Contagion, Cascades and Disruptions to the Interbank Payment System

NEW DIRECTIONS FOR UNDERSTANDING SYSTEMIC RISK

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Morten L. Bech
Federal Reserve Bank of New York

Walter E. Beyeler
Sandia National Laboratories

Robert J. Glass
Sandia National Laboratories

Kimmo Soramäki
Helsinki Technical University

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clearing and settlement
financial markets
markets for goods and services
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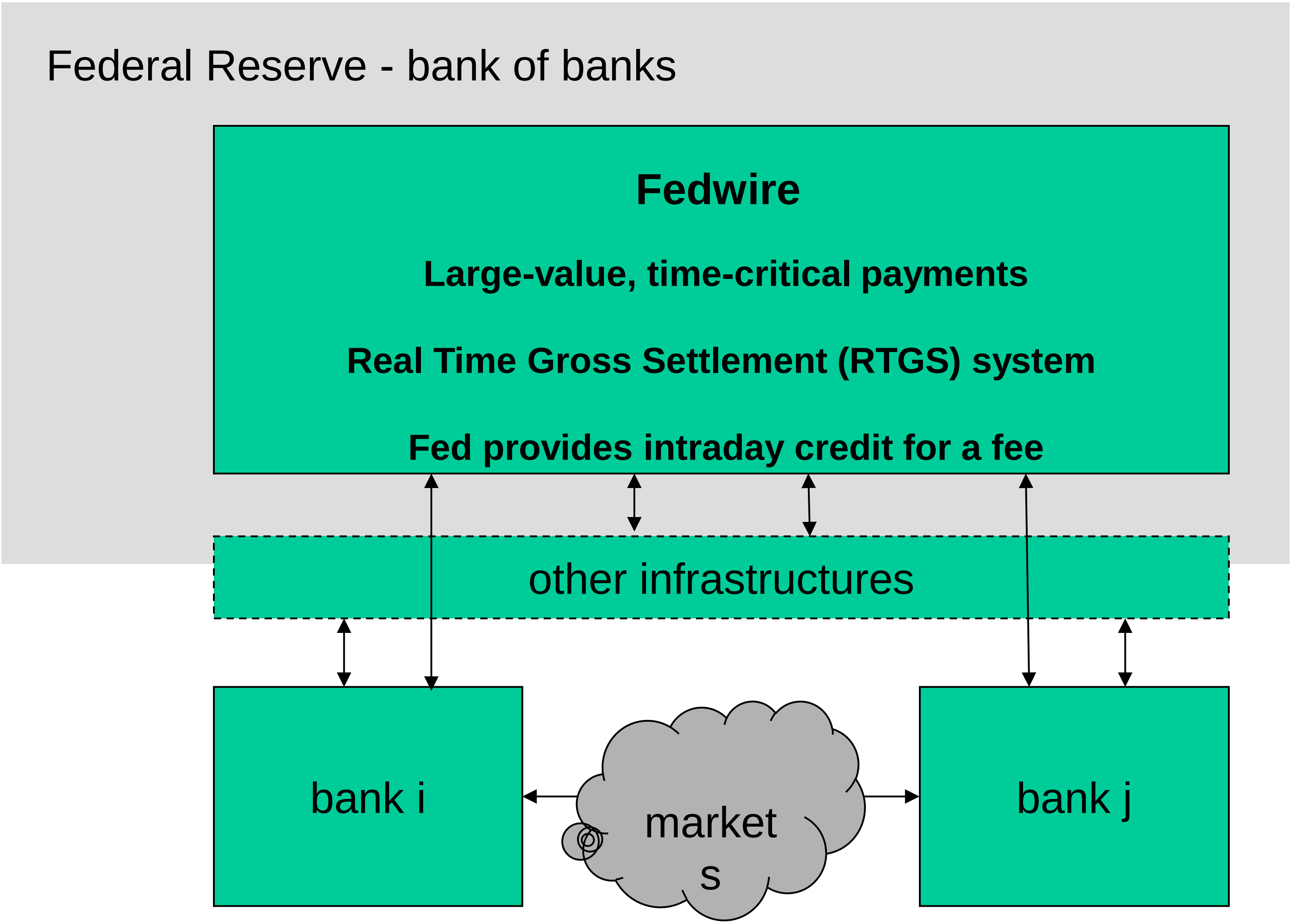
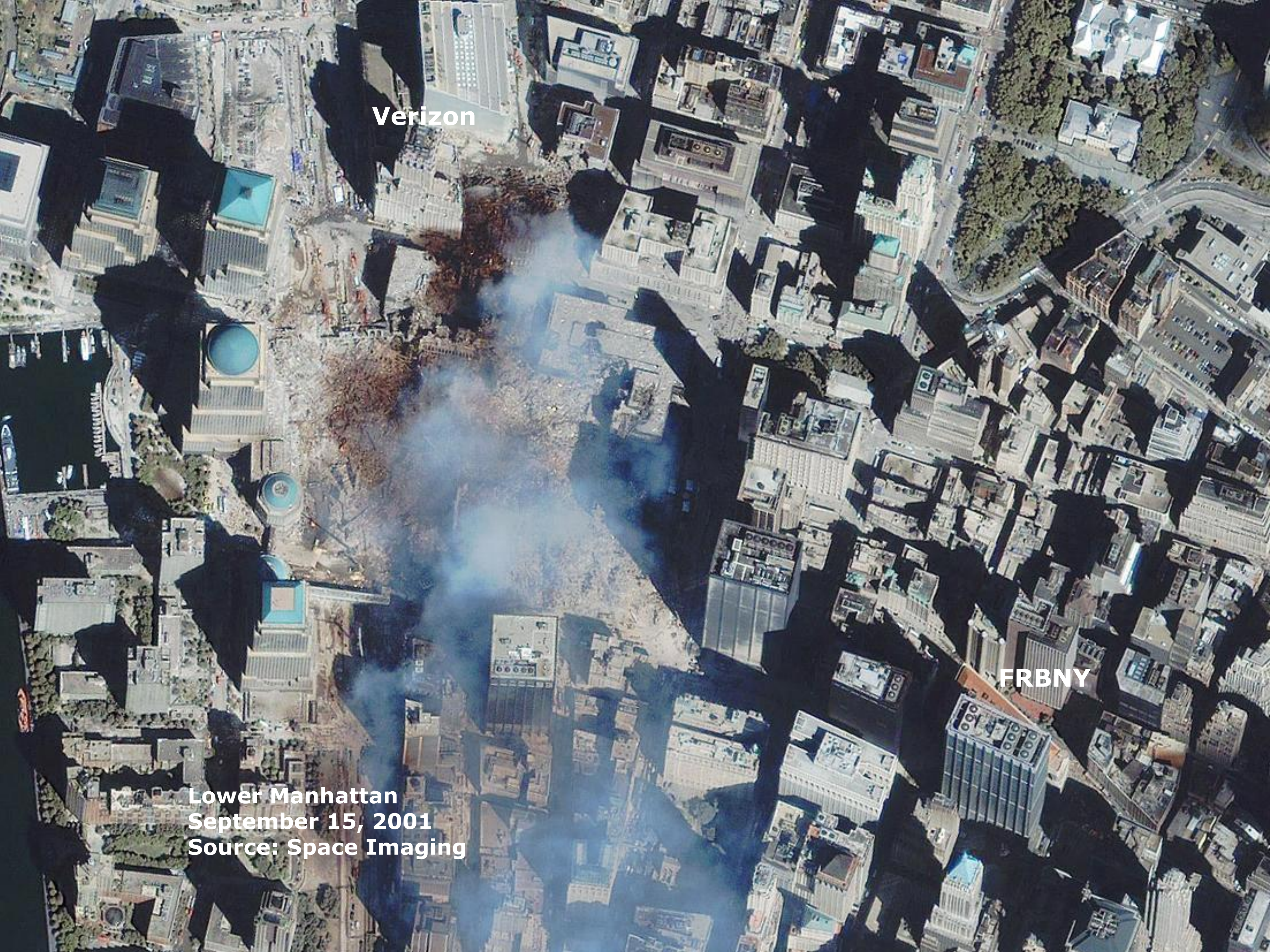
Primer on Interbank Payment System



Max day = 800,000 payments worth \$2.9 trillion

Turnover = US GDP every six business days

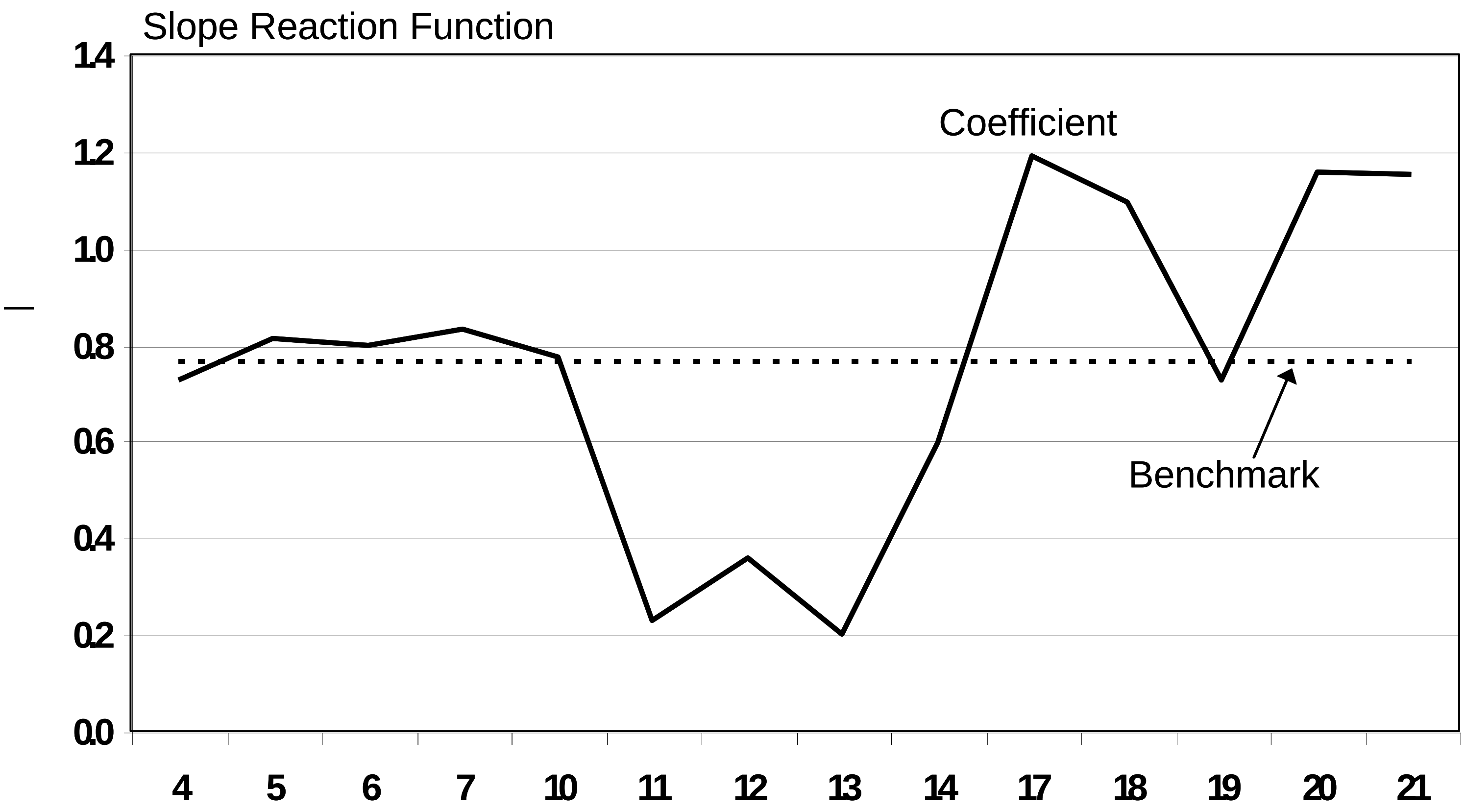
7600 participants


Verizon
FRBNY
Lower Manhattan
September 15, 2001
Source: Space Imaging

A Break Down in Coordination

$$\text{Payments Sent}_t = \alpha + \beta \cdot \text{Payments Received}_t + \varepsilon_t$$

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



McAndrews and Potter (2002)

The Intraday Liquidity Management Game

Fee F charged by central bank for overdrafts

Bank A (rows) / Bank B (columns)

	Morning	Afternoon
Morning	0, 0	F, D
Afternoon	D, F	D, D

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

F < D

Bank A (rows) / Bank B (columns)

	Morning	Afternoon
Morning	0, 0	3, 4
Afternoon	4, 3	4, 4

Total cost = 0 (FIRST BEST)

F > D

Stag Hunt

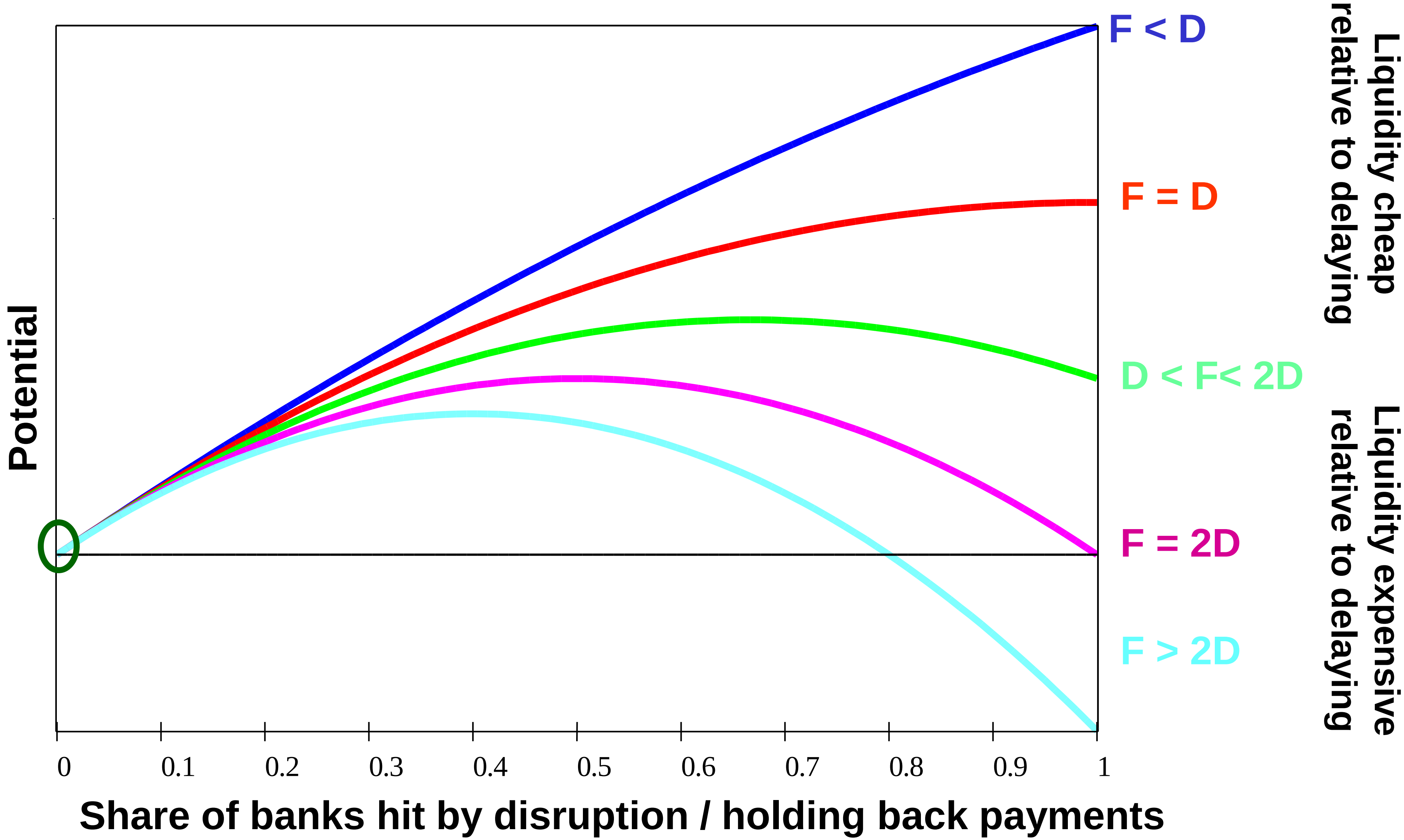
Bank A (rows) / Bank B (columns)

	Morning	Afternoon
Morning	0, 0	4, 3
Afternoon	3, 4	3, 3

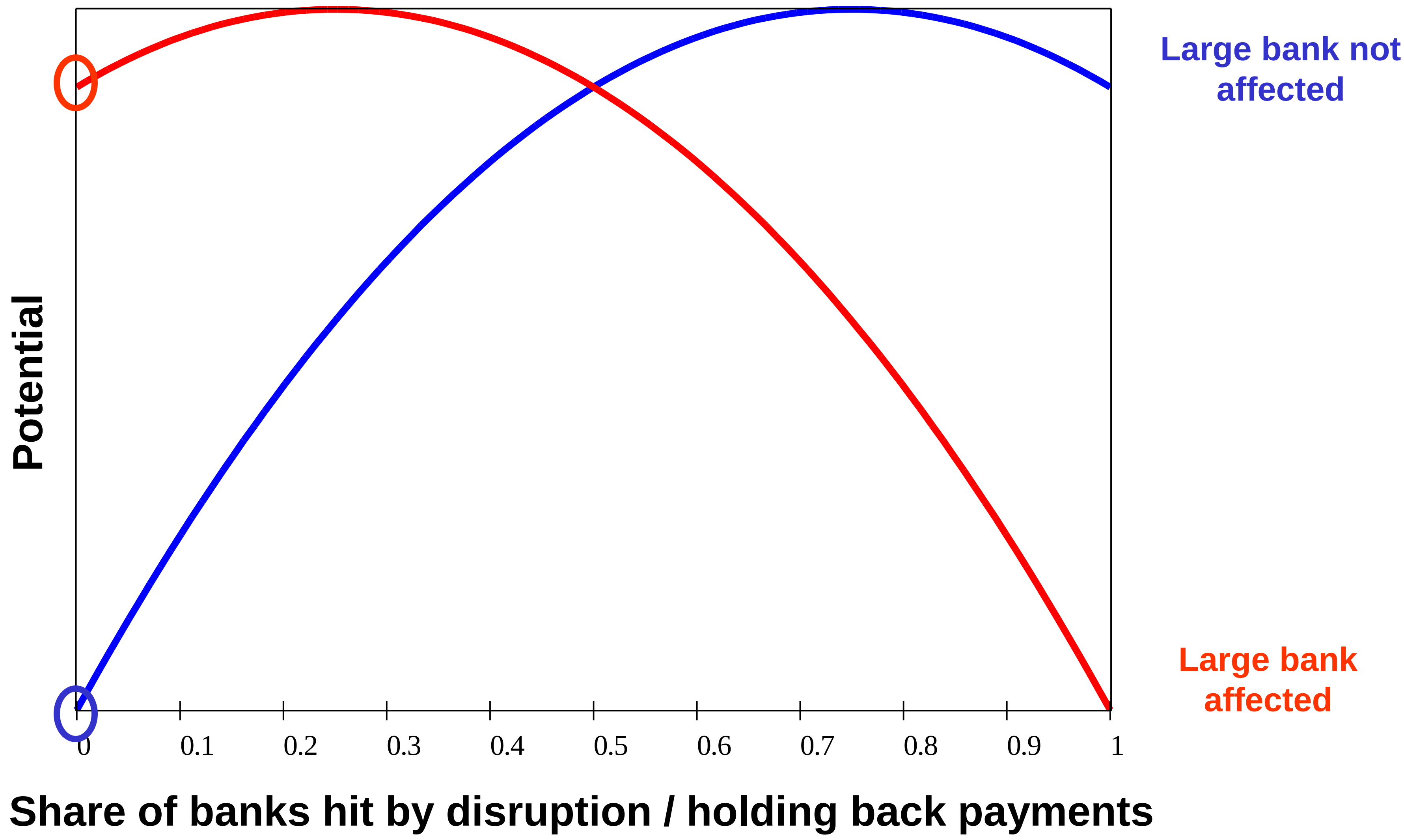
Total cost = 0 or (6)

Rational players are pulled in one direction by considerations of mutual benefit and in the other by considerations of personal risk

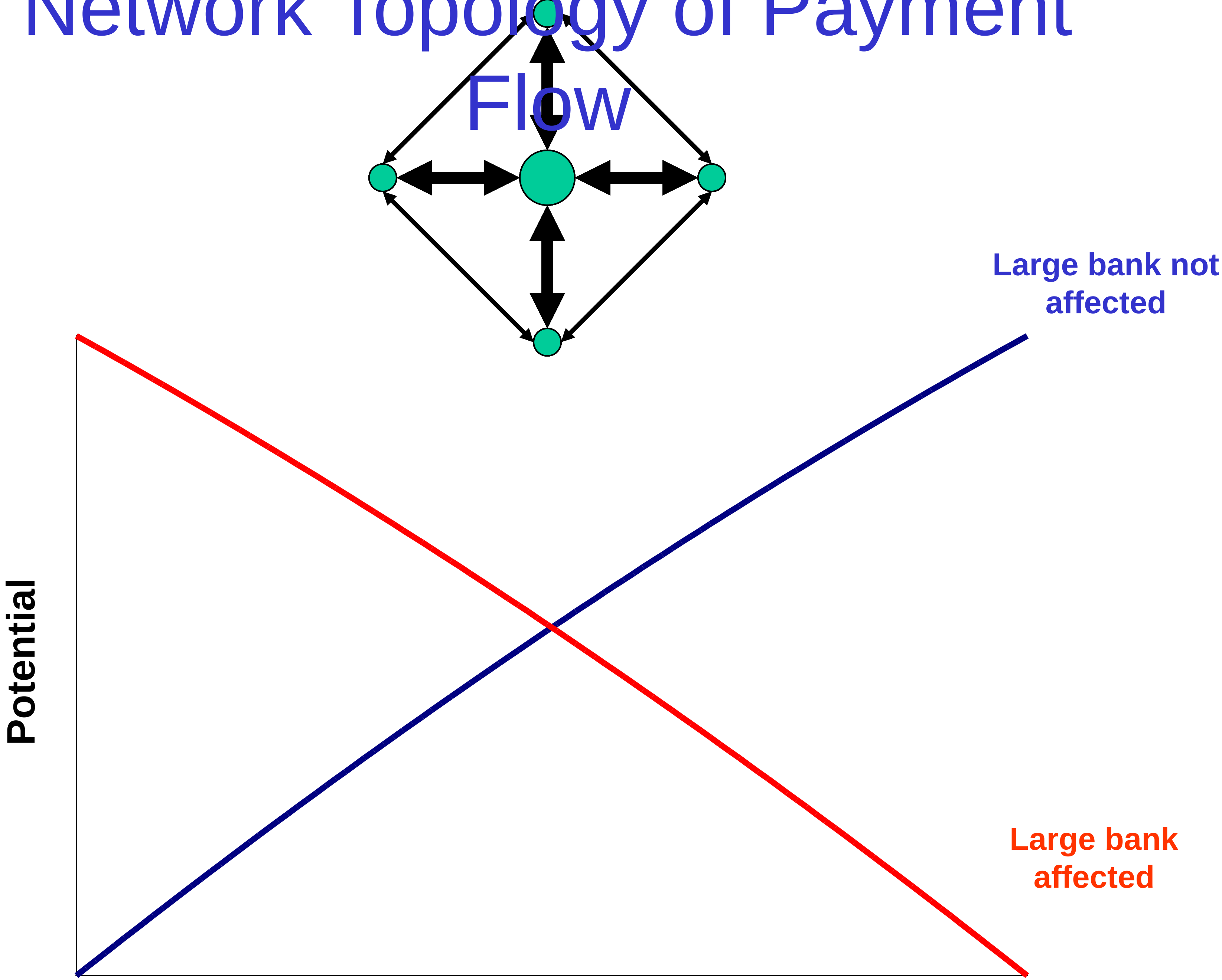
Adjustment following Wide-Scale Disruption



Heterogeneous Banking Sector



Network Topology of Payment Flow

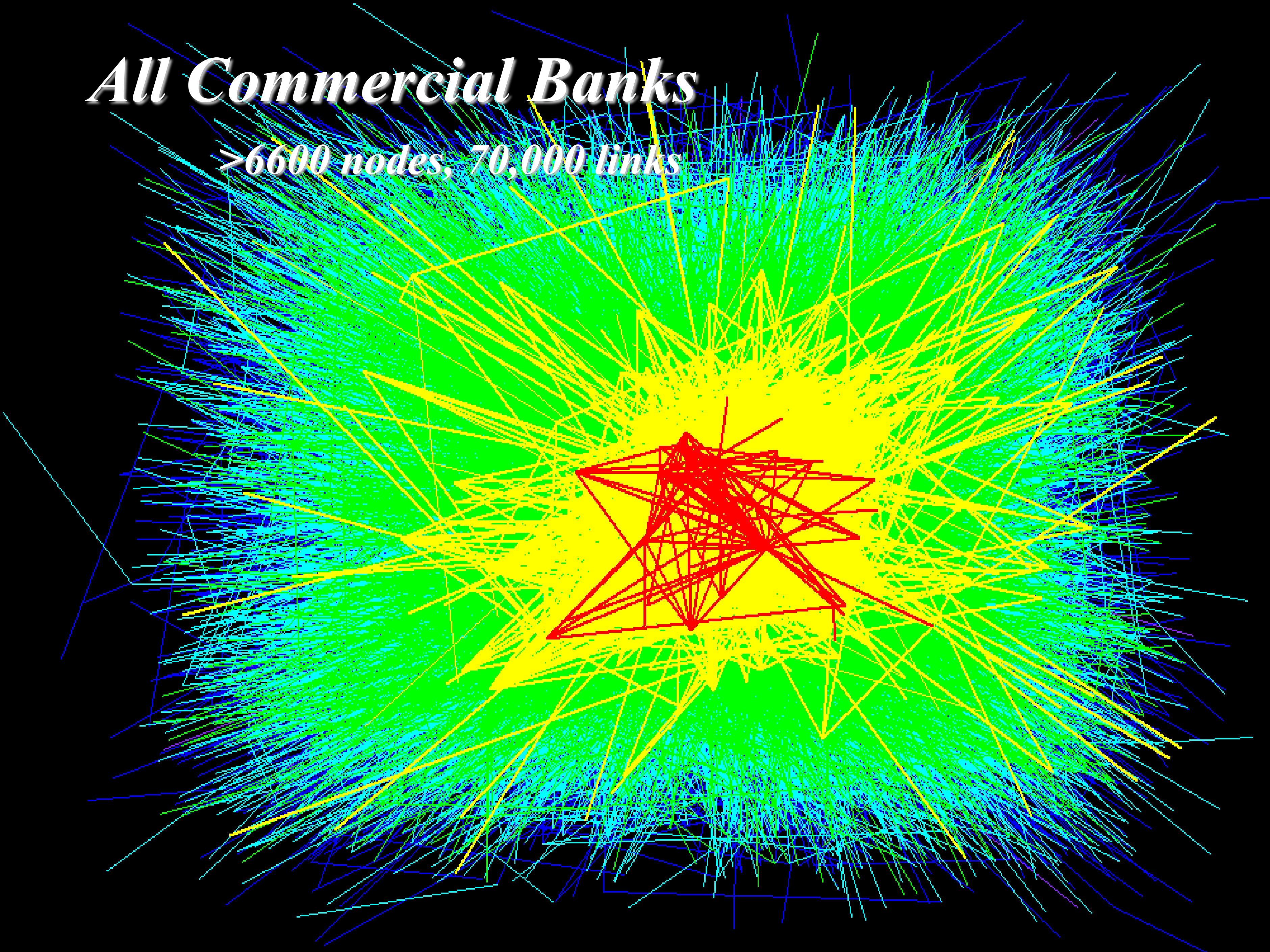


Research Goals

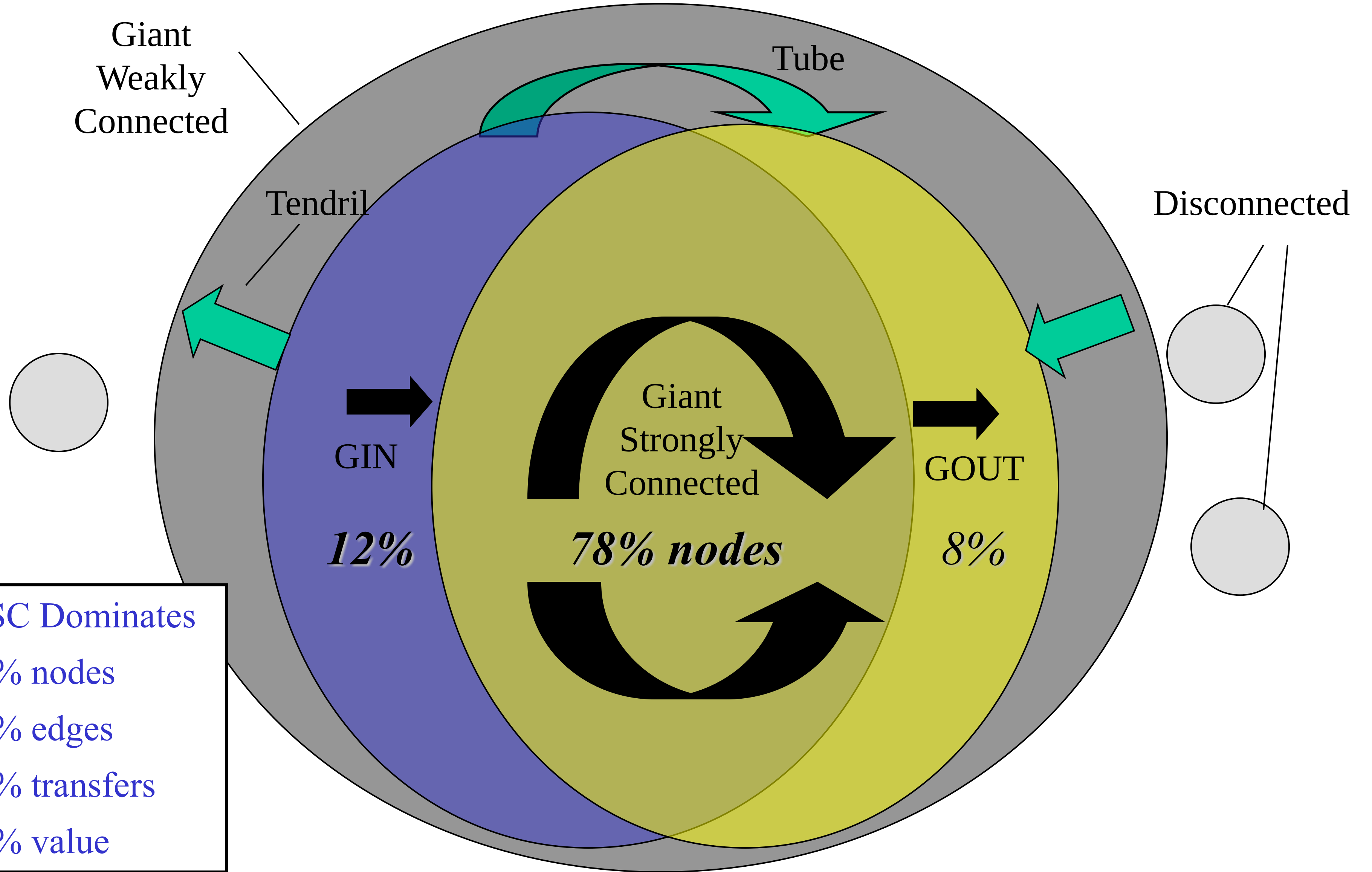
1. Evaluate the actual network topology of interbank payment flows through analysis of Fedwire transaction data
2. Build a parsimonious agent based model for payment systems that honors network topology
3. Evaluate response of payment systems to shocks and the possibility of cascading failure

All Commercial Banks

>6600 nodes, 70,000 links



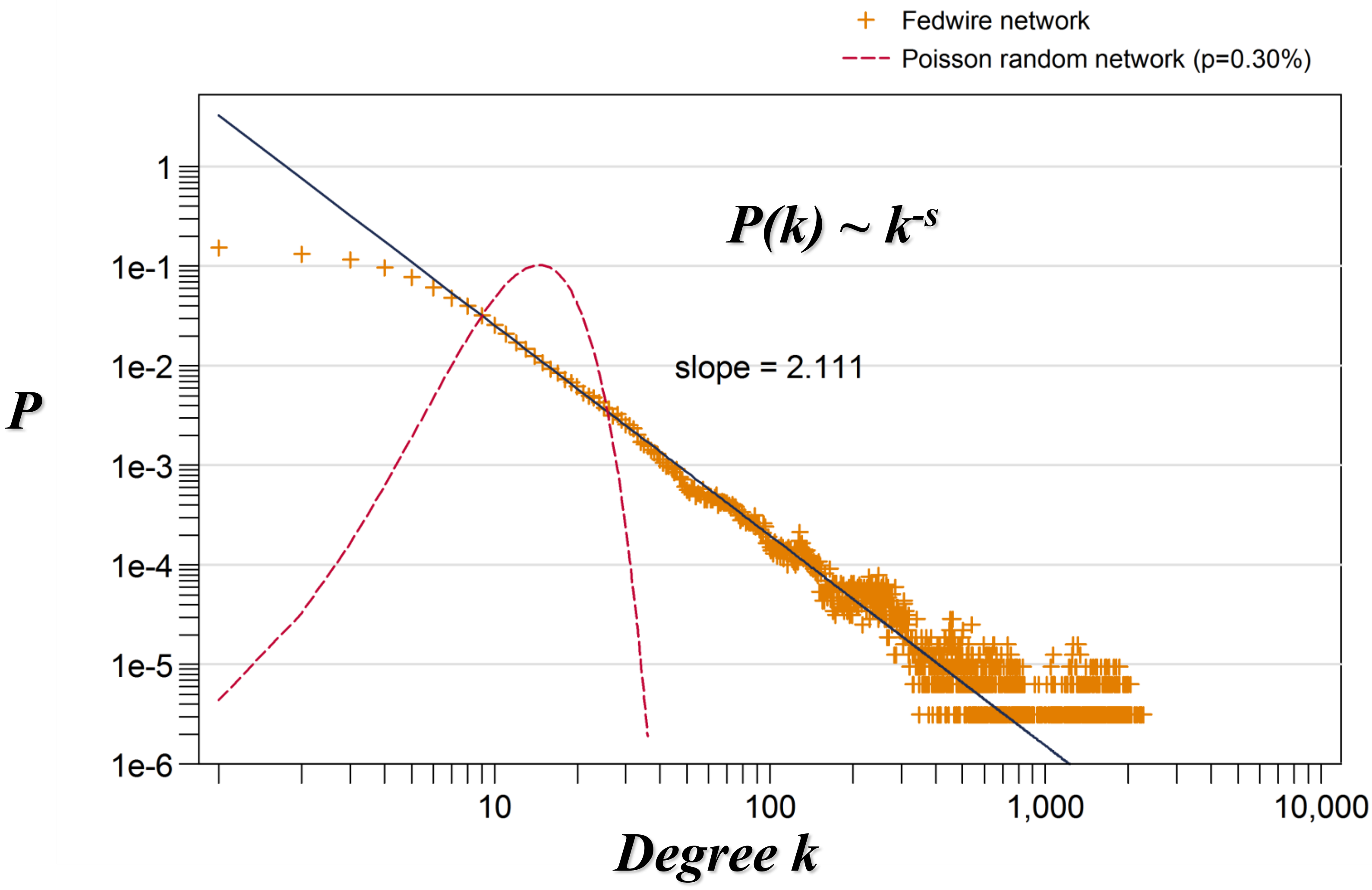
Network Components



GSSC Dominates

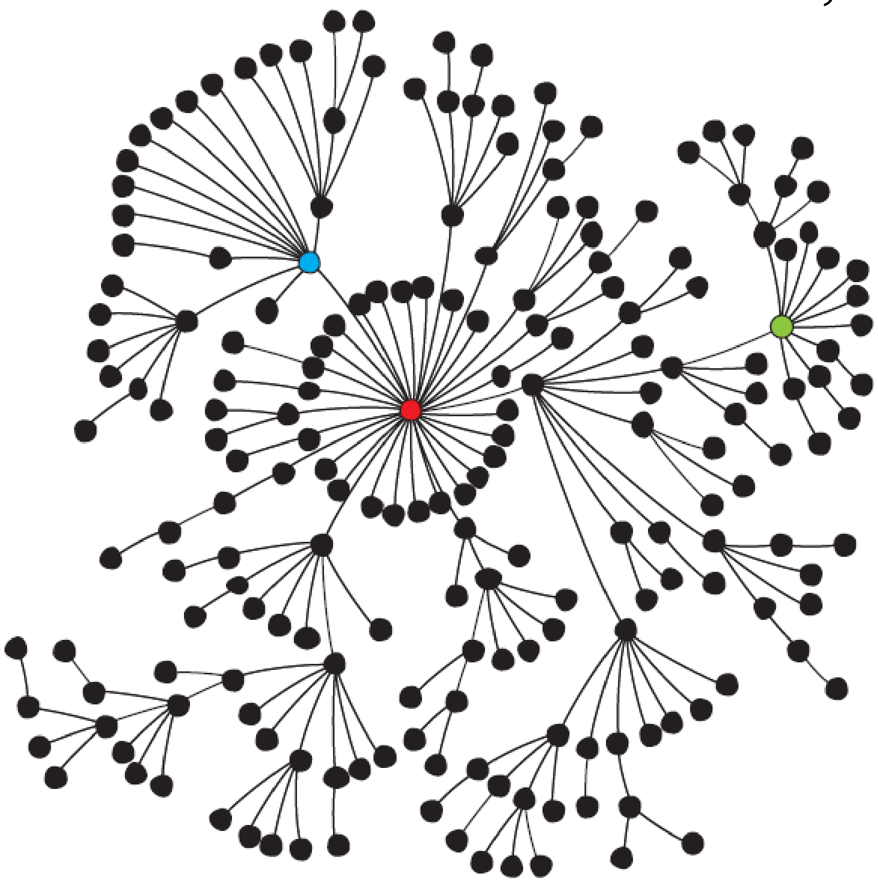
- 78% nodes
- 90% edges
- 92% transfers
- 90% value

Out-Degree Distribution



Scale-free Networks

Albert, Jeong, Barabasi, Nature 2000



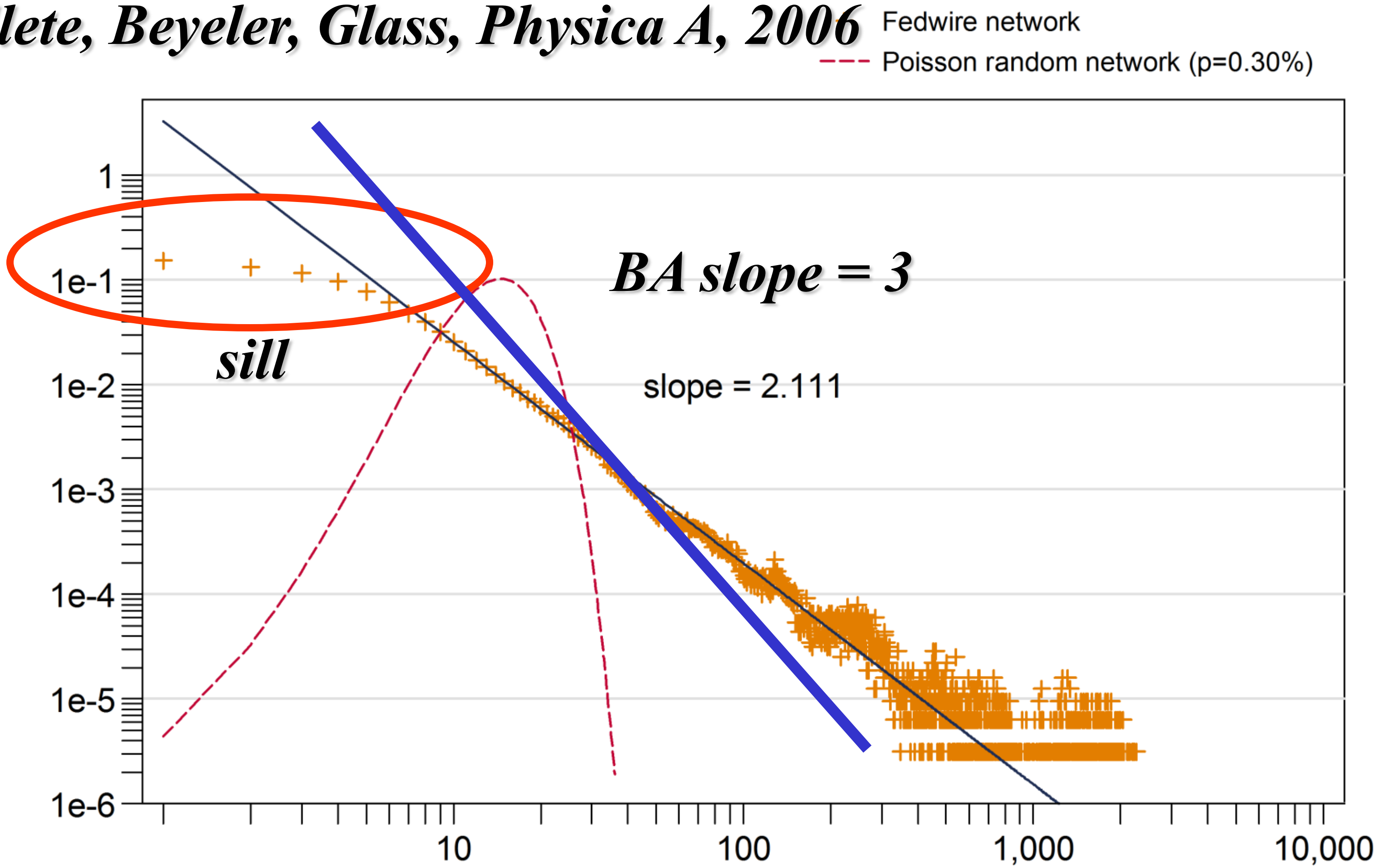
Preferential attachment
"*rich get richer*"

tolerant to random failure…

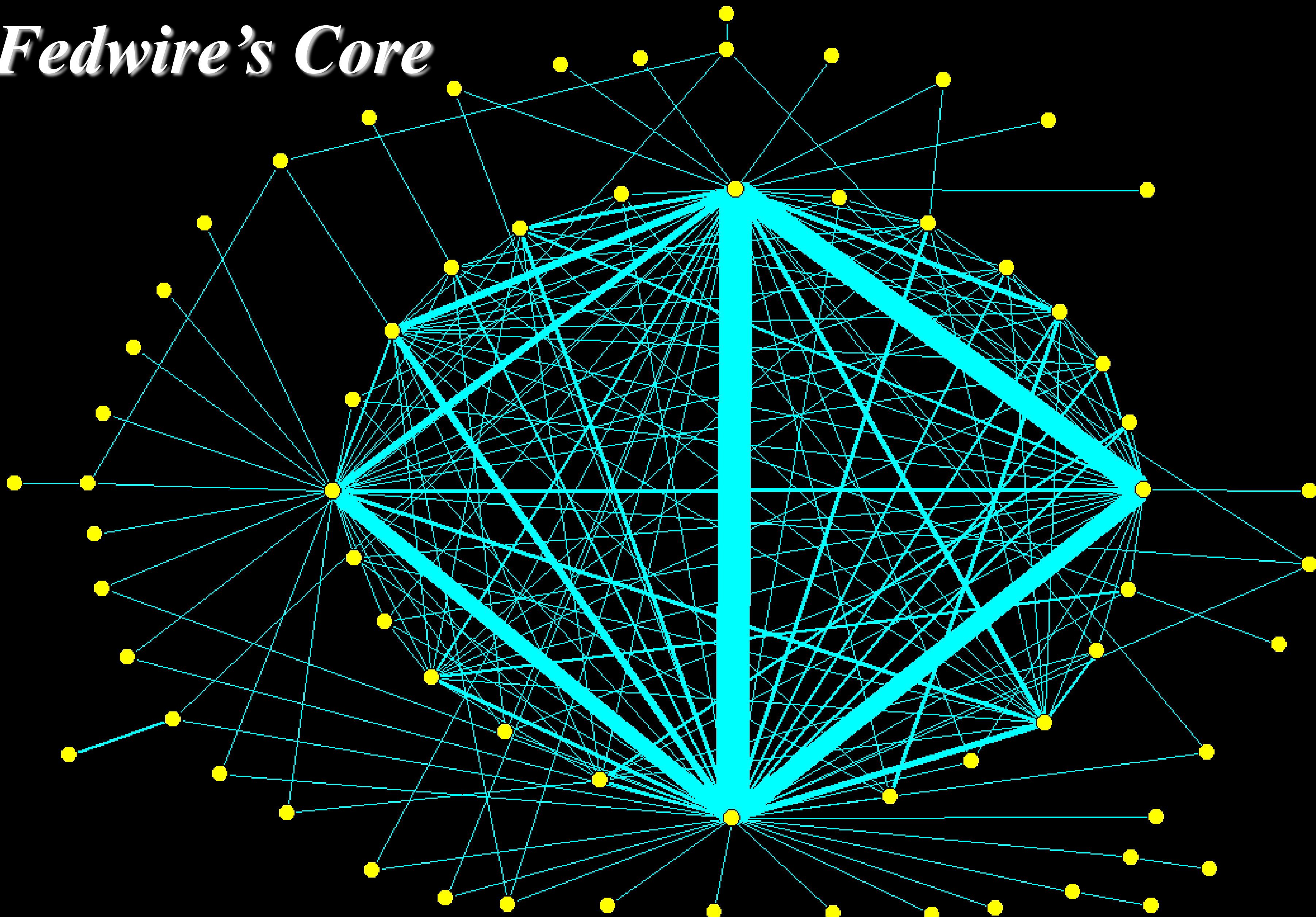
vulnerable to informed attack

But, not all scale free networks are created Equal

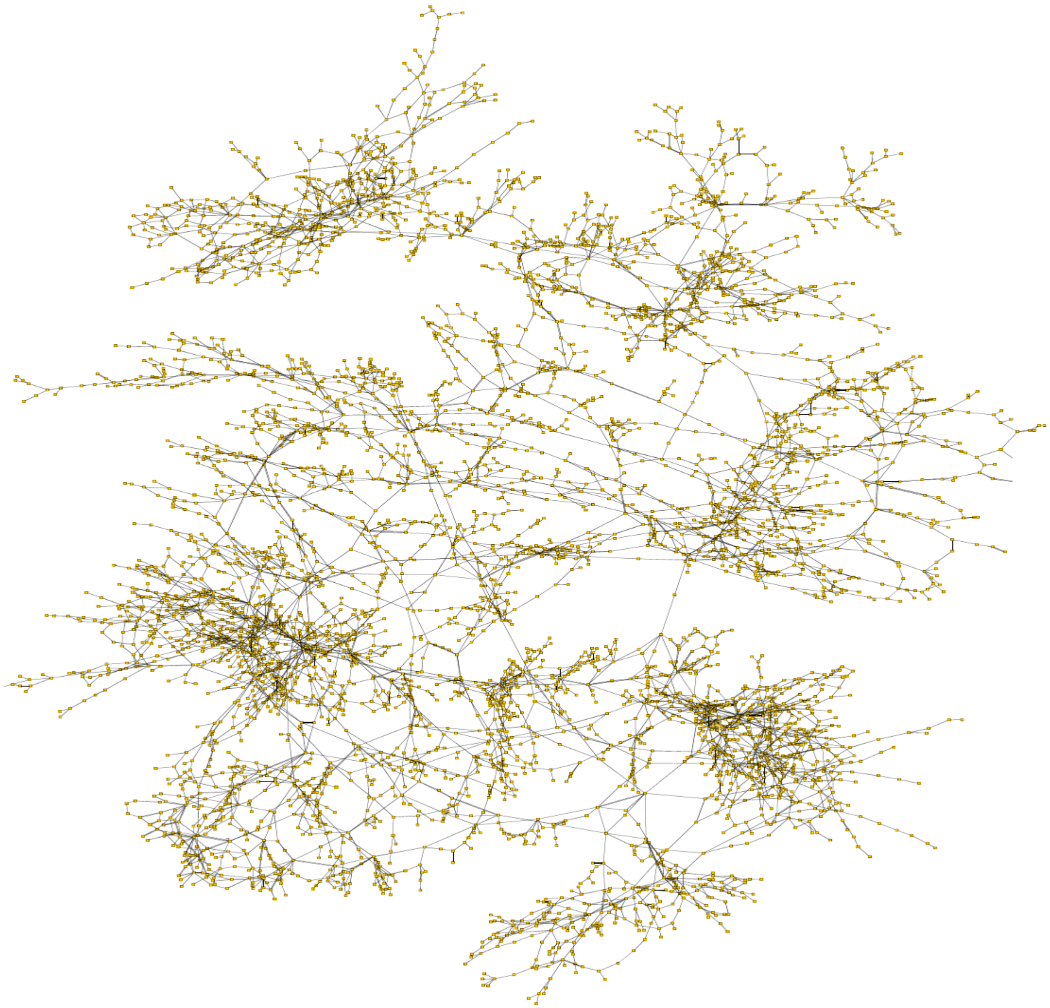
LaViollete, Beyeler, Glass, Physica A, 2006



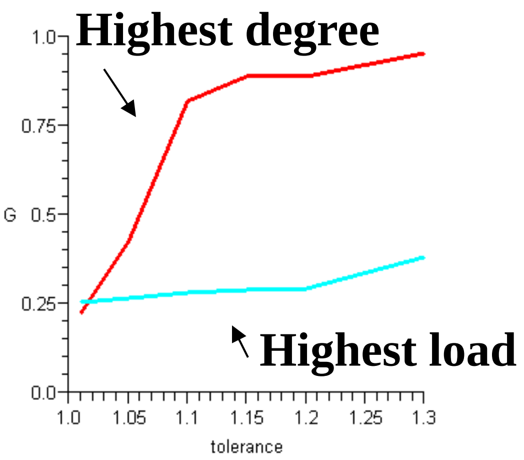
Fedwire's Core



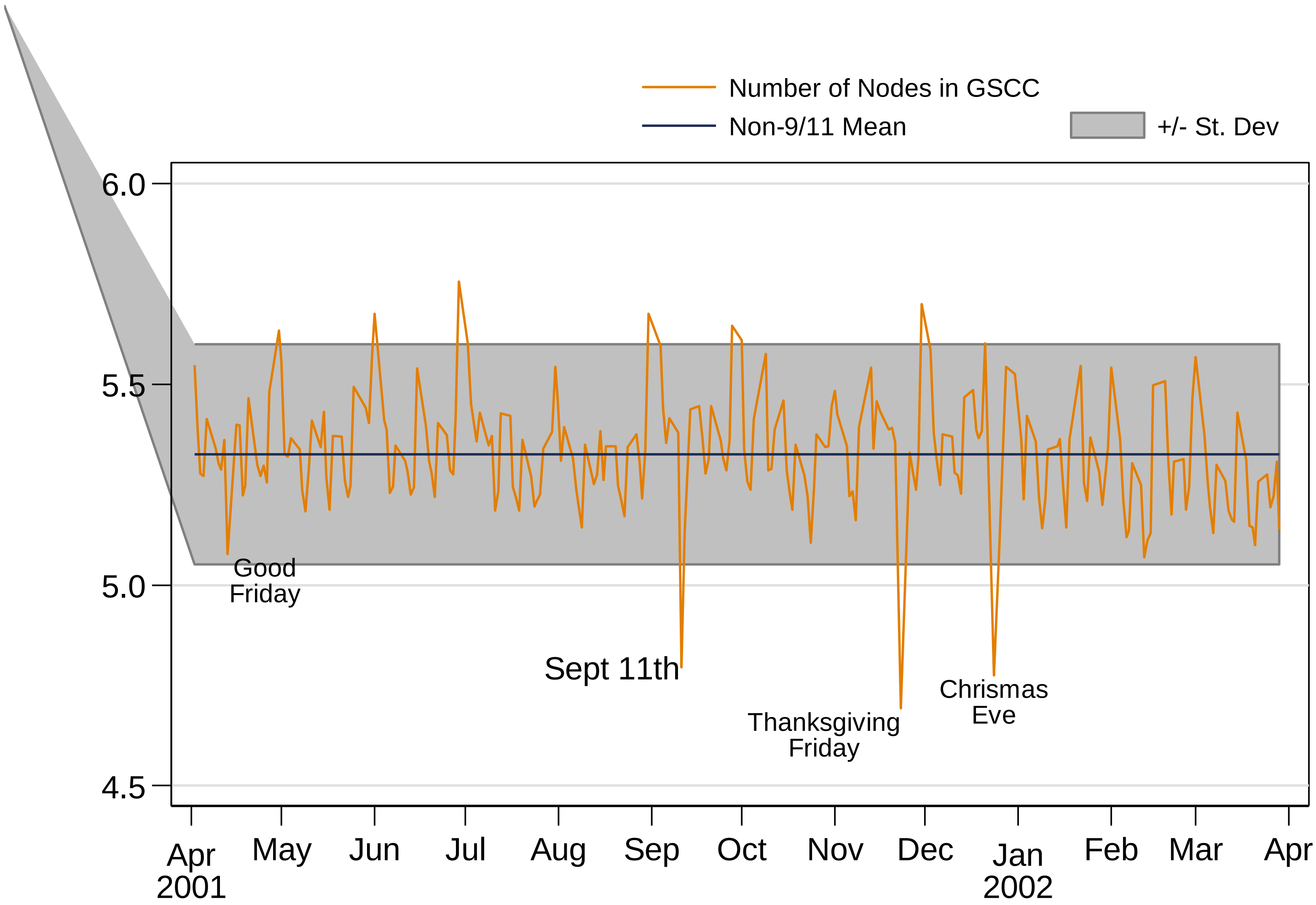
Congestive failure of the WECC



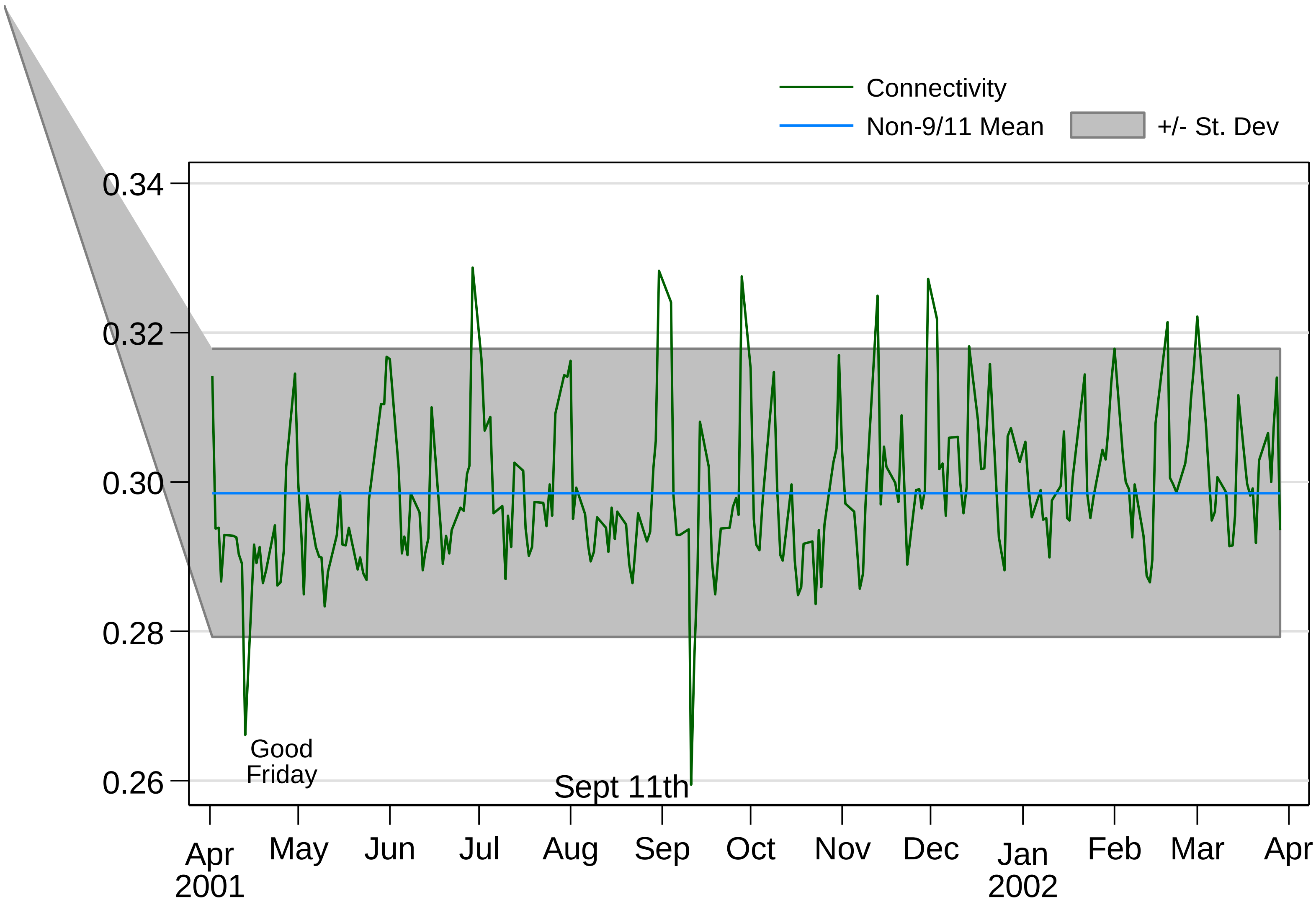
Western Power Grid (WECC), 69 kev lines and above



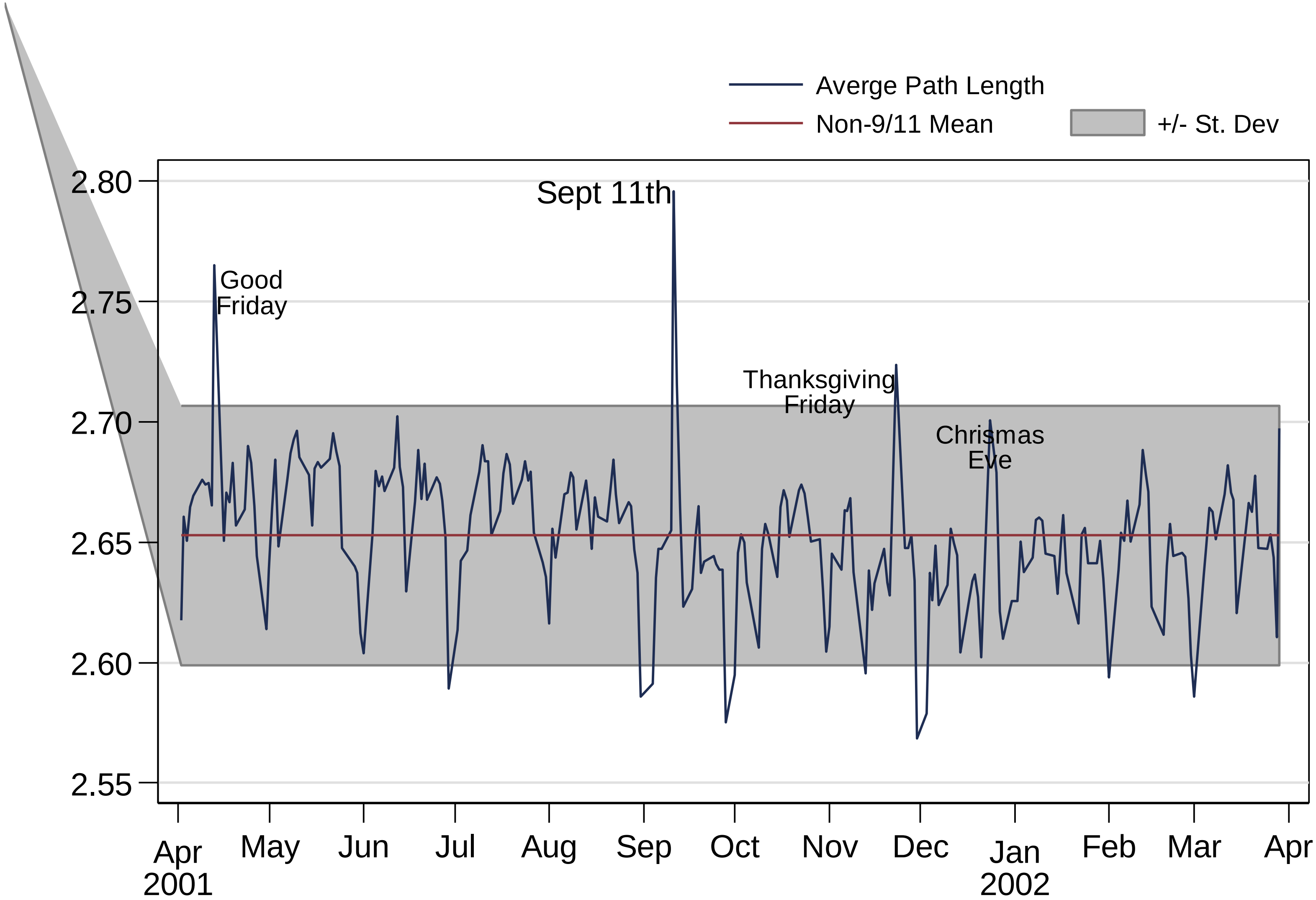
Number of Nodes in GSCC



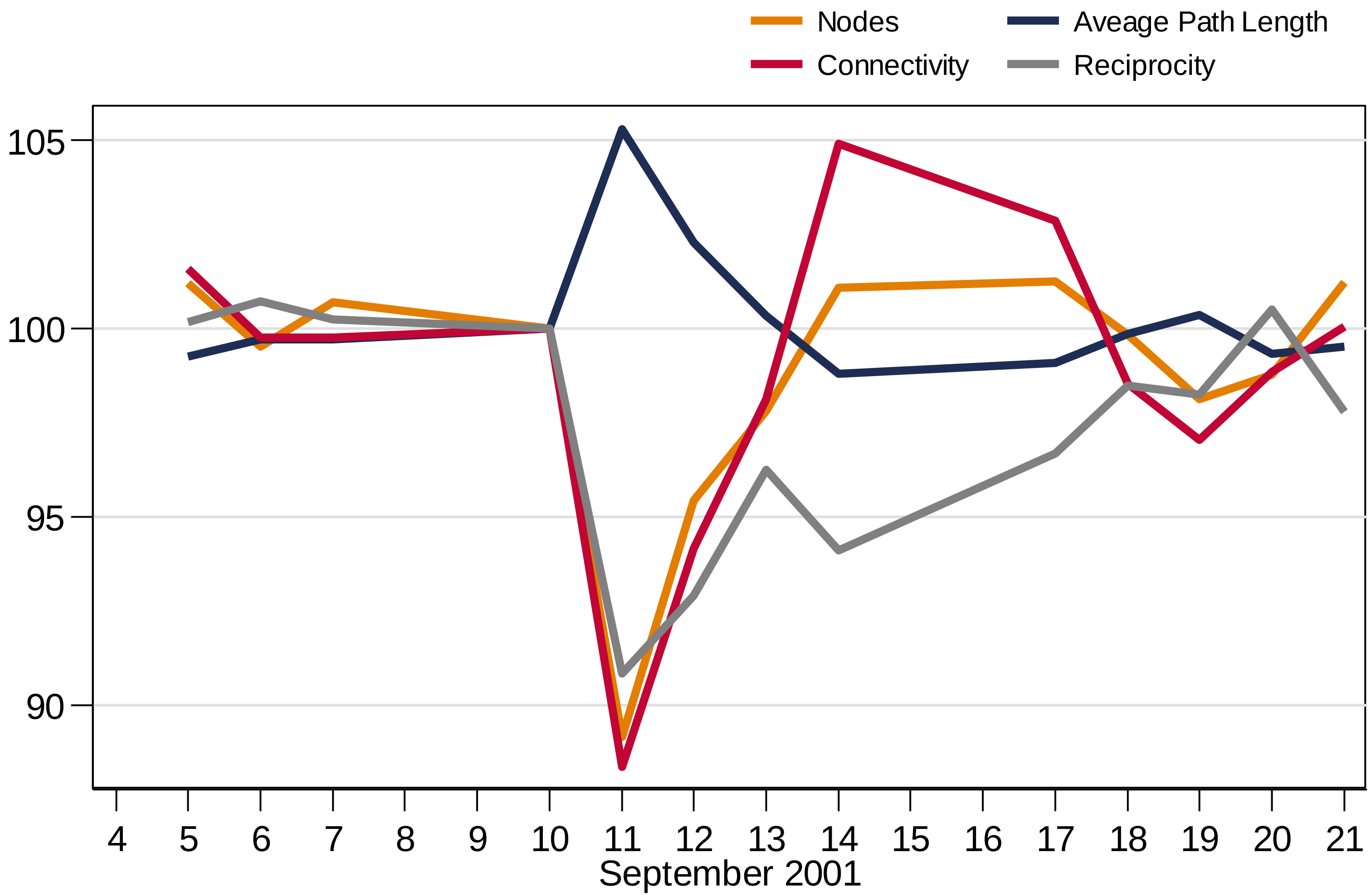
Connectivity



Average Path Length



9/11



Note: 100 = September 10th, 2001.

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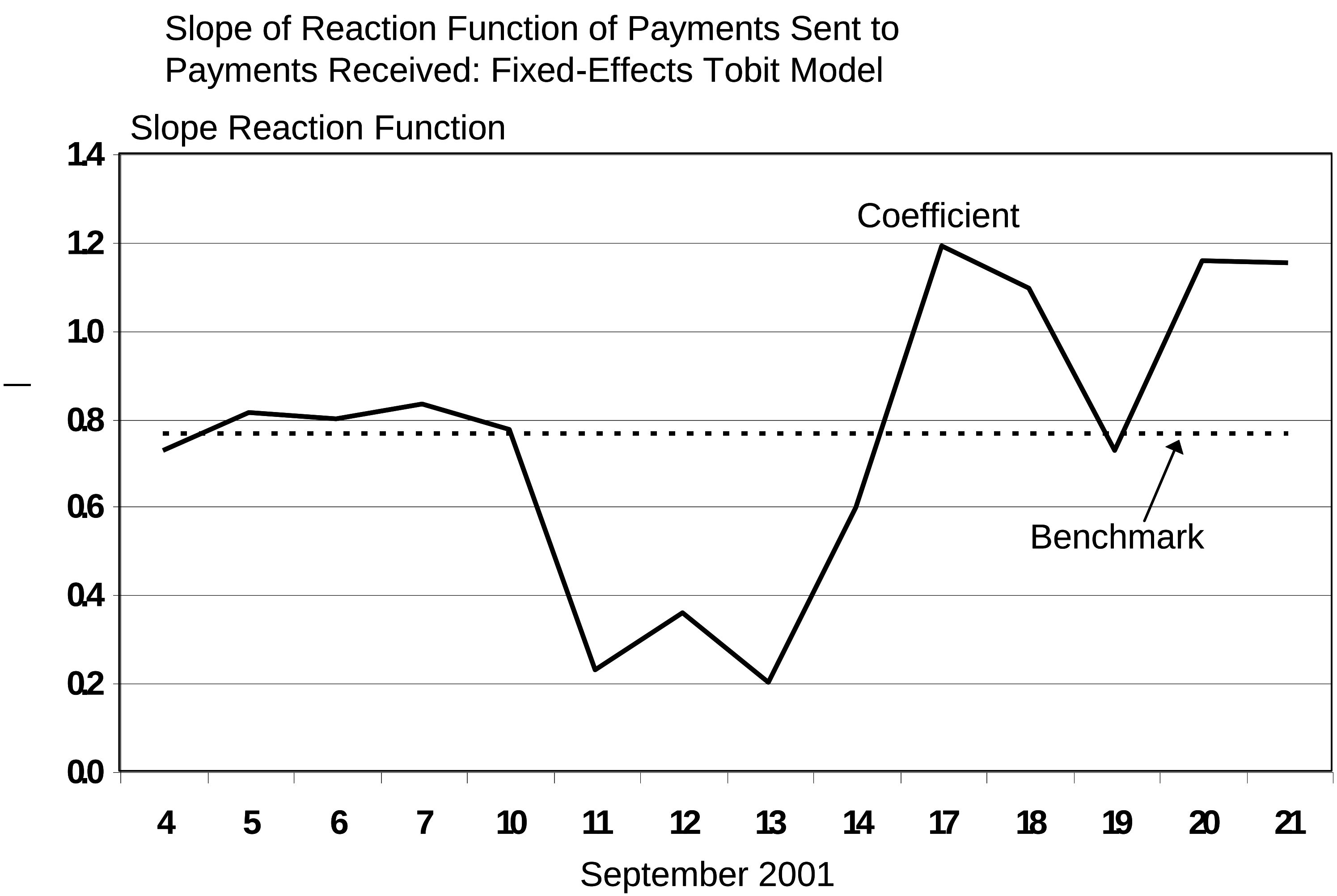

McAndrews and Potter (2002)

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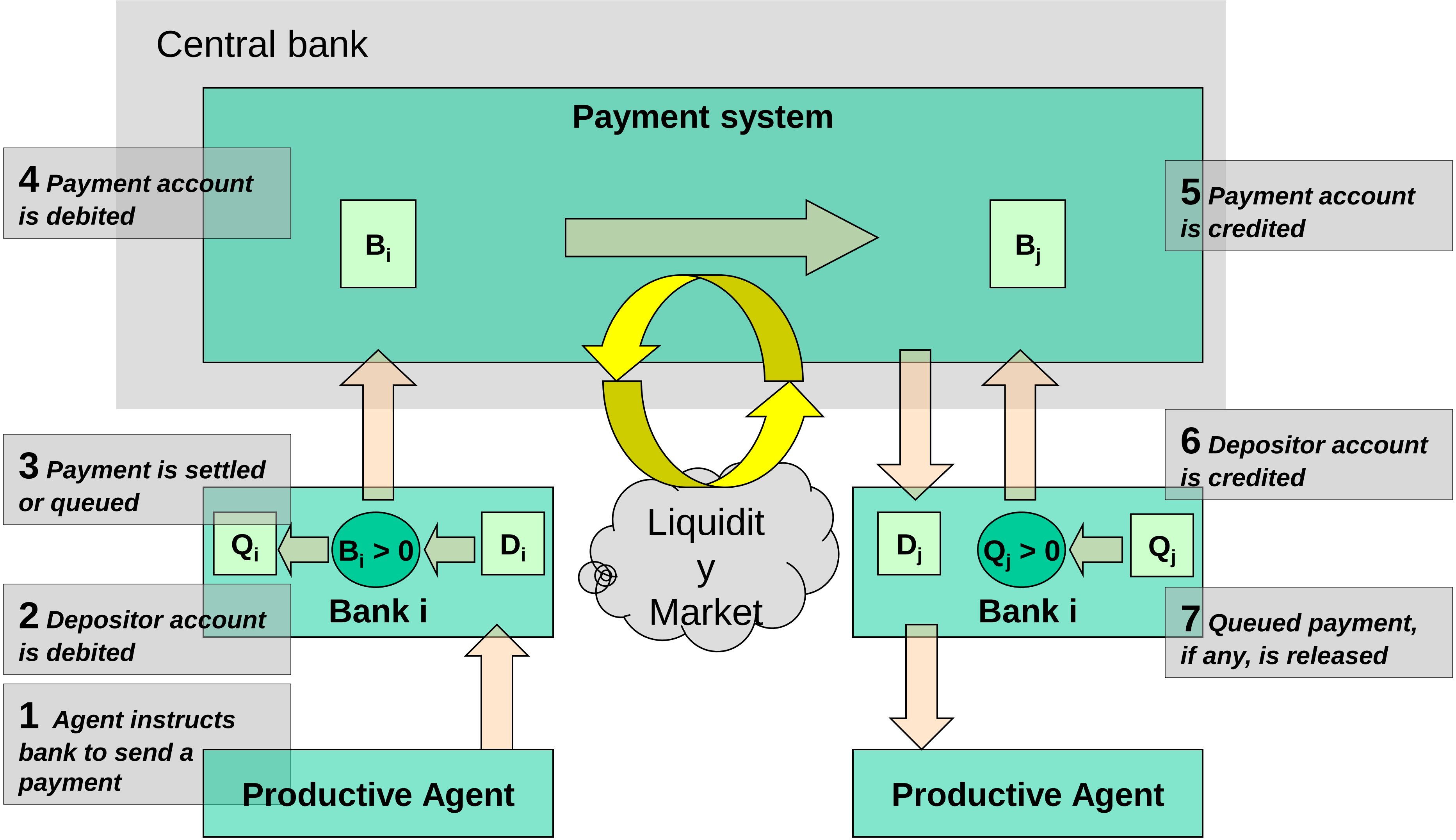
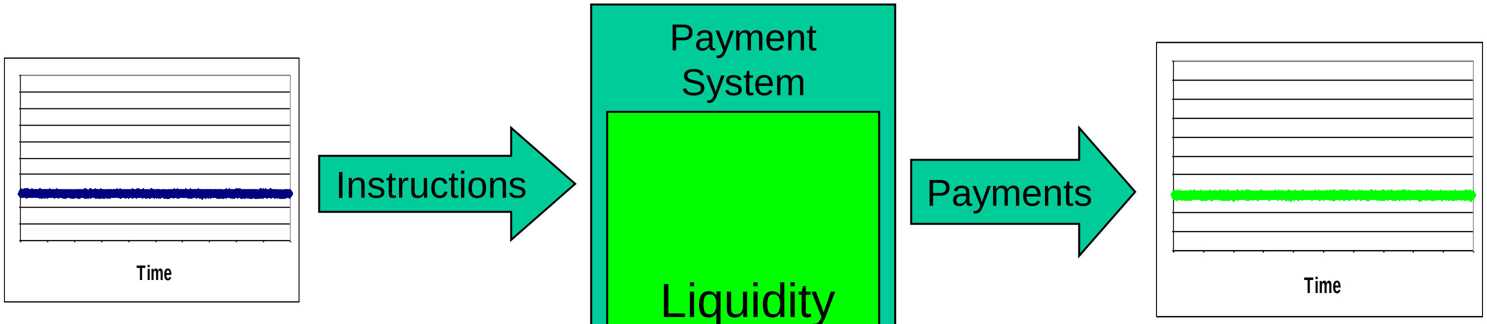
Payment Physics Model

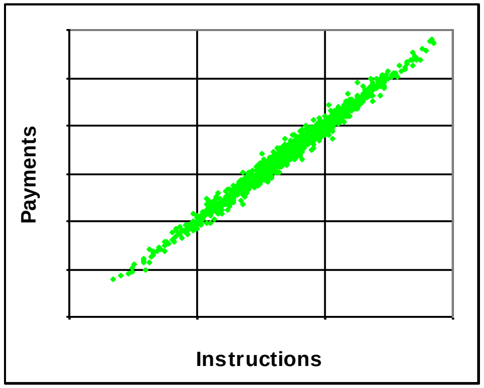


Influence of Liquidity

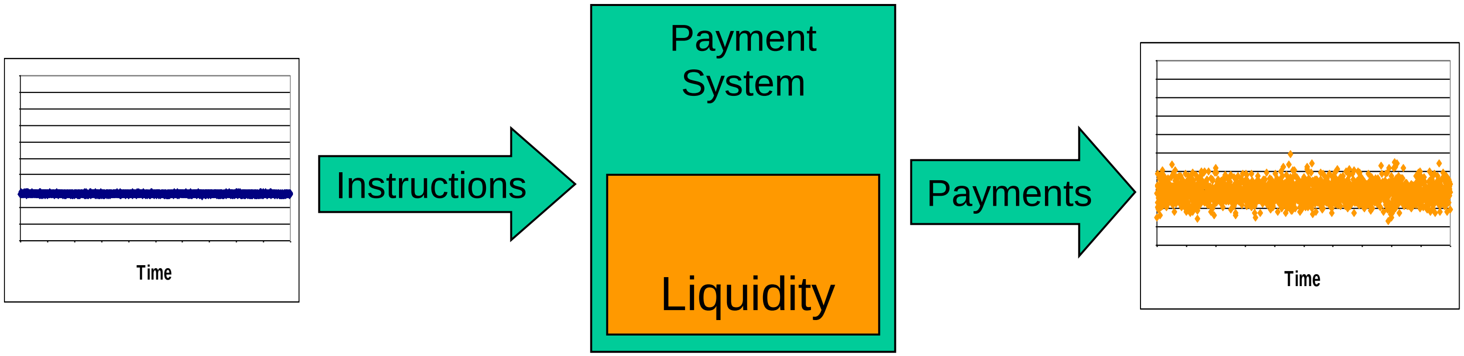


Summed over the network, instructions arrive at a steady rate

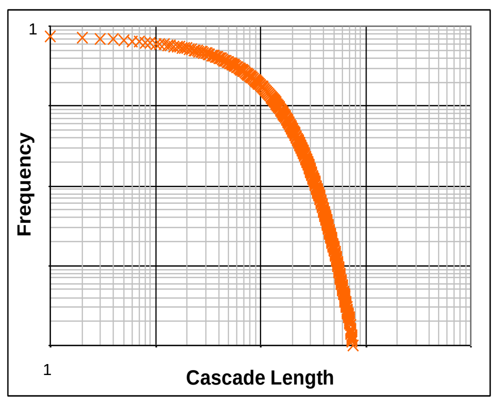
When liquidity is high payments are submitted promptly and banks process payments independently of each other

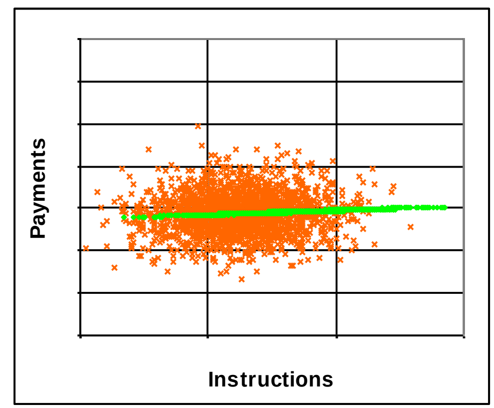


Influence of Liquidity

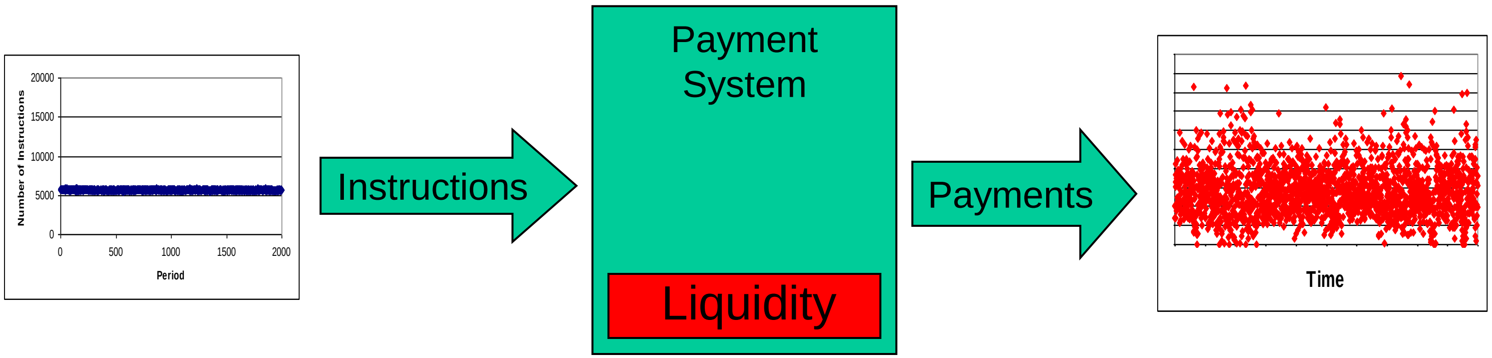


Reducing liquidity leads to episodes of congestion when queues build, and cascades of settlement activity when incoming payments allow banks to work off queues. Payment processing becomes coupled across the network

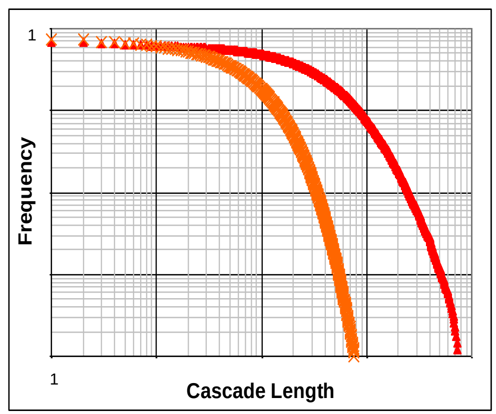


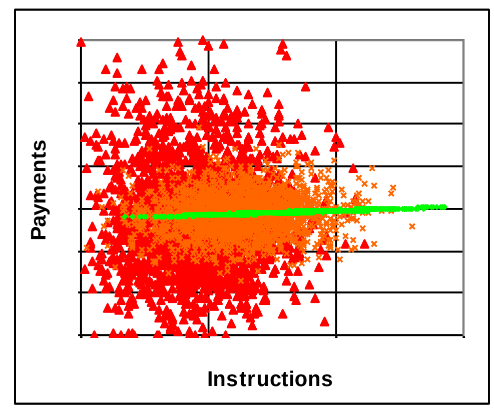


Influence of Liquidity

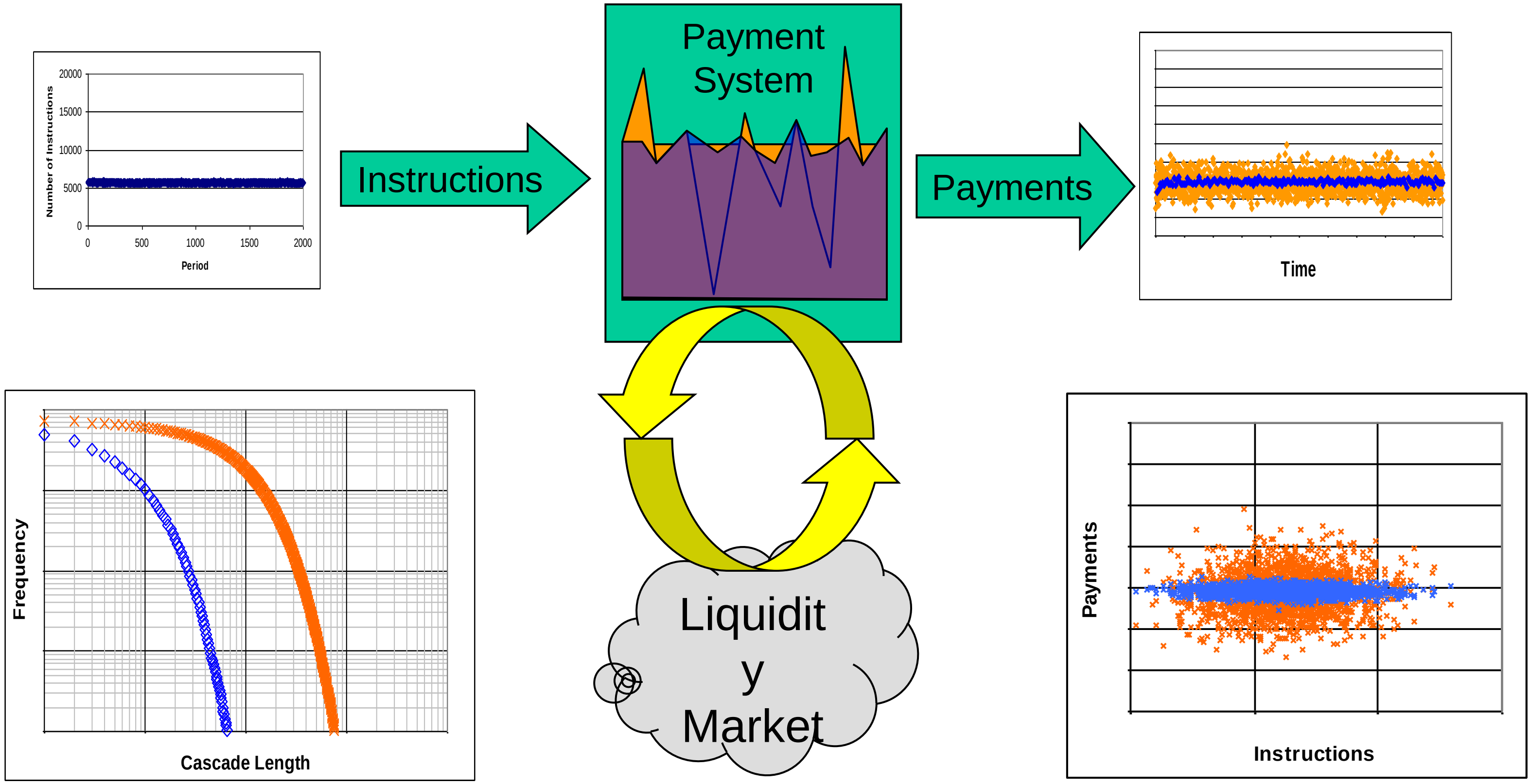


At very low liquidity payments are controlled by internal dynamics. Settlement cascades are larger and can pass through the same bank numerous times





Influence of Market



A liquidity market substantially reduces congestion using only a small fraction (e.g. 2%) of payment-driven flow

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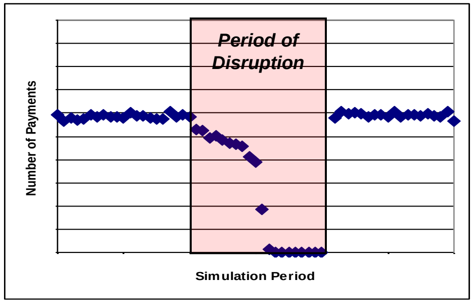
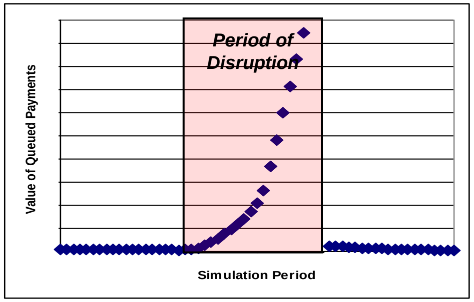
Ongoing Disruption Analyses

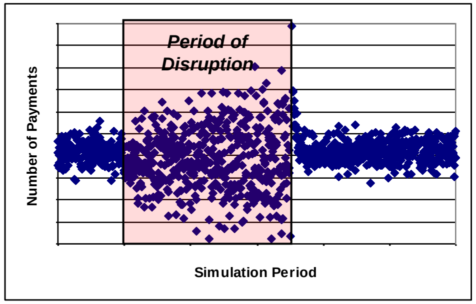
Disruption of a bank creates a liquidity sink in the system

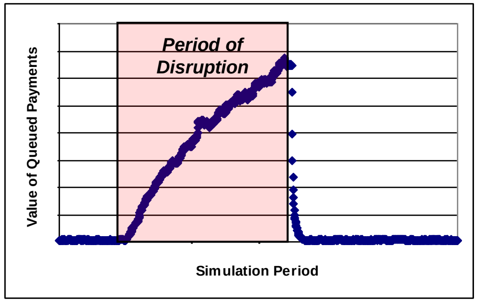




System throughput can be rapidly degraded

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 researches 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