Contagion, Cascades and Disruptions to the Interbank Payment System

NEW DIRECTIONS FOR UNDERSTANDING SYSTEMIC RISK
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The views expressed in this presentation do not necessarily reflect those of the Federal Reserve Bank of New York or the Federal Reserve System.

The National Infrastructure Simulation and Analysis Center (NISAC) is a program under the Department of Homeland Security’s (DHS) Preparedness Directorate.
The Big Picture

Complex, Adaptive System

- markets for goods and services
- financial markets
- clearing and settlement
- central bank
central bank

clearing and settlement

financial markets

markets for goods and services
Primer on Interbank Payment System

Federal Reserve - bank of banks

Fedwire
Large-value, time-critical payments
Real Time Gross Settlement (RTGS) system
Fed provides intraday credit for a fee

other infrastructures

bank i
market s
bank j

Max day = 800,000 payments worth $2.9 trillion
Turnover = US GDP every six business days

7600 participants
A Break Down in Coordination

Payments Sent_t = \alpha + \beta \cdot Payments Received_t + \varepsilon_t

Slope of Reaction Function of Payments Sent to Payments Received: Fixed-Effects Tobit Model

McAndrews and Potter (2002)
Fee F charged by central bank for overdrafts

Time is money (also intraday) so delay is costly. The cost is D > 0 per dollar

Rational players are pulled in one direction by considerations of mutual benefit and in the other by considerations of personal risk
Adjustment following Wide-Scale Disruption

Liquidity cheap relative to delaying

Liquidity expensive relative to delaying

\[ F = D \]
\[ D < F < 2D \]
\[ F = 2D \]
\[ F > 2D \]

Share of banks hit by disruption / holding back payments

Potential

0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1
Heterogeneous Banking Sector

![Graph showing the share of small banks affected by disruption and the potential impact on large banks.]

- **Potential Share of banks hit by disruption / holding back payments**

Large bank not affected

Large bank affected
Network Topology of Payment Flow

Large bank not affected

Large bank affected
Research Goals

1. Evaluate the actual network topology of interbank payment flows through analysis of Fedwire transaction data
2. Build a parsimonious agent based model for payment systems that honors network topology
3. Evaluate response of payment systems to shocks and the possibility of cascading failure
Network Topology after 9/11

Fedwire’s Core
All Commercial Banks

>6600 nodes, 70,000 links
Network Components

GSSC Dominates

- 78% nodes
- 90% edges
- 92% transfers
- 90% value
Out-Degree Distribution

+ Fedwire network
- Poisson random network (p=0.30%)

slope = 2.111
Number of Nodes in GSCC

- **Sept 11th**
- **Good Friday**
- **Thanksgiving**
- **Christmas Eve**

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Note: 100 = September 10th, 2001.
Structure ↔ Behavior

• Perhaps Switch Between the Two with Morten Animation Magic
1. Evaluate the actual network topology of interbank payment flows through analysis of Fedwire transaction data
2. Build a parsimonious agent based model for payment systems that honors network topology
3. Evaluate response of payment systems to shocks and the possibility of cascading failure
**Payment Physics Model**

1. **Agent instructs bank to send a payment**
2. **Depositor account is debited**
3. **Payment is settled or queued**
4. **Payment account is debited**
5. **Payment account is credited**
6. **Depositor account is credited**
7. **Queued payment, if any, is released**
Influence of Liquidity

Summed over the network, instructions arrive at a steady rate.

When liquidity is high payments are submitted promptly and banks process payments independently of each other.
Reducing liquidity leads to episodes of congestion when queues build, and cascades of settlement activity when incoming payments allow banks to work off queues. Payment processing becomes coupled across the network.
At very low liquidity, payments are controlled by internal dynamics. Settlement cascades are larger and can pass through the same bank numerous times.
A liquidity market substantially reduces congestion using only a small fraction (e.g. 2%) of payment-driven flow.
Research Goals

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Disruption of a bank creates a liquidity sink in the system

System throughput can be rapidly degraded

Disruptions to liquidity market represented as decreased conductance

Queues build; system becomes increasingly congested; recovery quickly follows restoration
What we’re learned

- Payment system participants have learned to coordinate their activities, and this coordination can be re-established after massive disruption.
- Payment flows, like many other networks, follow a scale-free distribution.
- Performance is a function of both topology and behavior – neither factor alone is enough to evaluate robustness.
- Liquidity limits can lead to congestion and a deterioration of throughput, but a shift in behavior is evidently needed to understand responses to disruption.
- System performance can be greatly improved by moving small amounts of liquidity to the places where it’s needed.
- Collaboration among researchers with different backgrounds helps bring new theoretical perspectives to real problems, and helps shape theoretical development to practical ends.
Next steps

- Intraday analysis of network topology –
  - How does it get built?
  - Over what time scales do banks manage liquidity?
  - Are there discernable behavioral modes (e.g. early/late settlement) or triggers (e.g. settlement of market transactions)?
- Long-term network dynamics (e.g. changes in TARGET topology with integration)
- Disruption/recovery behavior of simple model, including a central bank
- Adaptation of decision process, including market participation, to minimize cost (ongoing).
  - How is cooperative behavior established and maintained?
  - How might it be disrupted, restored, through institutions’ policies and reactions?
- Modeling the processes that drive payment flows (banks’ and customer investments, market movements, etc.) to:
  - introduce plausible correlations and other structure on the payment instruction stream
  - explore the feedbacks between payment system disruptions and the economy