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CCFEA
Centre for Computational Finance and Economic Agents

Systemic Risk from Derivatives: Network Analysis

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Outline

- Financial Derivatives Market and Systemic Risk
- Network Analysis of US Financial Derivatives Market
- Contagion Analysis
- Concluding Remarks and Further Work

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Financial stability and systemic risk

- The recent financial crisis has emphasized the importance of contagion and systemic risk, defined as risk which can influence the stability of the financial system as a whole
- Control over systemic risk has been the main motivation of the recent bailouts of large financial institutions
- Regulators have had great difficulties anticipating the impact of defaults partly due to a lack of visibility and lack of relevant indicators on the structure of the financial system

$603 Trillion Dec 2009 OTC Derivatives

- When compared to the size of world GDP at $70 tn, and size of the global bond market (total debt outstanding) at about $82 tn, the implication is that the size of off balance sheet activities of financial intermediaries (FIs) has grown to many multiples of their assets and derivatives obligations of FIs under conditions of market wide adverse movements on the underlying (such as interest rates, house prices, exchange rates, external debt of countries including sovereign debt) could overwhelm the equity and assets of FIs.

- Indeed, the key structural aspect of the networks underpinning financial derivatives has been summarized in the 2009 Fitch survey: “dependence on a limited number of counterparties looks to be a permanent feature of the market; this is underscored by the fact that the top 12 counterparties comprised 78% of total exposure in terms of the number of times cited, up from the 67% reported last year. The top five institutions that provided volume figures accounted for 95% of total notional amount bought and sold. This concentration is a reflection of the dominant role of banks and dealers as counterparties, particularly after the collapse of a limited number of financial institutions who were important intermediaries in this market.” http://www.scribd.com/doc/37557210/Fitch-Market-Research-Global-Credit-Derivatives-Survey-09162010 .
- These are Goldman Sachs, JP Morgan Chase, Barclays, Bank of America, Deutsche Bank, Morgan Stanley, Credit Suisse, BNP Paribas, UBS, Bank of America, Merrill Lynch, Royal Bank of Scotland.

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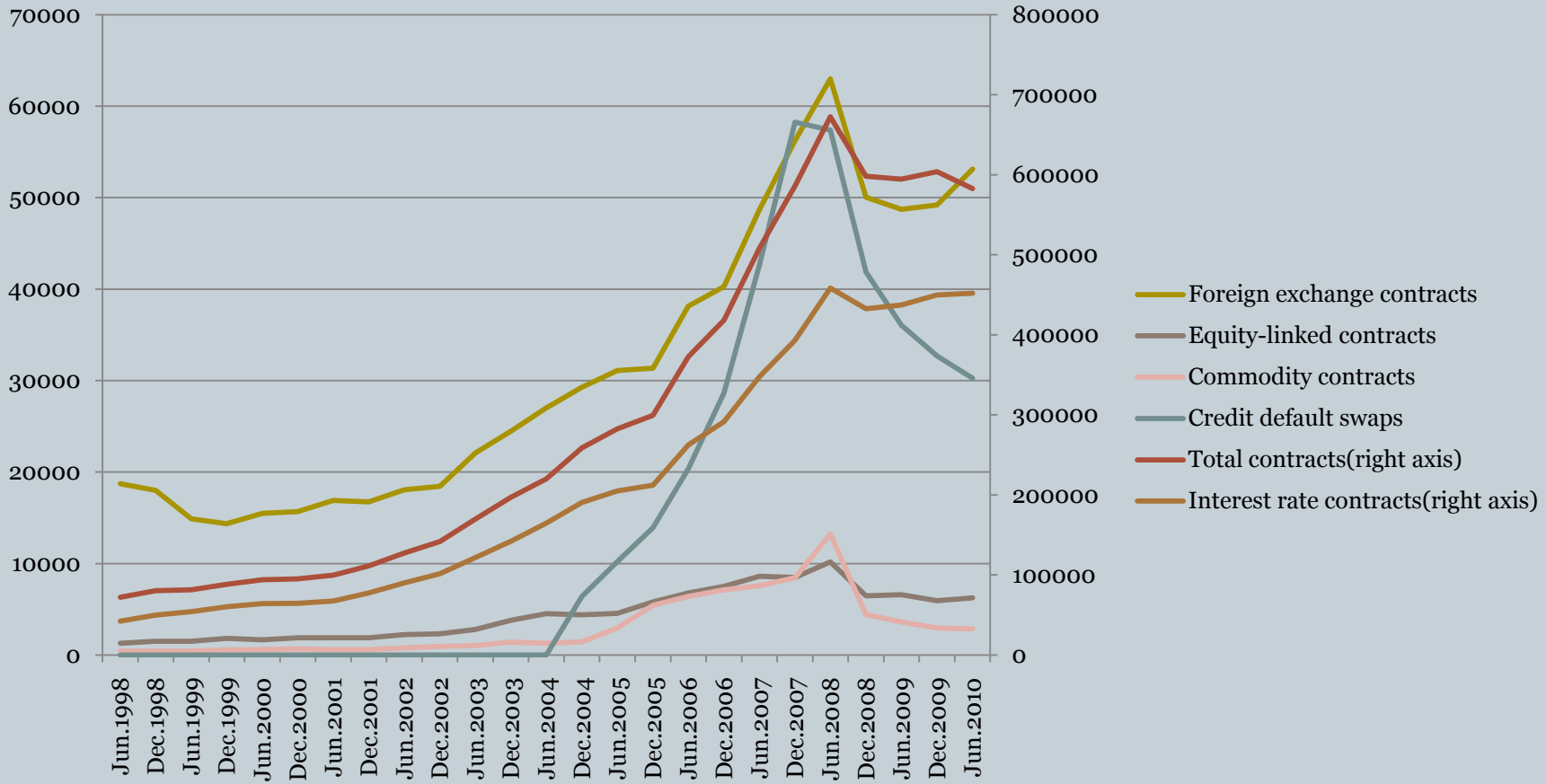
Derivative Dilemmas

- The degree to which derivatives had created a dangerously interconnected financial system became clear amid the collapse of **Bear Stearns, Lehman Brothers** and **AIG** in 2008. A default by one bank at the centre of a tangled web of derivatives contracts could paralyse the entire financial system, because the derivatives could become worthless if the bank writing the contract went under. http://www.ft.com/cms/s/0/fa3794be-a57b-11df-a5b7-00144feabdc0.html#axzz1E4jpq2G1

Notional amounts outstanding: Bns(source BIS)

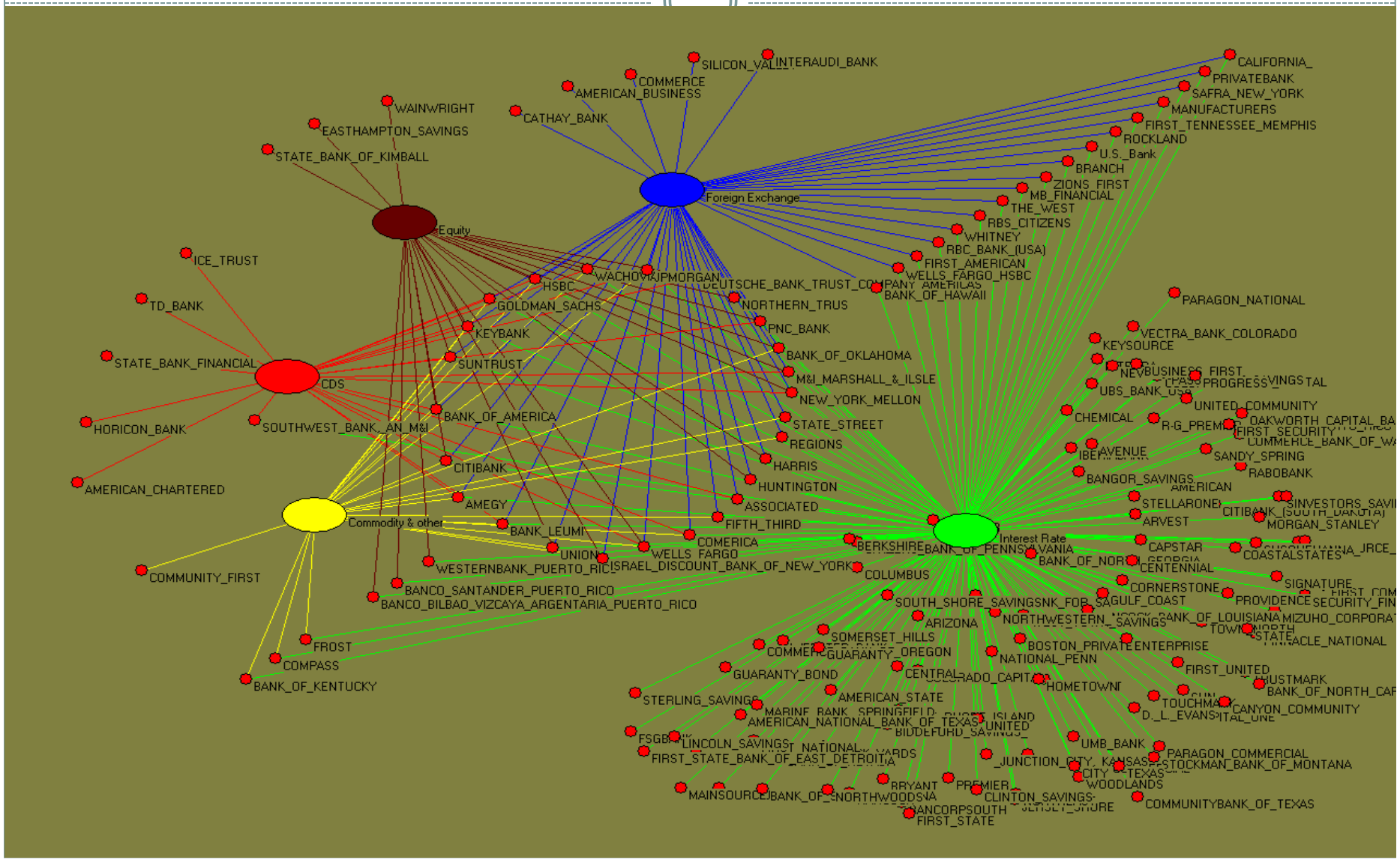


US Banks With Derivative Positions($):2009 Q4 FDIC Data

F.I.Name	IR	F.I.Name	FX	F.I.Name	Equity	F.I.Name	Commodity	F.I.Name	CDS SOLD GN	F.I.Name	Total
JPMORGAN	63,382,511,000	JPMORGAN	7,082,377,000	JPMORGAN	1,238,114,000	JPMORGAN	738,168,000	ICE	3,301,673,718	JPMORGAN	75,381,081,000
GOLDMAN	39,278,924,000	CITIBANK	3,856,043,000	BoA	162,675,418	CITIBANK	58,800,000	JPMORGAN	2,939,911,000	BoA	42,222,864,886
BoA	37,849,749,439	BoA	2,240,063,347	CITIBANK	161,300,000	STATE STREET	52,947,641	BoA	1,964,463,832	GOLDMAN	41,118,442,000
CITIBANK	30,920,952,000	GOLDMAN	1,493,888,000	WACHOVIA	50,275,000	WACHOVIA	47,263,000	CITIBANK	1,089,611,000	CITIBANK	36,086,706,000
WACHOVIA	1,981,439,000	HSBC USA	573,909,305	HSBC USA	24,150,553	HSBC USA	28,055,496	HSBC USA	372,604,526	ICE	3,301,673,718
HSBC USA	1,489,008,938	STATE_STREET	567,798,875	FARGO	20,847,000	FARGO	23,450,000	GOLDMAN	339,144,000	HSBC USA	2,487,728,818
NY MELLON	1,033,472,000	NY MELLON	234,277,000	SUNTRUST	10,252,532	GOLDMAN	6,168,000	WACHOVIA	85,699,000	WACHOVIA	2,263,355,000
FARGO	960,528,000	NORTHERN	163,587,384	NY MELLON	7,653,000	BoA	5,912,850	KEYBANK	1,916,952	NY MELLON	1,275,404,000
SUNTRUST	178,222,685	WACHOVIA	98,679,000	HARRIS	816,666	OKLAHOMA	5,583,549	PNC_BANK	542,000	FARGO	1,073,469,000
PNC	124,850,181	FARGO	68,304,000	PNC	343,956	UNION	3,405,389	FARGO	340,000	STATE STREET	622,692,567
Others	517,244,091	Others	58,711,625	Others	1,339,142	Others	5,100,690	Others	485,772	Others	1,070,136,563
Total	177,716,901,334	Total	16,437,638,536	Total	1,677,767,267	Total	974,854,615	Total	10,096,391,800	Total	206,903,553,552

Market	Mean ($000s)	Standard Deviation (σ)	Skewness	Kurtosis	Max
IR	875,452,715.9	6,214,603,264.6	7.9	65.8	63,382,511,000.0
FX	80,973,588.8	595,760,179.8	9.7	103.5	7,082,377,000.0
Equity	8,264,863.4	88,307,824.6	13.6	188.9	1,238,114,000.0
Other	4,802,239.5	52,188,019.6	13.9	195.8	738,168,000.0
CDS	49,735,920.2	347,192,019.0	8.0	65.8	3,301,673,718.0
Total	1,019,229,327.8	7,131,250,614.2	8.1	71.0	75,381,081,000.0

Structure of Financial Derivatives Market: (2009, Q4): Green(Interest Rate), Blue (Forex), Maroon (Equity); Red (CDS); Yellow (Commodity); Circle Broker Dealers in all markets (Bi-partite Graph)



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Use of Networks in Finance and Economics

- Relatively new but since the financial crises of 2008-2009 has received more interest
- Real world complex networks: unsuspected regularities across many domains, ranging from biology or computer systems to society and economics
- Universal or at least generic mechanisms are at work in the formation of many such networks
- (Estrada et al. 2010)

Levels of Network Analysis

- First: purely topological approach(best optimised by a binary adjacency matrix where links simply exist or not
- Second: allowing the links to carry weights, or weights and direction
- Third: the nodes themselves are assigned a degree of freedom or fitness

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Type of Financial Networks

- It is important to understand which type of networks can be constructed for financial systems , and evaluating the imperial results on networks obtained by investigating large databases of financial data ranging from individual transactions in a financial market to strategic decisions at a bank level.
- In this regard there are three main type of networks that has been studied (Estrada et al. 2010)
- 1)Networks to extract information from *Correlation Matrices*
- 2)Networks of control as, for example, the *Ownership Network* and the *Board of Directors* Network
- 3)Trading networks as the *World Trade Web* and the *Banks' Credit networks*

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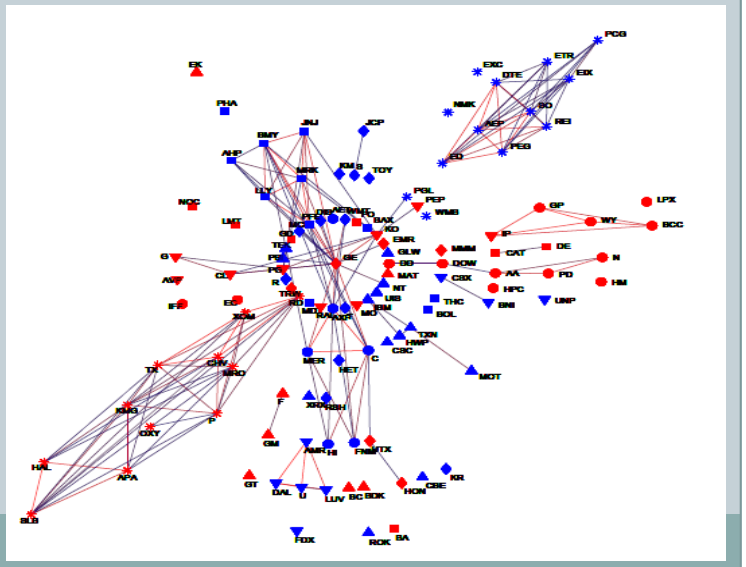
General Financial Network

- In general terms we can divide networks into similarity based networks and direct interaction networks
- Example for similarity based network: characterisation of the cross-correlation structure of price returns in stocks portfolio



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Transaction Networks

- Interbank Networks and Bank-Firm Networks(Boss et al. Interbank market and payment system

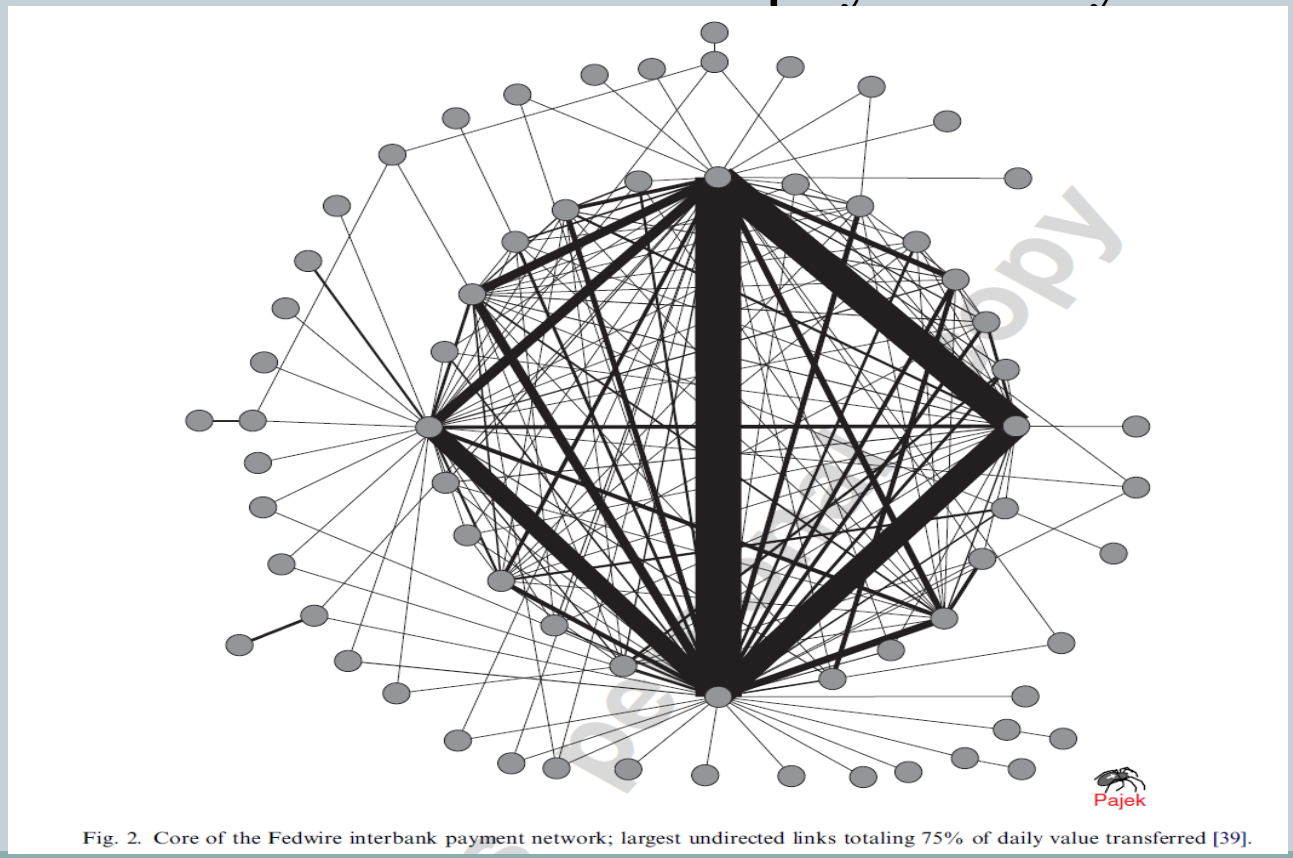
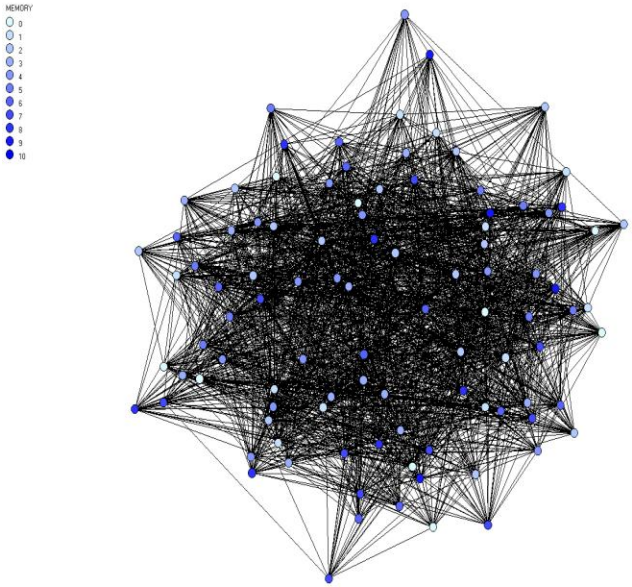
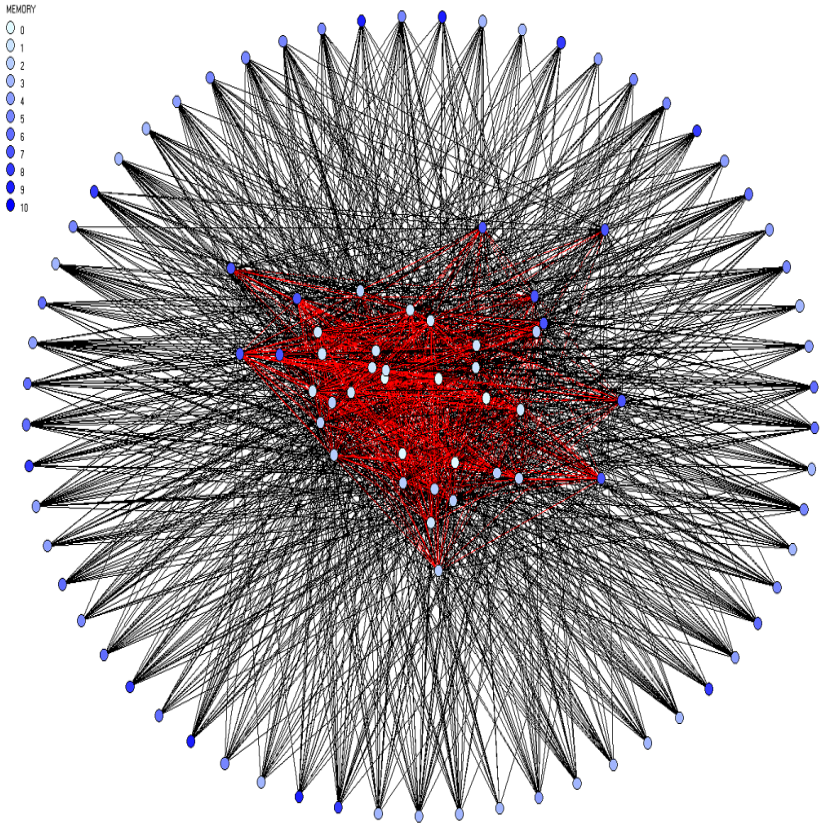


Fig. 2. Core of the Fedwire interbank payment network; largest undirected links totaling 75% of daily value transferred [39].

Some Network Concepts : A graphical representation of random graph (left) and small world graph with hubs, Markose et. al. 2004 High Assortative





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Properties of Networks

Diagonal Elements Characterize Small World Networks

Watts and Strogatz (1998), Watts (2002) See Markose et. al. (2004)

Properties / Networks	Clustering Coefficient	Average Path Length	Degree Distribution
Regular	*High*	High	Equal and fixed In-degrees to each node
Random	Low	*Low*	Exponential/ Poisson
Scale Free/Power Law	Low	Variable	*Fat Tail Distribution*

Financial Networks for the Derivatives Obligations: High Clustering from broker dealer behaviour and Barabasi et. al. Preferential attachment model

- Our algorithm assigns in and out degrees for a bank in terms of its respective market shares ($s_i^{B/G}$) for Derivatives purchases(B) and Derivatives sales (G), resp. GNFV and GPFV

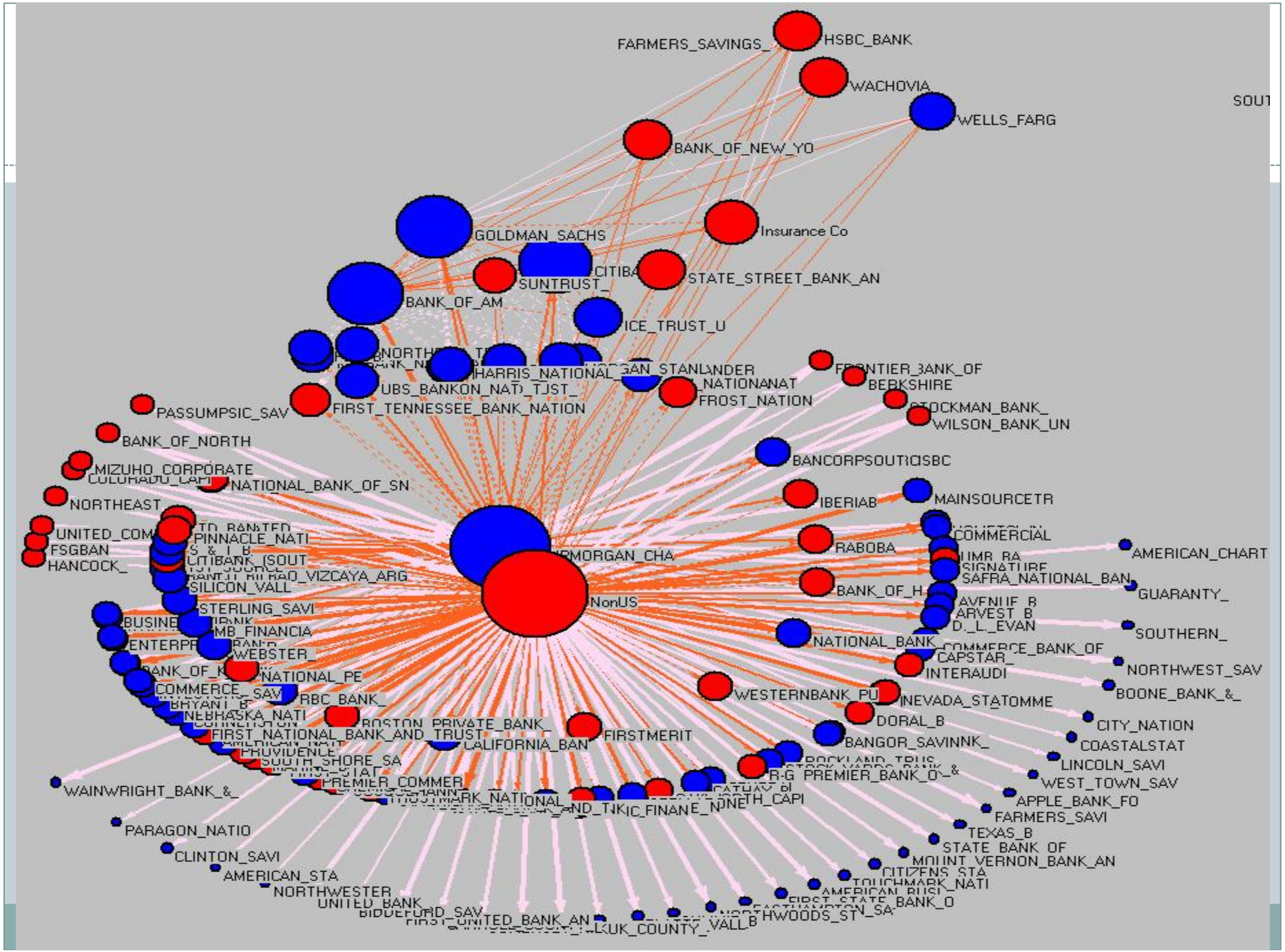
$$X = \left[\begin{array}{cccccc|c} 0 & x_{12} & x_{13} & ..x_{ij}. & .... & x_{1N+1} & \Gamma = \sum_i G_i \\ x_{21} & 0 & x_{23} & .... & .... & x_{2N+1} & G_1 \\ . & . & 0 & .... & .... & . & G_2 \\ x_{i1} & . & & 0 & & x_{iN+1} & . \\ . & . & & & 0 & & G_i \\ x_{N+11} & & & x_{N+1j} & & 0 & . \\ & & & & & & G_{N+1} \\ \hline \Theta = \sum_j B_j & B_1 & . & . & B_j & .... & B_{N+1} \end{array}\right]$$

$$x_{ij} = \begin{cases} G^i s_j^B & \text{for the largest } (1+Ns_i^G)\text{'s counterparties} \\ 0 & otherwise \end{cases}$$

Empirical Validation of Constructed Network

- The Table below gives the FDIC amount of assets and liabilities for a sample number of FIs compared to model estimated values derived from the network construction algorithm. The original bilateral payables and receivables are shuffled, so that the empirical bilaterally netted amounts are obtained.

FI Name	Actual Assets	Actual Liabilities	Model Estimated Assets	Model Estimated liabilities
'JPMORGAN_CHASE_BANK'	72,008,000	64,340,000	53.96947572	20.63947572
'BANK_OF_AMERICA'	29,452,150	8,471,760	38.92072465	18.41826065
'CITIBANK'	58,966,000	46,986,000	34.96444539	18.73644539
'HSBC_BANK_USA'	8,615,308	5,196,214	10.72017734	11.84431334
'GOLDMAN_SACHS_BANK_USA'	22,662,000	12,040,000	98.1738958	35.1038958
'WACHOVIA_BANK'	14,381,000	4,612,000	10.62476032	10.95076032
'KEYBANK_NATIONAL_ASSOCIATION'	848,516	918,223	1.141161049	1.046082049
'PNC_BANK'	595,504	322,404	1.46812615	1.45225215
'WELLS_FARGO_BANK'	7,023,000	4,350,000	5.838533597	4.349533597


FARMERS_SAVINGS_
HSBC_BANK
WACHOVIA
WELLS_FARG
BANK_OF_NEW_YO
GOLDMAN_SACHS
Insurance Co
SUNTRUST_
STATE_STREET_BANK_AN
BANK_OF_AM
ICE_TRUST_U
HARRIS_NATIONAL
UBS_BANKON_NAT_TJST_
FIRST_TENNESSEE_BANK_NATION
FROST_NATION
FRONTIER_BANK_OF
BERKSHIRE
WILSON_BANK_UN
PASSUMPSIC_SAV
BANK_OF_NORTH
MIZUHO_CORPORATE
NATIONAL_BANK_OF_SN
NORTHEAST
BANCORPSOUTHSBC
IBERIAB
MAINSOURCETR
COMMERCIAL
RABOBA
AMERICAN_CHART
SAFRA_NATIONAL_BAN
GUARANTY_
SOUTHERN_
NorthWest_SAV
BOONE_BANK_&_
CITY_NATION
COASTALSTAT
LINCOLN_SAVI
WEST_TOWN_SAV
APPLE_BANK_FO
FARMERS_SAVI
TEXAS_B
STATE_BANK_OF
MOUNT_VERNON_BANK_AN
TOUCHMARK_NATI
PARAGON_NATIO
CLINTON_SAVI
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NORTHWESTER
UNITED_BANK
PMORGAN_CHA
NonUS
STERLING_SAVI
SILICON_VALL
PINNACLE_NATI
CITIBANK_(SOUT
HANCOCK_
FSGBAN
UNITED_COM
WEBSTER_
NATIONAL_PE
RBC_BANK_
FIRST_NATIONAL_BANK_AND_TRUST
FIRSTMERIT
CALIFORNIA_BAN
BANGOR_SAVINNK_
DORAL_B
WESTERNBANK_PU
NEVADA_STATOMME
CAPSTAR_
INTERAUDI
NATIONAL_BANK_COMMERCE_BANK_OF
WAINWRIGHT_BANK_&_
PREMIER_COMMER
PREMIER_BANK_O_&
SOUTH_SHORE_SA
PHUVIDENCE
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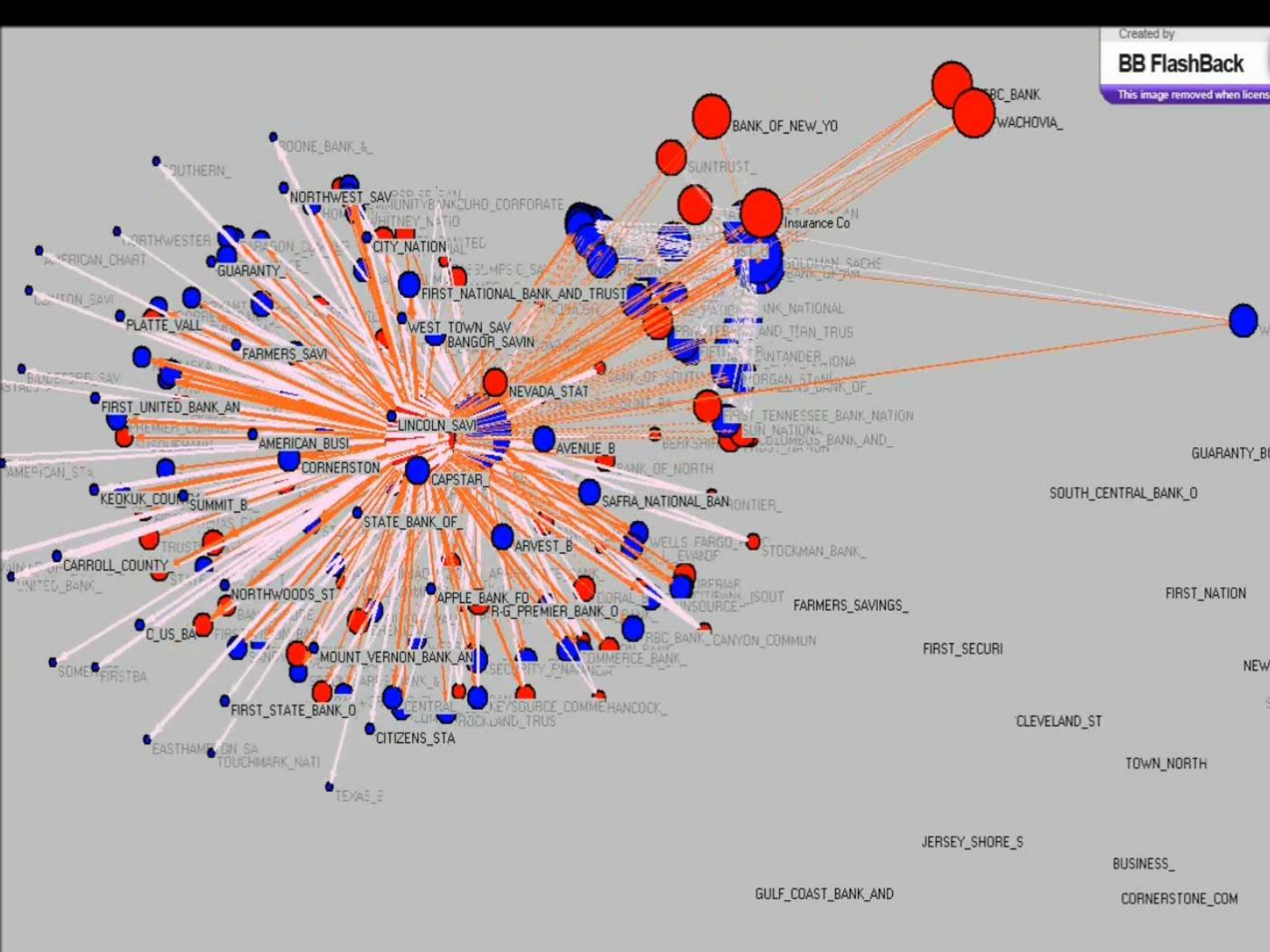
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BANK_OF_NEW_YO
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Insurance Co
NORTHWEST_SAV
CITY_NATION
GUARANTY_
FIRST_NATIONAL_BANK_AND_TRUST
PLATTE_VALL
WEST_TOWN_SAV
BANGOR_SAVIN
FARMERS_SAVI
NEVADA_STAT
FIRST_UNITED_BANK_AN
LINCOLN_SAVI
AMERICAN_BUSI
AVENUE_B
CORNERSTON
CAPSTAR_
SAFRA_NATIONAL_BAN
SUMMIT_B_
STATE_BANK_OF_
ARVEST_B
CARROLL_COUNTY
NORTHWOODS_ST
APPLE_BANK_FO
MOUNT_VERNON_BANK_AN
FIRST_STATE_BANK_O
CITIZENS_STA
GUARANTY_BU
SOUTH_CENTRAL_BANK_O
FARMERS_SAVINGS_
FIRST_NATION
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CLEVELAND_ST
TOWN_NORTH
JERSEY_SHORE_S
BUSINESS_
GULF_COAST_BANK_AND
CORNERSTONE_COM

Contagion

- The first step to measuring credit exposure in derivative contracts involves identifying those contracts where a bank would lose value if the counterparty to a contract defaulted today. The total of all contracts with positive value (i.e., derivatives receivables) to the bank is the gross positive fair value (GPFV) and represents an initial measurement of credit exposure. The total of all contracts with negative value (i.e., derivatives payables) to the bank is the gross negative fair value (GNFV) and represents a measurement of the exposure the bank loses to its counterparties.(2009 OCC Derivatives Report)

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Too Interconnected To Fail :Stress Test

- Objective: Build Derivatives Network and Conduct Stress Tests

  There is very high correlation between the dominance of market share in Derivatives market and network connectivity

- Stress Tests: Follow Furfine (2003) Algorithm
- We use 2% reduction of Tier 1 capital to signal bank failure
- Experiment : (A) The loss of derivatives payables due to the failed bank as counterparty suspending its guarantees will have a contagion like first and multiple order effects. Full bilateral tear up assumed; No possibility for Novation

  NET EXPOSURE > 2% Tier 1 Capital

		JPMorgan		BoA		Goldman		CITI		ICE		Wells Fargo	KeyBank
Financial_Institution_Name	**Tier 1 capital**	Loss($)in bn	%	Loss($)in bn	%	Loss($)in bn	%	Loss($)in bn	%	Loss($)in bn	%		
JPMORGAN_CHASE	96.372	-96.372	-100.000%	-1.423	-1.477%	-9.706	-10.071%	-10.331	-10.720%	-0.036	-0.037%	0	0
BANK_OF_AMERICA	111.916	-0.271	-0.242%	-111.916	-100.000%	-0.271	-0.242%	-0.271	-0.242%	-0.022	-0.020%	0	0
GOLDMAN_SACHS	17.152	-18.617	-108.544%	-10.940	-63.783%	-17.152	-100.000%	-8.306	-48.425%	-0.068	-0.395%	0	0
CITIBANK,_N.A.	96.833	-0.401	-0.414%	-0.115	-0.119%	-0.401	-0.414%	-96.833	-100.000%	-0.017	-0.018%	0	0
ICE_TRUST_U.S._LLC	0.046	0.000	0.000%	0.000	0.000%	0.000	0.000%	0.000	0.000%	-0.046	-100.000%	0	0
HSBC_BANK_USA	13.354	-9.664	-72.373%	-10.720	-80.279%	-9.664	-72.373%	-9.664	-72.373%	0.000	0.000%	0	0
WACHOVIA_BAN	39.786	-9.503	-23.886%	-10.625	-26.705%	-9.503	-23.886%	-9.503	-23.886%	0.000	0.000%	0	0
NEW_YORK_MELLON	10.149	-2.368	-23.335%	-2.662	-26.231%	-2.368	-23.335%	-2.762	-27.219%	0.000	0.000%	0	0
WELLS_FARGO_BANK	43.765	-2.810	-6.422%	-2.632	-6.014%	-2.379	-5.436%	-2.775	-6.340%	0.000	0.000%	0	0
STATE_STREET_BANK	11.378	-0.920	-8.088%	-0.953	-8.378%	-0.920	-8.088%	-1.073	-9.434%	0.000	0.000%	-43.765	0
SUNTRUST_BANK	11.973	-0.560	-4.673%	-0.852	-7.115%	-0.560	-4.673%	-0.653	-5.451%	0.000	0.000%	0	0
NORTHERN_TRUST	4.756	-0.291	-6.122%	-0.443	-9.321%	-0.291	-6.122%	-0.340	-7.141%	0.000	0.000%	0	0
PNC_BANK	24.491	-0.398	-1.625%	-0.606	-2.474%	-0.398	-1.625%	-0.862	-3.520%	0.000	0.000%	0	0
KEYBANK	8.090	-0.323	-3.995%	-0.463	-5.725%	-0.304	-3.760%	-0.355	-4.386%	0.000	0.000%	0	-8.090
REGIONS_BANK	10.577	-0.212	-2.008%	-0.463	-4.379%	-0.212	-2.008%	-0.248	-2.342%	0.000	0.000%	0	0
U.S._BANK	16.250	-0.170	-1.044%	-0.404	-2.486%	-0.170	-1.044%	-0.347	-2.135%	0.000	0.000%	0	0
FIFTH_THIRD_BANK	13.575	-0.143	-1.055%	-0.361	-2.662%	-0.143	-1.055%	-0.310	-2.287%	0.000	0.000%	0	0
UNION_BANK	7.207	-0.095	-1.320%	-0.237	-3.292%	-0.095	-1.320%	-0.204	-2.827%	0.000	0.000%	0	0
RBS_CITIZENS	8.237	-0.179	-2.177%	-0.191	-2.323%	-0.179	-2.177%	-0.272	-3.305%	0.000	0.000%	0	0
BRANCH_BANKING	13.544	-0.072	-0.533%	-0.169	-1.247%	-0.072	-0.533%	-0.150	-1.109%	0.000	0.000%	0	0
BANK_OF_OKLAHOMA	1.079	-0.051	-4.767%	-0.078	-7.259%	-0.051	-4.767%	-0.060	-5.561%	0.000	0.000%	0	0
DEUTSCHE_AMERICAS	8.289	-0.689	-8.307%	-0.466	-5.627%	-0.306	-3.696%	-0.357	-4.311%	0.000	0.000%	0	0
HUNTINGTON	2.873	-0.051	-1.790%	-0.063	-2.200%	-0.051	-1.790%	-0.090	-3.130%	0.000	0.000%	0	0
COMERICA_BANK	5.763	-0.072	-1.249%	-0.166	-2.874%	-0.072	-1.249%	-0.142	-2.468%	0.000	0.000%	0	0
MANUFACTURERS	4.988	-0.055	-1.111%	-0.120	-2.414%	-0.055	-1.111%	-0.103	-2.073%	0.000	0.000%	0	0
Total US Banks	705.221												
No of Banks Failed		**18**		**32**		**18**		**32**		**1**		**1**	**1**
Tier1 Capital loss for top 25		**-144.290**		**-157.071**		**-55.326**		**-146.012**		**-0.189**		**-43.765**	**-8.090**
Total Tier 1 Capital Loss		**-151.809**		**-159.899**		**-62.837**		**-153.585**		**-0.189**		**-43.765**	**-8.090**

Conclusion and Future Work

- "Systemic risk involves understanding structure and dynamics of complex financial networks. Efficient methods for large scale simulation and optimization of these networks provide better insight than simplistic equilibrium models based on homogeneous network structures" (Rama Cont)
- The extension of the current model will focus on global derivatives market specifically the addition of European institutions.
- Also the current aggregate model could be extended to the activity of financial intermediaries in multiple markets, for this the theory of hyper-networks could be utilised