

High-Throughput Computing and Financial Regulation

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Research Question: Background Info

THE WALL STREET

DOW JONES
A NEWS CORPORATION COMPANY

WEDNESDAY, SEPTEMBER 17, 2008 - VOL. CCLIII

DJA 11059.02 ▲ 141.51 1.3% NASDAQ 2207.90 ▲ 1.3% NIKKEI 11609.72 ▼ 5.0% DJ STOXX 50 2658.77 ▼ 3.1% 10-YR TREAS ▼ 3/32, yield 3.493

U.S. to Take Over AIG in \$85 Central Banks Inject Cash as

*Emergency Loan Effectively Gives Government Control of Insurer;
Historic Move Would Cap 10 Days That Reshaped U.S. Finance*

THE WALL STREET JOURNAL

THURSDAY, SEPTEMBER 18, 2008 - VOL. CCLIII NO. 67 ***** E2-50 *****
DJA 10609.66 ▼ 449.36 -4.1% NASDAQ 2098.05 ▼ 4.9% NIKKEI 11749.79 ▲ 1.2% DJ STOXX 50 2597.65 ▼ 2.3% 10-YR TREAS ▲ 22/32, yield 3.432% OIL \$97.16 ▲ \$6.01 GOLD \$846.60 ▲ \$9.10 EURO \$1.4552 YEN 104.14

Mounting Fears Shake World Markets As Banking Giants Rush to Raise Capital

By TOM LAURICELLA,
LEE RAPPAPORT
AND ANNELENA LOBB

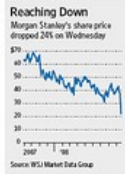
Fear coursed through the U.S. financial system on Wednesday, as hope for a resolution to the year-old credit crisis faded. Stocks tumbled, concerns grew about which financial firm would fail next, and investors rushed to ward the safe haven of government bonds in the wake of the collapse of Lehman Brothers Holding Inc. and the crisis at Insurer American International Group. The market turmoil is doing more than inflicting losses on investors. Borrowing costs for U.S. companies have skyrocketed, and the debt markets have become nearly inaccessible to all but the most creditworthy borrowers. The desperation was especially striking in the market for U.S. government debt, long considered the safest of investments. At one point during the day, investors were willing to pay more for one-month Treasury



Morgan Stanley in Talks With Wachovia, Others

By AARON LUCCHETTI,
RANDALL SMITH
AND JENNY STRASSBURG

Morgan Stanley sought shelter from the growing financial storm Wednesday, entering preliminary merger talks with Wachovia Corp. and other banks as a seventh straight decline in the company's share price sent the stock to its lowest level since 1998. After a harrowing day, Morgan Stanley's shares finished down \$6.95, or 24%, to \$21.75. Goldman Sachs Group, the largest U.S. investment bank by market value, also fell \$15.35, or 14%, to \$114.50. While the situation is more acute at Morgan Stanley, the two Wall Street banks are both battling extraordinary market pressures that have already crushed



Urgent Mission

Dismissing charges, enlisting credit

THE TIMES

Max 18C, min 5C

Tuesday September 16 2008 timesonline.co.uk No 69430

Lehman collapse sends shockwave round world

Shares and oil prices plunge, thousands lose jobs

By Duncan Economics Editor

Shares of a global financial meltdown yesterday as the world's biggest bankruptcy plunged markets into a tailspin. Investors were left reeling as the Dow Jones industrial average was down 300 points, or 2.6 per cent. Sentiment was also bolstered by steep falls in oil prices, which dropped by more than \$5 a barrel to \$96, closing under \$100 for the first time.

The New York Times

Monday, September 29, 2008 Last Update: 6:52 PM ET

BAILOUT FAILS; STOCKS PLUNGE Dow Loses 777 Points After Vote

House Rejects
Package, 228-205
By CARL HULSE and DAVID M.
HERSZENHORN 5:44 PM ET

In a moment of historic drama in the Capitol and on Wall Street, the House of Representatives voted to reject a \$700 billion rescue of the financial industry.



◀ Roll Call | Comments
• Norris: September Surprise
▶ Back Story with The Times's David



Research Question: Motivation

Opinions:

“If the crisis has a single lesson, it is that the too-big-to-fail problem must be solved.” Ben Bernanke, 2010.

“[T]he risk of failure of ‘large, interconnected firms’ must be reduced, whether by reducing their size, curtailing their interconnections, or limiting their activities.” Paul Volcker, 2012.

Legislation: Dodd-Frank Act 2010 (section 123) requires to estimate the benefits and costs of explicit or implicit limits on the maximum size of banks; limitations on the activities or structure of large financial institutions.

The argument:

- Financial markets are not casinos, allow efficient allocation of resources. Hundreds trillion dollars of notional is traded in over-the-counters financial markets.*
- There is a reason why too-big-to-fail banks are big and interconnected.*
- Restricting their size or number of connections can reduce efficiency, but might make the system more stable.*

Quadrillion dollar question(s)

- *What is the current structure of a financial architecture?*
- *What is the optimal financial architecture?*
- *What are the costs and benefits of too-interconnected-to-fail banks?*
- *How to quantify (measure) efficiency and stability of different financial architectures?*
- *Which banks are systemically important?*

Research Steps

Build a Model of Trading in Financial Markets



Estimate the Model



Rank Different Market Structures based on
Efficiency



Rank Different Market Structures based on
Stability



Derive Policy Implications for Financial
Regulation

Computational Intensity

Estimate the Model

- Requires solving the model 850 million times
- Can be done in parallel
- Feasible solutions: HTC (days)

High
computational
intensity

Rank Different Market Structures based on Efficiency

- Requires solving the model 1.41 million times
- Can be done in parallel
- Feasible solutions: HTC (\approx 1 hour) or Multi-core CPU (\approx 10 hours)

Low
computational
intensity

Rank Different Market Structures based on Stability

- Requires solving a trading model with contagion 5.64 million times
- Can be done in parallel
- Feasible solutions: HTC (several hours) or Multi-core CPU (several days)

Medium
computational
intensity

Total computation resources used (Condor + OSG): **391,406 CPU hours**

Estimation using Indirect Inference (SMM)

Unobservable:

Financial Architecture –
Network of Trading
Relationships.

Preferential attachment
model: 1 parameter, 17
possible values, 250
simulations

Price-setting mechanism:
bargaining, auctions.
4 different models

Distribution of endowment
shocks and shocks to
private values:
200 simulations per day, 250
days

Trading Model:

*Mapping from
endowments to
equilibrium
allocations for
any possible
network of
trading
relationships*

Observable:

Network of trades:

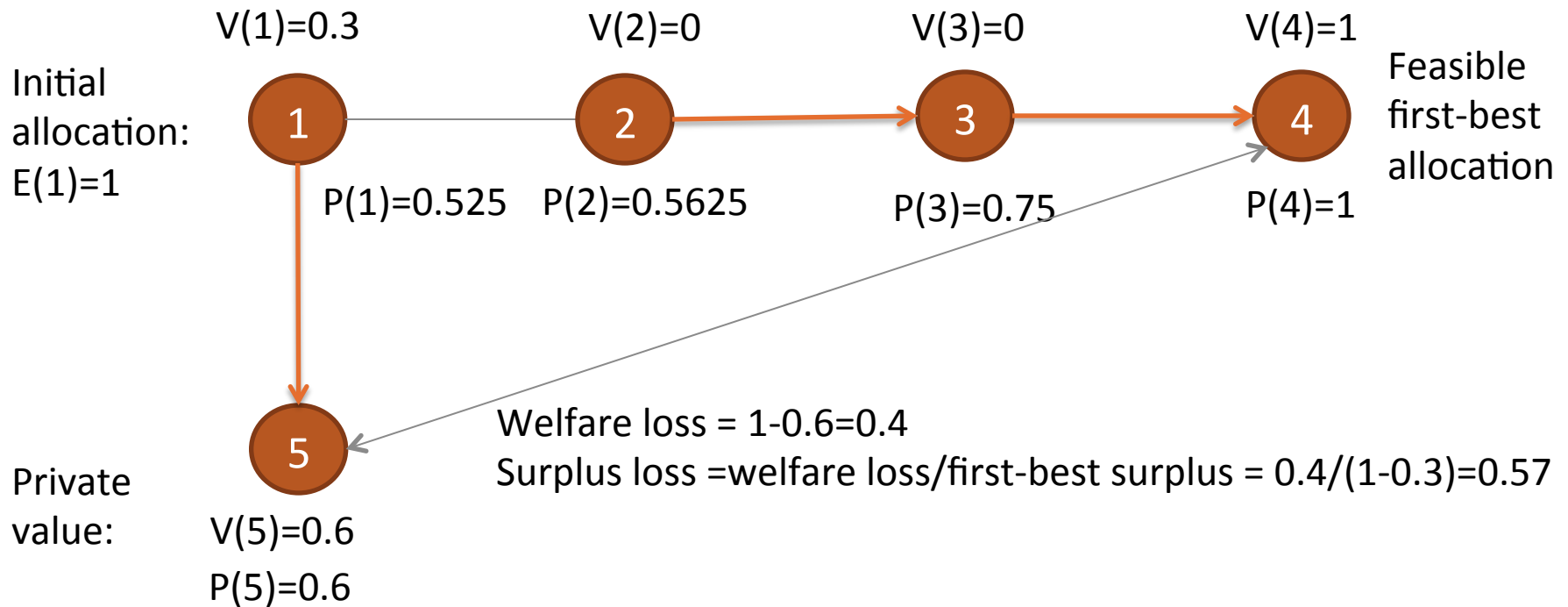
- Density
- Max in-degree
- Max out-degree
- Diameter
- Size

Unobservable:

Efficiency

Stability

Illustration of the Model



The Model

- n banks trade overnight unsecured loans
- Financial architecture is modeled as a trading network (\mathbf{g}) that describes trading relationships between banks. $\mathbf{N}(i, \mathbf{g})$ is a set of trading partners of bank i in network \mathbf{g} .
- One bank at a time receives a random endowment shock (excess liquidity). $\mathbf{F}(\mathbf{E})$ is distribution of endowment shocks.
- Bank i has a private value for excess liquidity (V_i) between 0 and 1. $\mathbf{G}(\mathbf{V})$ is distribution of private values across banks.
- Price-setting mechanism: $\mathbf{B}(i, j) \in (0, 1)$ captures the share of surplus that bank i receives when provides a loan to bank j . Surplus is the difference between the private value of the seller and an *endogenous valuation* of the buyer.
- Complete information.

Reference: “A Network-Based Analysis of Over-the-Counter Markets”, Gofman (2011)

Equilibrium

i. Bank i 's equilibrium valuation is given by:

$$P_i = \max \left\{ V_i, \max_{j \in N(i,g)} V_i + B_i(P_j - V_i) \right\}$$

ii. Bank i 's equilibrium trading decision is given by:

$$\sigma_i = \operatorname{argmax}_{j \in N(i,g) \cup i} P_j$$

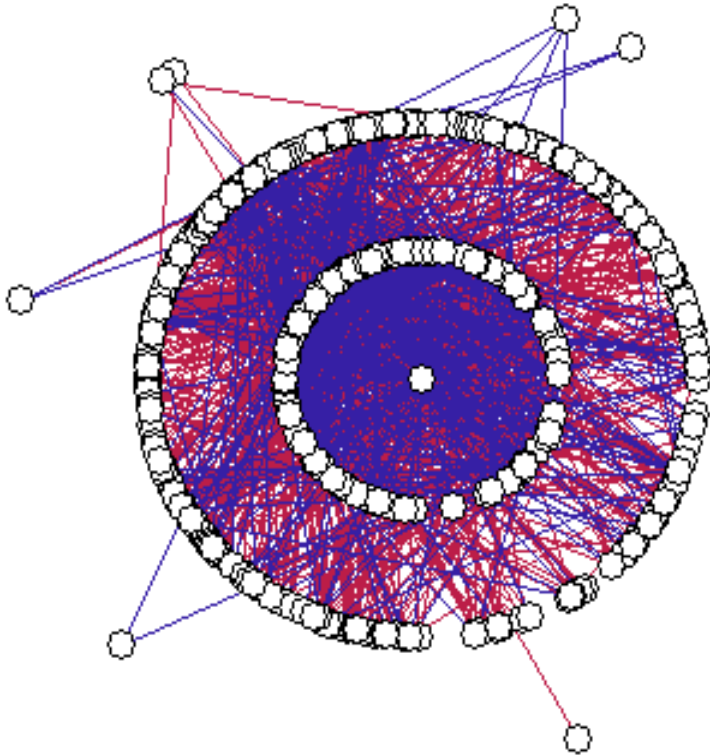
One “instance”
of the model
requires to
solve 986
equations

Equilibrium Properties:

- Contraction Mapping
- No bubbles
- Endogenous valuations are unique, decisions are generically unique
- Prices increase along the intermediation chain
- Intermediation chains are endogenous
- Intermediaries make profits
- The whole network structure matters because prices are forward looking.

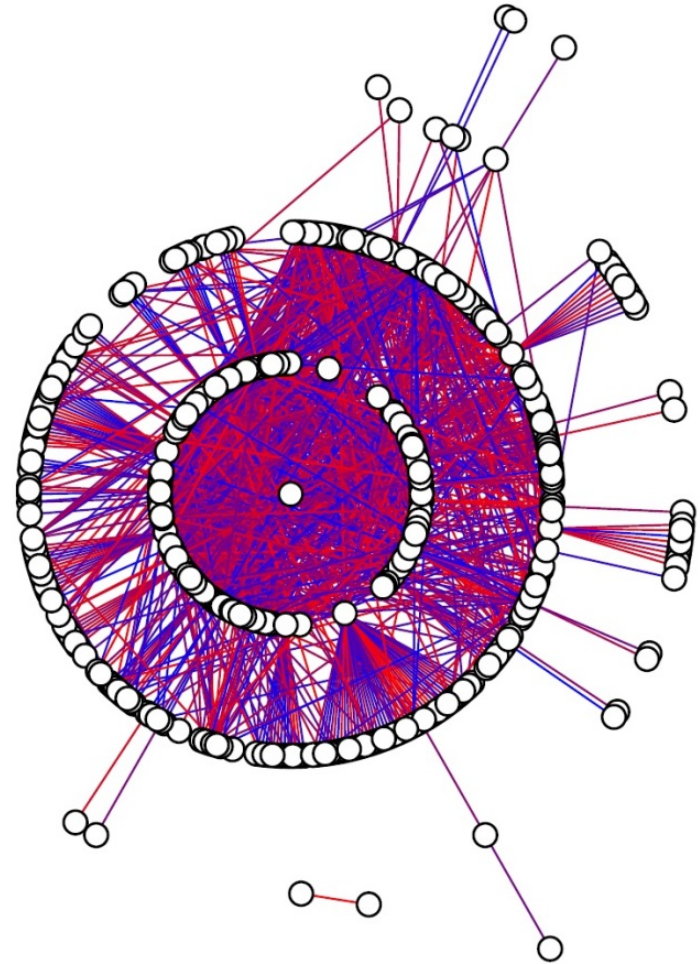
Model Fit: Visualization

Model



Equilibrium daily network of trades in the model. Only one third of all trading relationships are equilibrium trades.

Data



Network of trades in the Fed funds market on September 29, 2006
Source: Bech and Atalay (2010)

Equilibrium Network of Trades: Model vs. Data

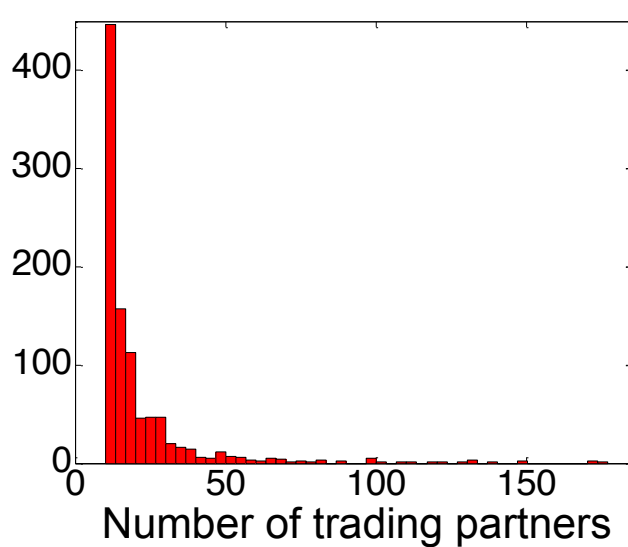
	Model 250 trading days	Federal Funds Data ('06) 250 trading days
Average density (%)	0.74%	0.70%
Standard deviation	0.04%	0.03%
Max number of lenders to a single bank	116.6	127.6
Standard deviation	11.21	16.3
Max number of borrowers from a single bank	48.2	48.8
Standard deviation	5.94	6.4
Average number of active banks	514	470
Standard deviation	19.05	15.3
Maximum number of intermediaries	6.2	6.3
Standard deviation	0.7	1

* Data Source: “The Topology of the Federal Funds Market” Bech and Atalay , *Physica A*, 2010

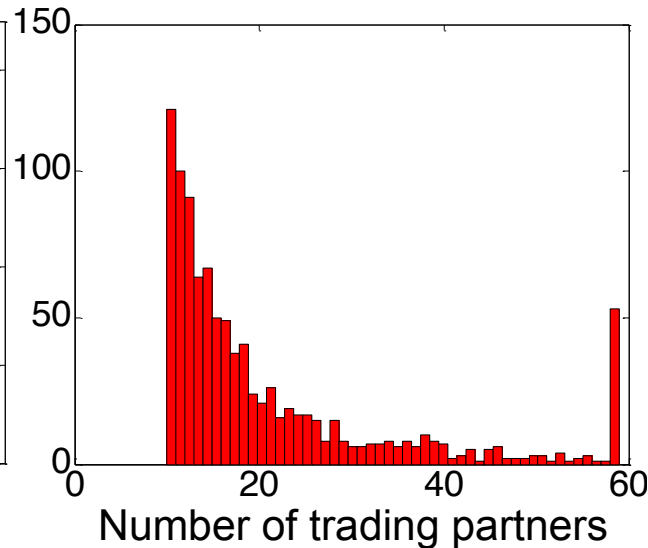
3 parameters to match 5 moments using SMM, 5 std. dev. (not targeted) also match well.

Estimated and Regulated Financial Architectures

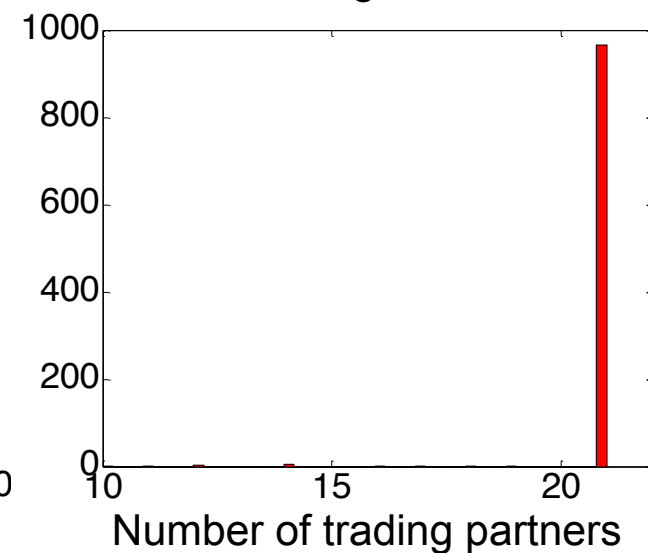
Estimated architecture
Average max degree=171



Medium level of regulation
Max degree=60



Extreme level of regulation
Max degree=22



All networks are generated using the estimated preferential attachment process:

- Start with a core of 11 banks (estimated parameter) and add new banks with 11 trading relationships until reach 986 banks in total.
- Banks are more likely to link to a bank that already has more trading relationships.
- Regulation experiment: Put a cap on the maximum number of trading partners.
- Nine regulated financial architectures (cap=120, 100, 80, 60, 50, 35, 30, 25, 22).

Policy Implications

- Restricting the number of trading partners of big banks reduces efficiency.
- Restricting the number of trading partners of big banks can improve stability only in some types of financial contagion.
- More strict regulation is not necessarily better because the relationship between contagion risk and limits on the number of trading partners is not monotonic.
- Most interconnected banks are not necessarily the ones that trigger the largest cascades of bank failures during a crisis.

HTC: Challenges and Recommendations

Challenges:

- Need to specify a different seed for randomization on each node.
- Requires to write a program to collect results from different folders.
- Needed to purchase a SSD hard drive to combine the output.
- No ability to utilize parallel computing on each node (parfor loops in Matlab don't work on multiple nodes)

Recommendations:

1. Always test a code on a small-scale
2. HTC is a shared resource, be thoughtful about utilizing it efficiently
3. The best part of the HTC resource at UW-Madison is the technical support. Always ask, they will help with 100% probability.
4. When need urgent results, ask for higher priority, but do it only if truly needed (see point 2).

Thank you!

Further reading: *“Efficiency and Stability of a Financial Architecture with Too-Interconnected-to-Fail Institutions”*

Download at: <http://gofman.info/SMM>