Co-Pierre Georg

Interdisciplinary Group of Complex Systems
Universidad Carlos III de Madrid

and

Graduate School “Foundations of Global Financial Markets”
Friedrich-Schiller-Universität Jena

CABDyN Complexity Center, Saïd Business School, Oxford University
Oxford, 02/07/2012
The financial system has become increasingly interconnected and complex.

Supervision of individual financial institutions insufficient

⇒ Network structure of interconnections matters

Systemic risk takes various forms and is highly dynamic

⇒ Better understanding needed to safeguard financial stability
The financial system has become increasingly interconnected and complex.

Supervision of individual financial institutions insufficient
⇒ Network structure of interconnections matters

Systemic risk takes various forms and is highly dynamic
⇒ Better understanding needed to safeguard financial stability

This talk: agent-based models and network theory to address these questions.
A Simple Bank Balance Sheet

Liabilities

- D
- L
- LC
- BC

Assets

- I
- E
- F
The Interconnectedness of the Financial System Increased

Figure: Deposit liabilities of euro area MFIs vs. other euro area MFIs, outstanding amounts at the end of the period, neither seasonally nor working day adjusted. Source: ECB Statistical Data Warehouse.
The Interconnectedness of the Financial System Increased

The Interconnectedness of the Financial System Increased

**Figure:** Left: Cross-border debt assets (from CPIS and BIS locational). Source: Kubelec and Sá (2010). Right: Cross-border banking (BIS locational). Source: Minoiu and Reyes (2011).
The Interconnectedness of the Financial System Increased

Figure: Global over-the-counter derivatives markets, notional amounts of contracts outstanding. Source: IMF
Indirect Linkages Amplify the Risk of Fire-sales

Figure: U.S. Mortgage-Related Securities Issuance. Source: Gorton and Metrick (2010).
Indirect Linkages Amplify the Risk of Fire-sales

Figure: Forced Sales Discounts and Time Between Sale and Event. Source: Campbell, Giglio and Pathak (2012)
Do We Need Yet Another Paper?

**Literature on Financial Networks**
- Becher et al. (2008), Gabrieli (2011), Chang et al. (2008), Brink and Georg (2011), Markose et al. (2010)

**Literature on Fire-sales**
- Shleifer and Vishny (1992): specialised asset holders are simultaneously in distress and sell to non-specialists
- Allen and Gale (1994): endogenous market participation

**Literature on Multi-Agent Models:**
- Iori et al. (2006), Nier et al. (2007)
- **However**: risk-free investments, no central bank, mechanistic agent behaviour, “fine-tuning”
What is Systemic Risk?

Definition by impact

- FSB definition: “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.”

Definition by cause

Figure: Left: direct connections (counterparty risk, contagion). Right: indirect connections (common shocks, fire-sales).
Complete dry-up of interbank markets in September 2008, central banks were forced to unprecedented non-standard measures

⇒ Q1: Can central banks stabilize interbank markets?

Systemic risk requires macroprudential oversight in addition to microprudential supervision

⇒ Q2: What are robust network structures?

Different forms of systemic risk can act differently on the financial system

⇒ Q3: What are the optimal policy responses?
Microfoundations of Banks Determine Model

Households $\rightarrow D$ $\rightarrow$ Liabilities $\rightarrow$ Assets

Co-Pierre Georg (UC3M & Jena)
Microfoundations of Banks Determine Model

Liabilities  Assets

Households $D$

Central Bank $LC$
Microfoundations of Banks Determine Model

Households → $D$ → Firms

Central Bank → $LC$ → $E$ → Central Bank

Liabilities  Assets
Microfoundations of Banks Determine Model

Households → \( D \) → Firms

Commercial Banks → \( L \) → Central Bank

Central Bank → \( LC \) → Commercial Banks

\( D \) → \( I \) → \( E \) → \( L \)
Microfoundations of Banks Determine Model

Households → $D$ → $I$ → Firms

Commercial Banks → $L$ → $E$ → Central Bank

Central Bank → $LC$ → $BC$ → Commercial Banks
Microfoundations of Banks Determine Model

Households ➔ Liabilities
Commercial Banks ➔ Assets
Central Bank ➔ Firms
Commercial Banks ➔


13 / 28
Agent Behaviour has to be Motivated

- Banks optimize their **portfolio structure and -volume** according to CRRA preferences

\[ u = \frac{1}{1 - \theta} \left( V(1 + \lambda \mu - \frac{1}{2} \theta \lambda^2 \sigma^2) \right)^{(1-\theta)} \]

where \( \theta \) is risk-aversion parameter

- **Update algorithm** for \( k = 1, \ldots, N \) banks and \( t = 1, \ldots, \tau \) update steps:
  1. Obtain returns on investments, pay interest on deposits
  2. Deposit in- and out-flows, required reserves
  3. Settle interbank loans
  4. Determine new investment level
  5. Settle liquidity position
  6. Pay dividends
Microfoundations of Banks Determine Model

![Diagram showing the microfoundations of banks]

- **Liabilities**:
  - Households
  - Commercial Banks
  - Central Bank
- **Assets**:
  - Firms
  - Commercial Banks

Symbols:
- $D$: Liabilities to Households
- $L$: Liabilities to Commercial Banks
- $LC$: Liabilities to Central Bank
- $E$: Assets to Firms
- $L$: Assets to Commercial Banks

Relationships:
- $\lambda$: Connection between Commercial Banks and Other Institutions

Co-Pierre Georg (UC3M & Jena)
Interbank Networks, Contagion, and Common Shocks
Oxford, 02/07/2012
Interbank Loans Form a Network Structure

Figure: Different scale free networks
## Model Parameters

<table>
<thead>
<tr>
<th>Sektor</th>
<th>Parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Households</td>
<td>deposit fluctuations $\gamma$</td>
</tr>
<tr>
<td>Firms</td>
<td>credit success probability $p_f$, realized credit return $(\rho_f^+, \rho_f^-)$</td>
</tr>
<tr>
<td>Commercial banks</td>
<td>deposit interest rate $r^d$, dividend level $\beta^k$, expected credit success probability $p_b$, expected credit return $(\rho_b^+, \rho_b^-)$, risk aversion parameter $\theta$</td>
</tr>
<tr>
<td>Central bank</td>
<td>main refinancing rate $r^b$, minimum reserve requirement $r$, quality of securities $\alpha^k$</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Network parameters</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>number of banks $N$, level of interbank connections $\text{connLevel}$</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Simulation parameters</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>number of update steps $\tau$, number of simulations $\text{numSimulations}$</td>
<td></td>
</tr>
</tbody>
</table>
Central Bank Liquidity Stabilizes in the Short-Run...

Figure: The effect of central bank activity \( \alpha^k \) on financial stability in a crisis scenario \((\rho_f^+ = 0.09, \rho_f^- = -0.08)\)
...but the Effect is Non-Monotonic

Figure: The effect of central bank activity $\alpha^k$ on interbank liquidity in a crisis scenario ($\rho_f^+ = 0.09, \rho_f^- = -0.08$)
Central Bank Liquidity Stabilizes in the Short-Run

Lesson 1:

- Central bank liquidity provision has non-linear effect on financial stability
  ⇒ Close threshold value, small changes have significant impact
  ⇒ Away from threshold value, even large changes can be ineffective

- Stabilizing effect in the short-run only

- Abundant central bank liquidity crowds out interbank liquidity
Some Network Structures are More Resilient Than Others

Figure: The impact of the network topology on financial stability in a normal scenario ($\rho_f^+ = 0.09, \rho_f^- = -0.05$) in a random network.
Some Network Structures are More Resilient Than Others

Figure: The impact of the network topology on financial stability in a crisis scenario \((\rho_f^+ = 0.09, \rho_f^- = -0.08)\) in a random network
Some Network Structures are More Resilient Than Others

Figure: The impact of the network topology on financial stability in a crisis scenario \((\rho_f^+ = 0.09, \rho_f^- = -0.08)\) in a BA network
Some Network Structures are More Resilient Than Others

Figure: The impact of the network topology on interbank liquidity in a crisis scenario \((\rho_f^+ = 0.09, \rho_f^- = -0.08)\) in a random network
Lesson 2:

- Network structure matters in crises
- Relationship between financial stability and interconnectedness in random networks is non-monotonic
- Scale-free networks tend to be more stable than random networks
- Interbank networks are robust-yet-fragile
  \[\Rightarrow\] Size of endogenous fluctuations matter
Different Forms of Systemic Risk Require Different Answers

Figure: The impact of different forms of systemic risk on financial stability in a crisis scenario ($\rho_f^+ = 0.09, \rho_f^- = -0.08$) in a random network ($\text{connLevel} = 0.8$)
Different Forms of Systemic Risk Require Different Answers

Figure: The impact of different forms of systemic risk on financial stability in a crisis scenario ($\rho_f^+ = 0.09, \rho_f^- = -0.08$) in a random network (connLevel=0.8)
Lesson 3:

- Common shocks can pose greater threat to financial stability
- Contagion mainly reduces **liquidity** available in the system
- Common shock mainly reduces **banking capital** and increases (relative) size of endogenous fluctuations

⇒ Different optimal responses, for different forms of systemic risk

⇒ Implications for financial Regulation
Lesson 3:

- Common shocks can pose greater threat to financial stability
- Contagion mainly reduces **liquidity** available in the system
- Common shock mainly reduces **banking capital** and increases (relative) size of endogenous fluctuations

⇒ Different optimal responses, for different forms of systemic risk

⇒ Implications for financial Regulation

Thank you!


Silvia Gabrieli. The microstructure of the money market before and after the financial crisis: a network perspective. CEIS Research Paper 181, Tor Vergata University, CEIS, 2011.


