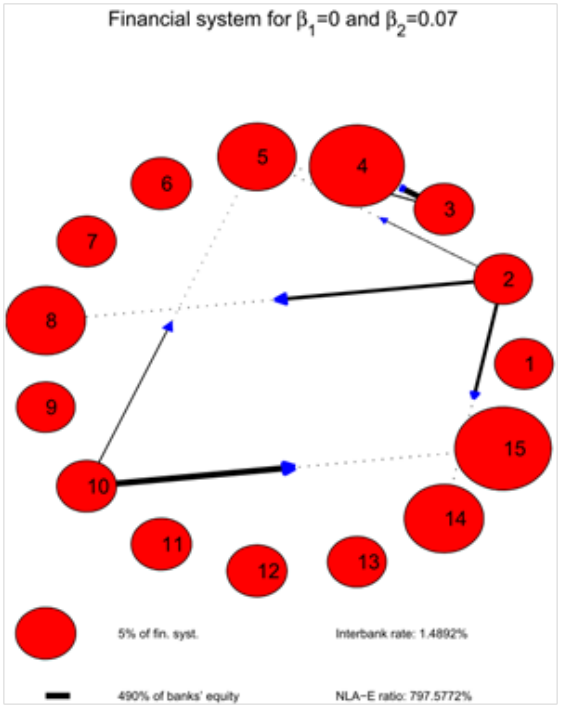
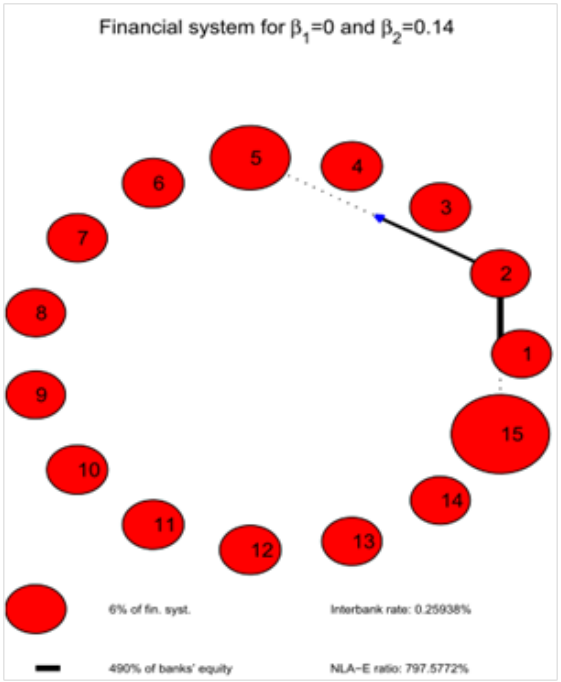


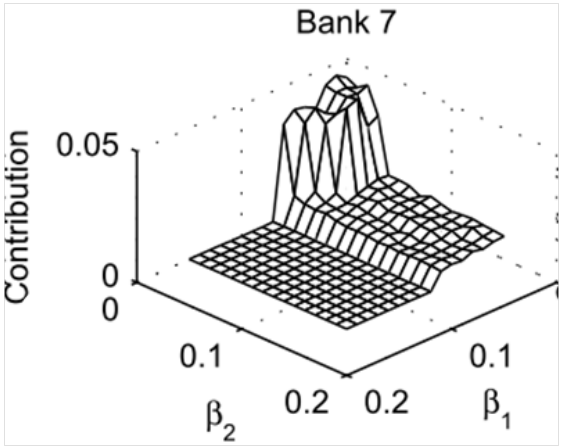
(b) Low risk charge



(c) High risk charge

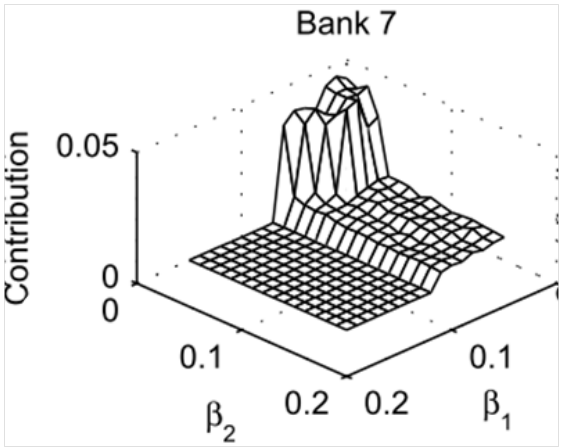
- Risk charge on interconnectedness$\uparrow \Rightarrow$fraction of banks engageing in borrowing $\downarrow$;
- Results: interbank market rates $\downarrow$; financial system heterogeneity and interonnectedness $\downarrow$.

Prudential Policy Regimes: Systemic Risk Charge

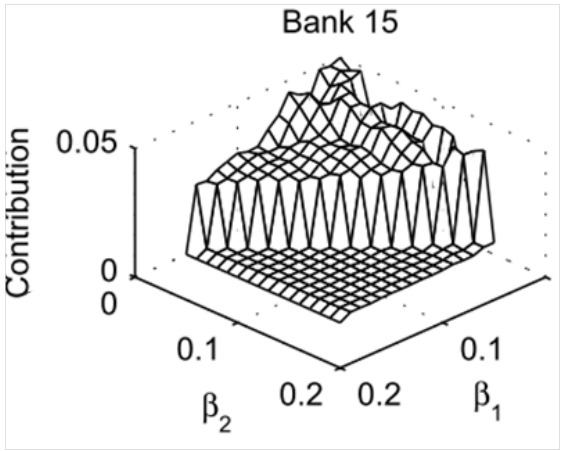


(a) Contr. of Bank 7

Prudential Policy Regimes: Systemic Risk Charge

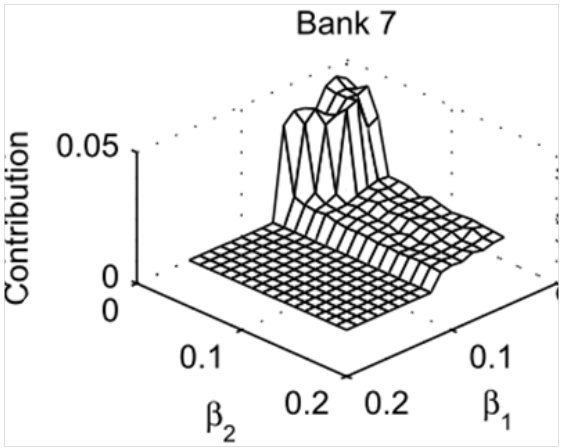


(a) Contr. of Bank 7

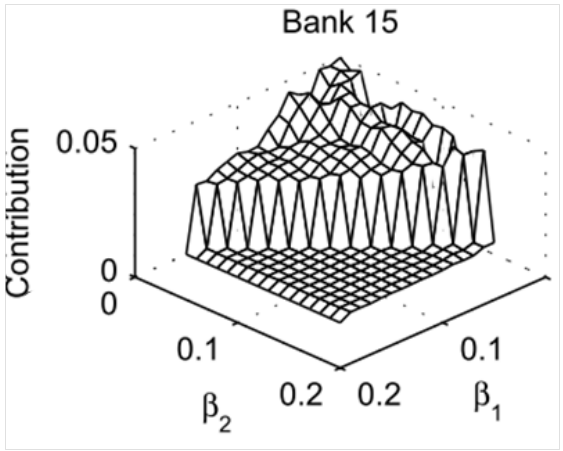


(b) Contr. of Bank 15

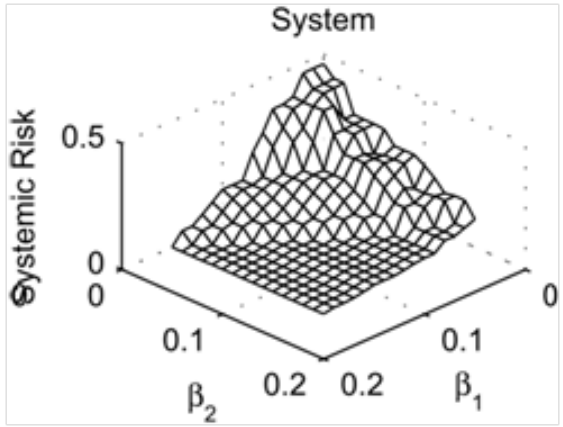
Prudential Policy Regimes: Systemic Risk Charge



(a) Contr. of Bank 7



(b) Contr. of Bank 15



(c) Systemic Risk

Network Model of Heterogenous Banks: Portfolio Optimization

Assets	Liabilities
Cash (c^i)	Deposits (d)
Bank lendings (bl^i)	Bank borrowings (bb^i)
Non-liquid assets (nla^i)	Equity (e^i)

$$max_{bl^i, nla^i, bb^i, c^i} \quad E(\pi^i) = bl^i \cdot r^{rf} + \frac{r^{i,nla}}{p} \cdot nla^i - bb^i \cdot r^{rf} \cdot \frac{1}{1 - \xi PD^i}$$

s.t.

- $c^i \geq \alpha \cdot d$;
- $er^i = \frac{c^i + p^{nla} \cdot nla^i + bl^i - d - bb^i}{\chi_1 \cdot p^{nla} \cdot nla^i + \chi_2 bl^i} \geq \gamma + \tau$;
- further (feasibility) constraints.

Network Model of Heterogenous Banks: Portfolio Optimization

Assets	Liabilities
Cash (c^i)	Deposits (d)
Bank lendings (bl^i)	Bank borrowings (bb^i)
Non-liquid assets (nla^i)	Equity (e^i)

$$max_{bl^i, nla^i, bb^i, c^i} \; E(\pi^i) = bl \cdot r^{rf} + \frac{(r^{i,nla} - \beta_2)}{p} \cdot nla^i - bb^i \cdot \left(r^{rf} \cdot \frac{1}{1 - \xi PD^i} + \beta_1 \right)$$

s.t.

- $c^i \geq \alpha \cdot d$;
- $er^i = \frac{c^i + p^{nla} \cdot nla^i + bl^i - d - bb^i}{\chi_1 \cdot p^{nla} \cdot nla^i + \chi_2 bl^i} \geq \gamma + \tau$;
- further (feasibility) constraints.

Baseline Setting: Parameter Choice

Parameter	Source	Value
Liquidity requirement	0.1	Required cash reserve in U.S.
Capital requirement	0.08	FED regulatory agency definition
Risk weight on nla	1	Basel II (commercial bank loans)
Risk weight on ibm	0.2	Interb. dep. betw. OECD countr.
Deposits	600	See DB Q1 2012
Equity	$N(65, 10)$	See DB Q1 2012
Yield on NLA	$U(0, 0.15)$	Free parameter
Shock	$MVN(5, 25)$	Free parameter