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

1. Model

2. Regulatory Taxation and Systemic Risk

3. Conclusion and Outlook
Network Model of Heterogenous Banks: Portfolio Optimization

Model consists of $N$ bank balance sheets:

<table>
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<tr>
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Banks choose balance sheet via maximizing expected profit:

$$\max E(\pi^i) = E(\pi^{lending^i}) + E(\pi^{nla^i}) - E(cost^{borrowing^i})$$
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s.t.
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s.t.
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⇒ How to generate and analyze financial system from microfounded decisions?
Stage 1: Establish financial system matrix
→ Determine optimal portfolio for each bank
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Stage 2: Financial system exposed to shock
→ Contagious **shock absorption**, banks re-optimize portfolio
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   → Determine **optimal portfolio** for each bank

Stage 2: Financial system exposed to shock
   → Contagious **shock absorption**, banks re-optimize portfolio

Stage 3: Investigate financial system after shock is absorbed
   → Compute **systemic risk** and banks’ contribution
1. Model

2. Regulatory Taxation and Systemic Risk

3. Conclusion and Outlook
Different prudential policy regimes affect financial system via regulatory requirements (constraints) and risk charges (objective function);
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Banks optimization affected by regulatory policy changes, resulting in an endogenous reaction of the equilibrium financial system to macroprudential policy;
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Banks optimization affected by regulatory policy changes, resulting in an endogenous reaction of the equilibrium financial system to macroprudential policy;

Risk charges affect banks’ expected profit:

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

where \(\beta_1\) and \(\beta_2\) are risk charges on non-liquid asset investments and banks’ interconnectedness, respectively.
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What are the effects of regulatory taxation on financial system structure and stability?
Effect of risk charge on **non-liquid assets**: System becomes **more heterogenous and interconnected**; Potential of firesales decreases;

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Effect of risk charge on **non-liquid assets**: System becomes **more heterogenous and interconnected**; Potential of firesales decreases;

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

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.
Agenda

1. Model

2. Regulatory Taxation and Systemic Risk

3. Conclusion and Outlook
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.).


# Financial System Matrix

<table>
<thead>
<tr>
<th></th>
<th>Bank 1</th>
<th>Bank 2</th>
<th>...</th>
<th>R.O.W.</th>
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<td></td>
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Banks **optimize** portfolios for given parameters\(^1\) and interbank rates \(r^i = r^i(r_{rf}, r_{rp}(PD^i))\);

→ Obtain aggregate demand and supply on interbank market;

---

\(^1\)Deposits, equity\(^i\), return on non-liquid assets, and regulatory constraints.
1. Banks optimize portfolios for given parameters\(^1\) and interbank rates

\[ r^i = r^i (r^{rf}, r^{rp} (PD^i)) \]

→ Obtain aggregate demand and supply on interbank market;

2. Adjust \( r^{rf} \) in âtonnement process to match demand and supply;

→ Obtain equilibrium \( r^i \) (for given PDs);

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\(^1\)Deposits, equity\(^i\), return on non-liquid assets, and regulatory constraints.
Financial System Matrix Found via Iterative Algorithm

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

2. Adjust \( r^{rf} \) in **tâtonnement process** to match demand and supply;
   → Obtain equilibrium \( r^i \) (for given \( PDs \));

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

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

4. Expose banks to shock distribution and **update** $PD$s;

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Banks optimize portfolios for given parameters\(^1\) and interbank rates \(r^i = r^i(r^{rf}, r^{rp}(PD^i))\);

\[\rightarrow\] Obtain aggregate demand and supply on interbank market;

2. Adjust \(r^{rf}\) in tâtonnement process to match demand and supply;

\[\rightarrow\] Obtain equilibrium \(r^i\) (for given PDs);

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

4. Expose banks to shock distribution and update PDs;

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

\(^1\)Deposits, equity\(^i\), return on non-liquid assets, and regulatory constraints.
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).
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)

In our model **systemic risk** consecutive on a shock $j$ is defined as

$$\Phi_j = \frac{\sum_i b_i \text{assets}_i}{\sum_i \text{assets}_i}.$$
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“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)

In our model **systemic risk** consecutive on a shock $j$ is defined as

$$\Phi_j = \frac{\sum_{ib} assets_{ib}}{\sum_i assets_i}.$$ 

To measure contribution to systemic risk we use an approximated **Shapley value**:

$$\hat{\phi}_i(v) = \frac{1}{l} \sum_{K \ni i; K \subset I} v(K) - v(K - \{i\}).$$
Risk Charge on Non-Liquid Asset Investments

(a) No risk charges

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Risk Charge on Non-Liquid Asset Investments

(a) No risk charges

(b) Low risk charge

Results:
- Interbank market rates ↓
- Financial system heterogeneity and interconnectedness ↑
- Overall investment in NLA ↓
Risk Charge on Non-Liquid Asset Investments

(a) No risk charges

(b) Low risk charge

(c) High risk charge

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Risk Charge on Non-Liquid Asset Investments

(a) No risk charges
- Risk charge on nla ↑

(b) Low risk charge

(c) High risk charge

Results: interbank market rates ↓; financial system heterogeneity and interconnectedness ↑; overall investment in nla ↓.
Risk Charge on Non-Liquid Asset Investments

(a) No risk charges
- Risk charge on nla↑⇒yield on nla↓

(b) Low risk charge

(c) High risk charge

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Risk Charge on Non-Liquid Asset Investments

(a) No risk charges

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Risk charge on nla↑ ⇒ yield on nla↓ ⇒ fraction of banks engageing in lending ↑;

Results: interbank market rates ↓; financial system heterogeneity and interconnectedness ↑; overall investment in nla ↓.
Risk Charge on Non-Liquid Asset Investments

(a) No risk charges
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- Results: interbank market rates ↓; financial system heterogeneity and interconnectedness ↑; overall investment in nla ↓.

(b) Low risk charge

(c) High risk charge
Risk Charge on Interconnectedness

(a) No risk charges

Results: interbank market rates ↓; financial system heterogeneity and interconnectedness ↓.
Risk Charge on Interconnectedness

(a) No risk charges

(b) Low risk charge

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Risk Charge on Interconnectedness

- **(a) No risk charges**
- **(b) Low risk charge**
- **(c) High risk charge**

Results: interbank market rates ↓; financial system heterogeneity and interconnectedness ↓.
Risk Charge on Interconnectedness

(a) No risk charges

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Risk charge on interconnectedness↑

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Risk Charge on Interconnectedness

(a) No risk charges
- Risk charge on interconnectedness $\uparrow \Rightarrow$ fraction of banks engaging in borrowing $\downarrow$;

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Risk Charge on Interconnectedness

(a) No risk charges
- Risk charge on interconnectedness $\uparrow \Rightarrow$ fraction of banks engaging in borrowing $\downarrow$;
- Results: interbank market rates $\downarrow$; financial system heterogeneity and interconnectedness $\downarrow$.

(b) Low risk charge

(c) High risk charge
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

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

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.
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\max_{bl_i, nla_i, bb_i, c_i} E(\pi^i) = bl_i \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)
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s.t.

- $c_i \geq \alpha \cdot d$
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## Baseline Setting: Parameter Choice

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<td>Liquidity requirement</td>
<td>0.1</td>
<td>Required cash reserve in U.S.</td>
</tr>
<tr>
<td>Capital requirement</td>
<td>0.08</td>
<td>FED regulatory agency definition</td>
</tr>
<tr>
<td>Risk weight on nla</td>
<td>1</td>
<td>Basel II (commercial bank loans)</td>
</tr>
<tr>
<td>Risk weight on ibm</td>
<td>0.2</td>
<td>Interb. dep. betw. OECD countr.</td>
</tr>
<tr>
<td>Deposits</td>
<td>600</td>
<td>See DB Q1 2012</td>
</tr>
<tr>
<td>Equity</td>
<td>$N(65, 10)$</td>
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<td>$U(0, 0.15)$</td>
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