

Multiplex Financial Network Dependencies

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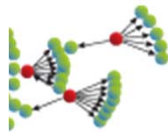
Boston University, USA



*Econophysics Lecture – Prof. Gene Stanley’s class
GRS - Physics Department, Boston University*

Acknowledgments

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Project Coordinator: Guido Caldarelli, IMT Lucca, Italy



*fo*c
forecasting financial crises



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Outline

- Motivation – Why Econophysics?
- Global financial crisis of 2008
- European sovereign debt crisis of 2010
- Why systemic risk matters?
- Connectivity of financial systems
- Discussion and Conclusion

Motivation - Fragility of Economic Systems

- Economic systems have recently become more globally interconnected - **globalization**
- Exogenous or endogenous shocks can provoke cascading failures (**9/11, Subprime mortgage crisis**)
- Financial systems are susceptible to sharp transitions from seemingly **stable** to irreversibly **unstable** states
- Sound **policies** are necessary to halt **cascading failures** or soften their impact



Bubbles and Financial Crisis

- Tulip Mania (1634-1638)
- The Mississippi Bubble (1719-1720)-JL
- The South Sea Bubble (1720) - LA
- Railway Mania (1840s) - UK
- The Bull Market of the Twenties (1924-1929)
- The Japanese "Bubble Economy" (1984-1989)
- 1997 Asian Financial Crisis (1997)
- The Dot-com bubble (1995–2000)
- United States housing bubble (2008)
- The European Sovereign Debt Crisis (2010)

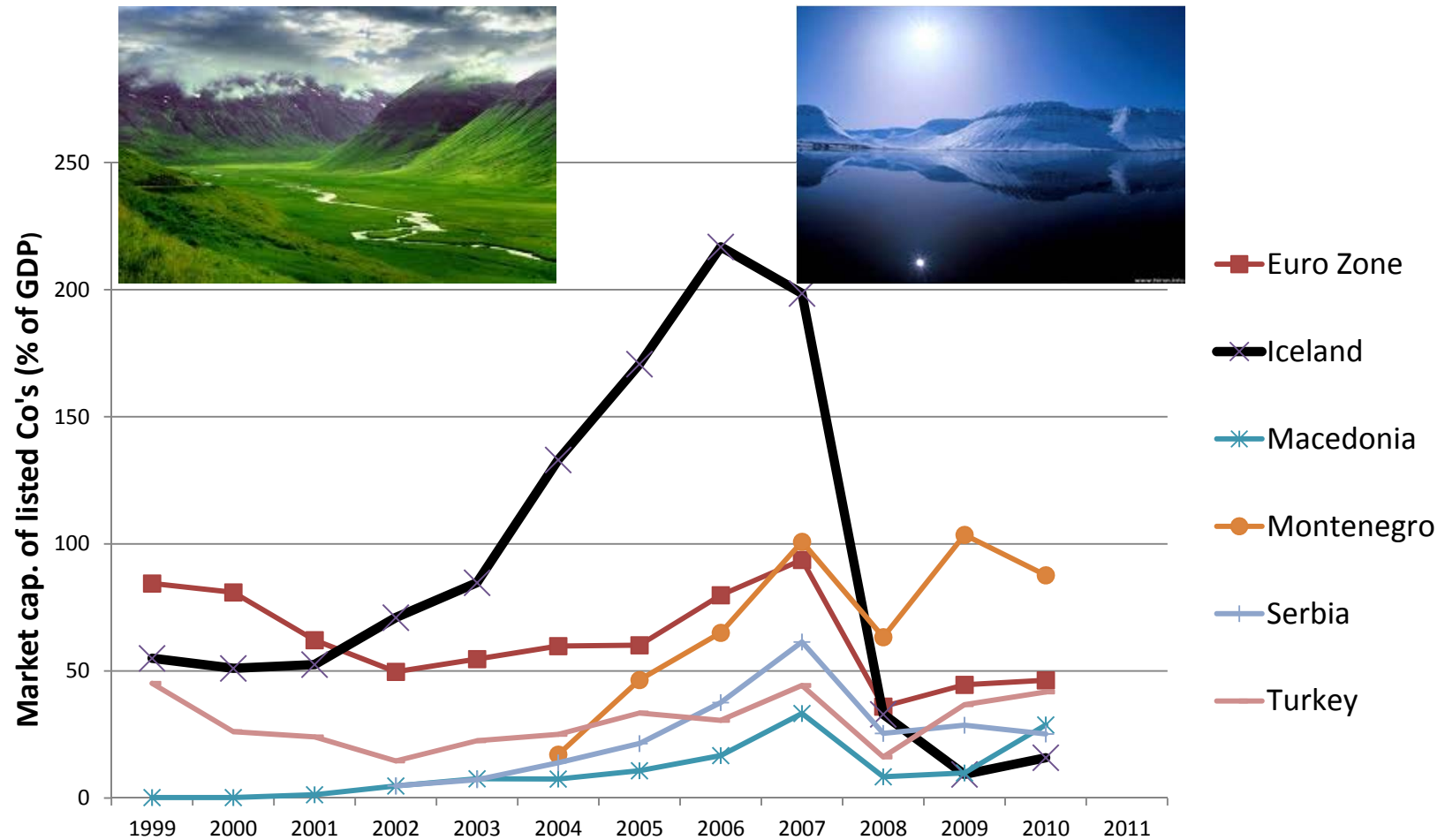


Edward Chancellor's Devil Take the Hindmost: A History of Financial Speculation. (New York: Penguin, 1999).

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Market Capitalization (as % of GDP) of exchange-listed companies – EU candidates



Vodenska - Econophysics lecture, GRS - Physics Department

Monday, April 14, 2014

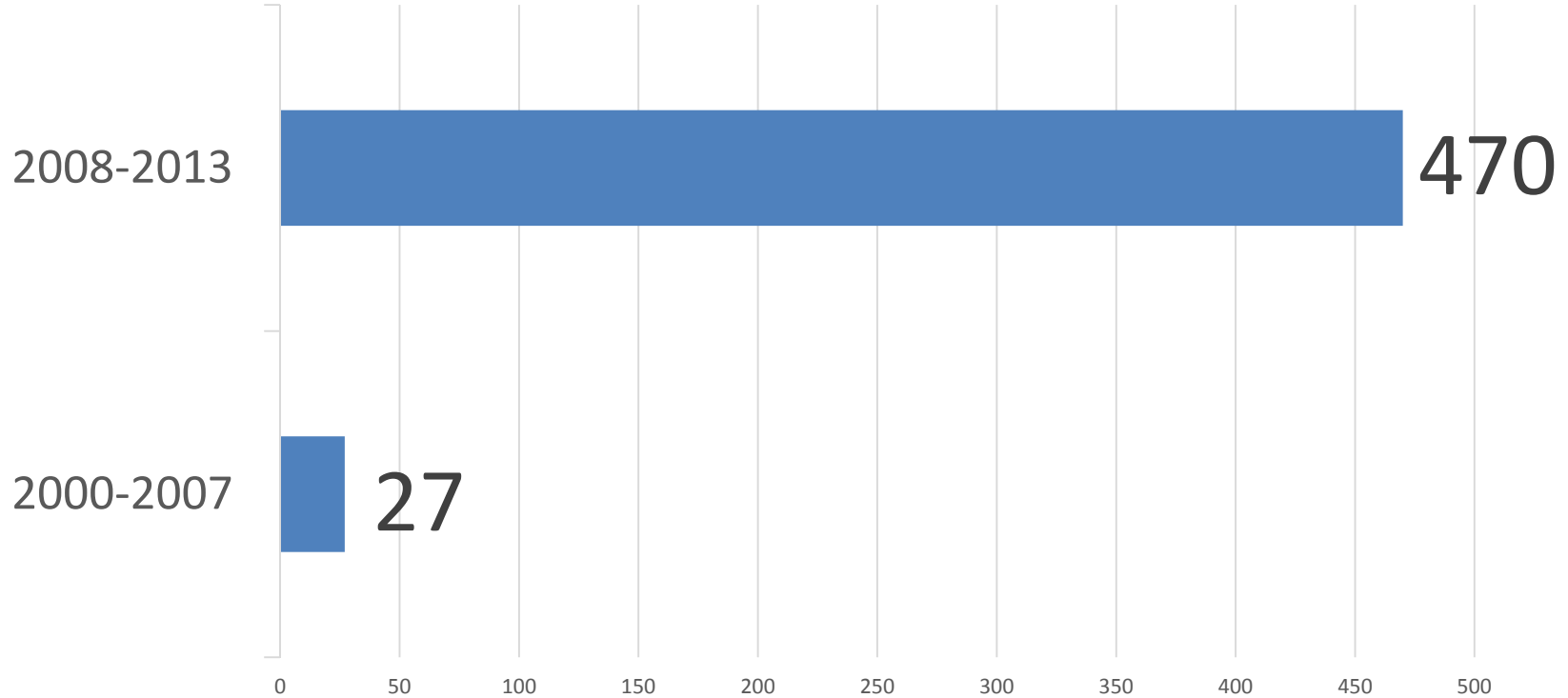
What happened to Iceland?



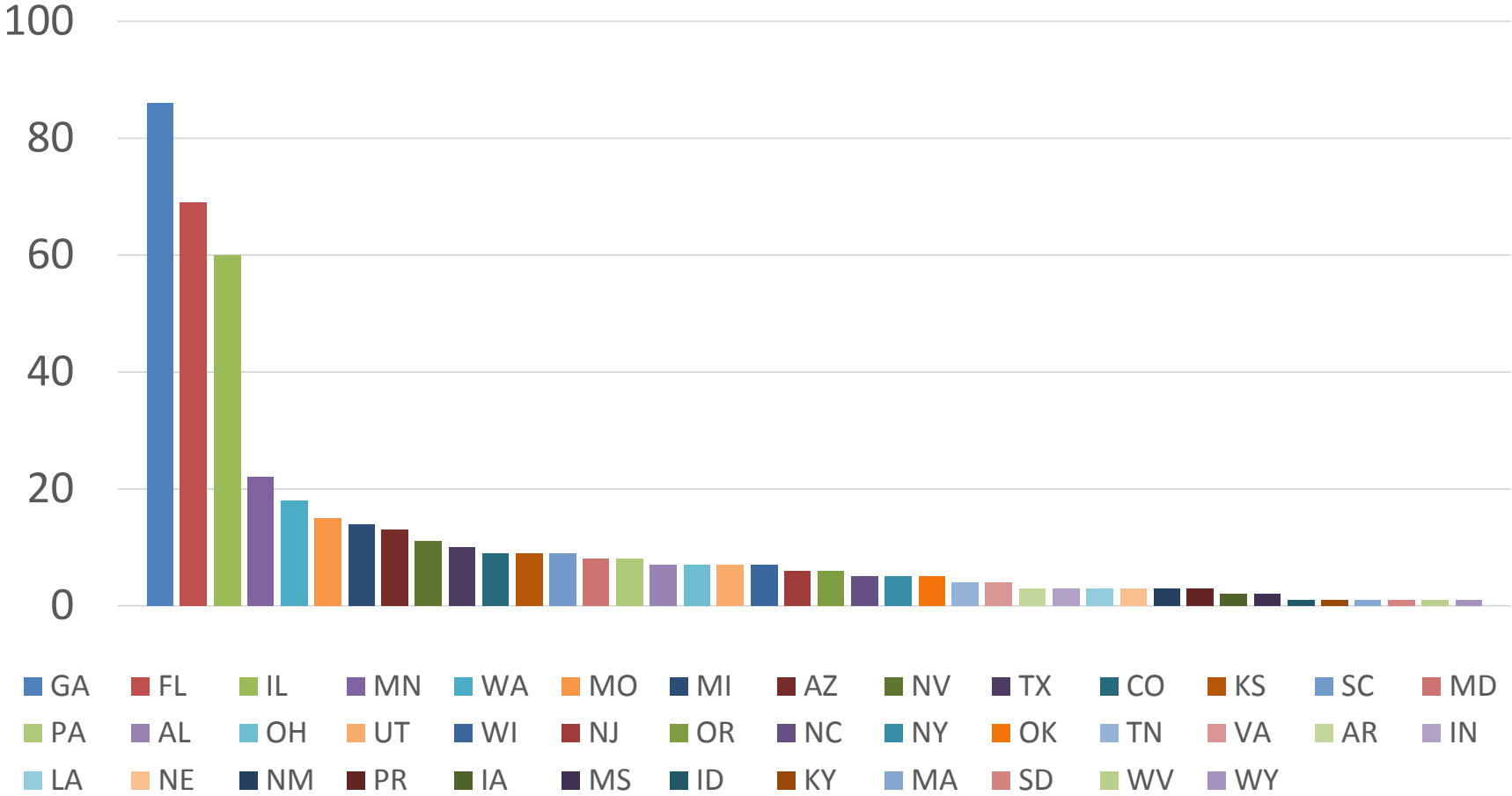
- In 2001 banks were deregulated
- By 2007, three major banks in Iceland held foreign debt of over € 50 billion compared to Iceland's GDP of € 8.5 billion
- The crisis contributed to the collapse of all three of the country's major banks following difficulties in debt refinancing and a run on foreign deposits
- In 2007, The Economist ranked the Icelandic krona as the most overvalued currency in the world
- The 2008–2012 financial crisis is characterized as a major economic and political crisis in Iceland
- Relative to the size of its economy, Iceland's banking collapse is the largest suffered by any country in economic history

Sources: Central Bank of Iceland: External Debt, Oct. 21, 2008,
The Economist: Cracks in the crust, Dec. 11, 2008,
The Financial Times: The big chill, Nov. 15, 2008

Number of Failed Banks in the US between 2000 and 2013



Number of Failed Banks in the US between 2008 and 2013 by State



Financial Institution Network

- Two channels of **bank risk contagion**
 - **Direct interbank liability linkages** (focus is on credit risk and loss propagation via the complex network of direct counterpart exposures when liquidity is inadequate)
 - **Contagion via reduction in bank asset value** (focus is on financial shocks to specific bank assets that contribute to asset value deterioration which adversely affect other banks with similar asset structures)



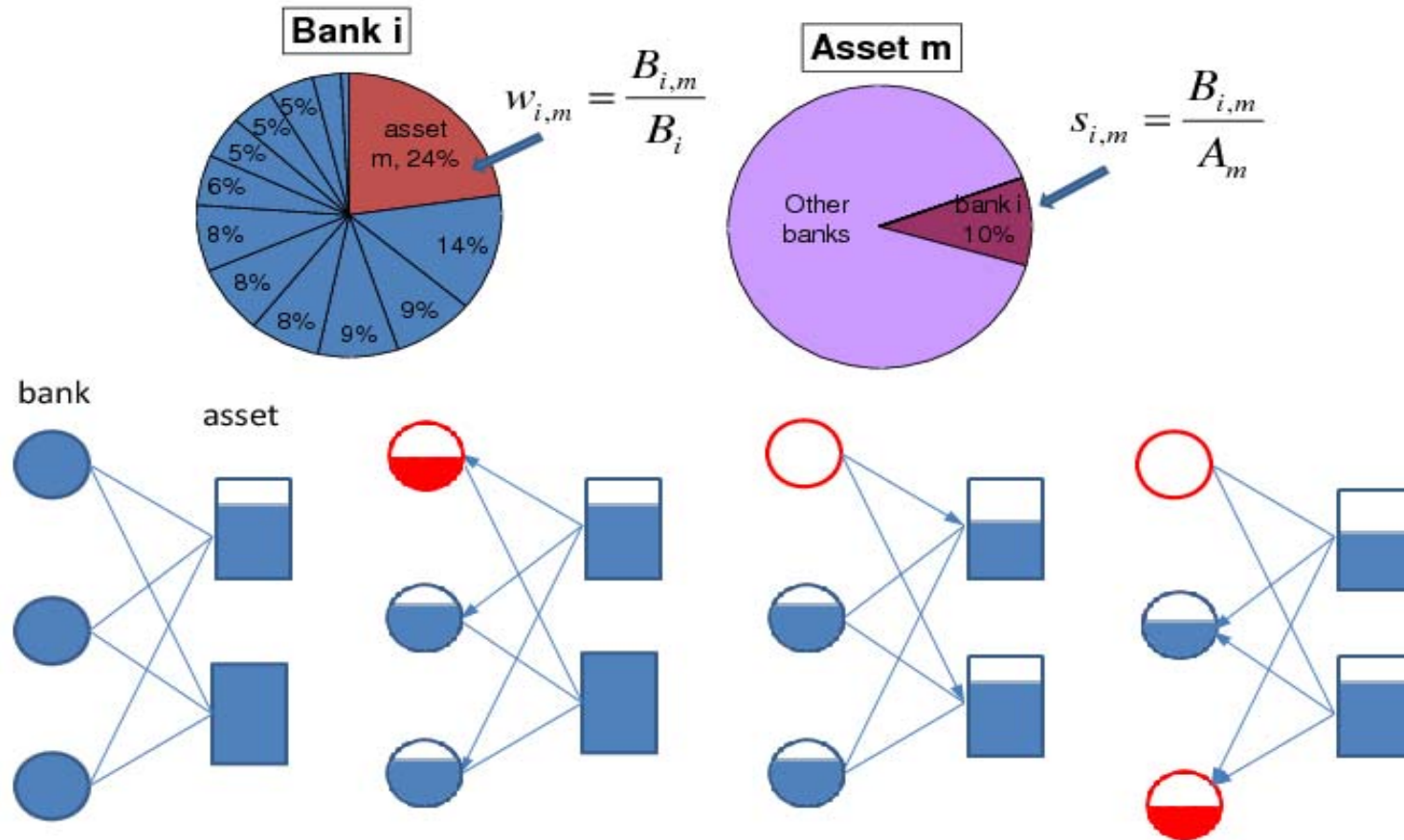


Bipartite network model for systemic risk propagation

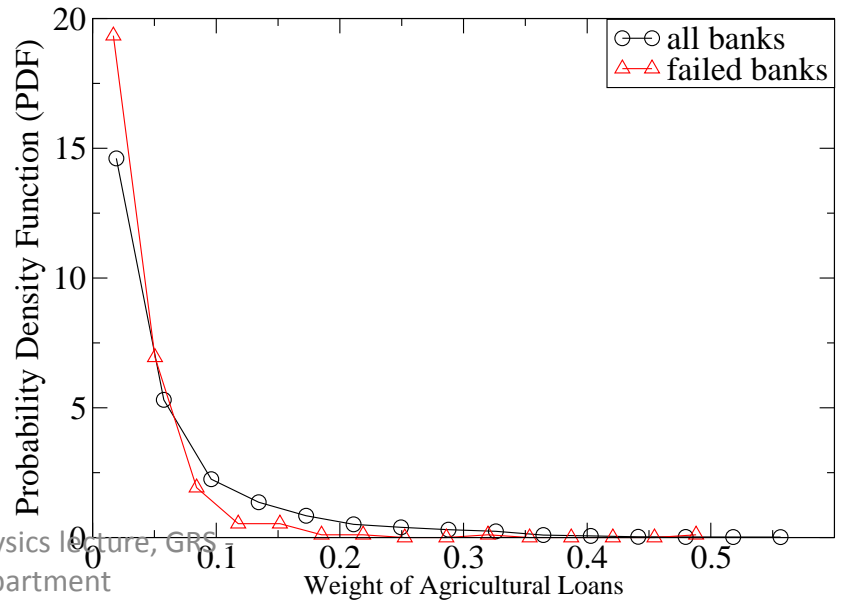
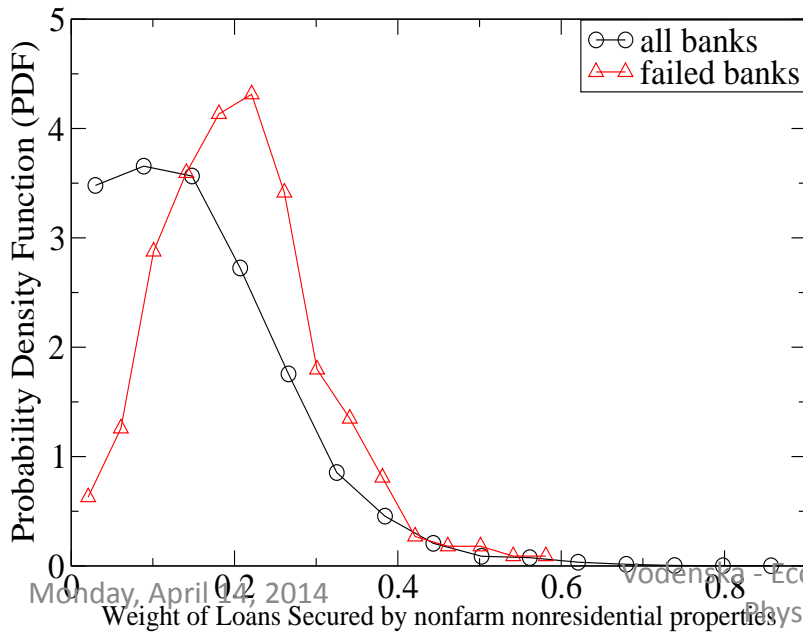
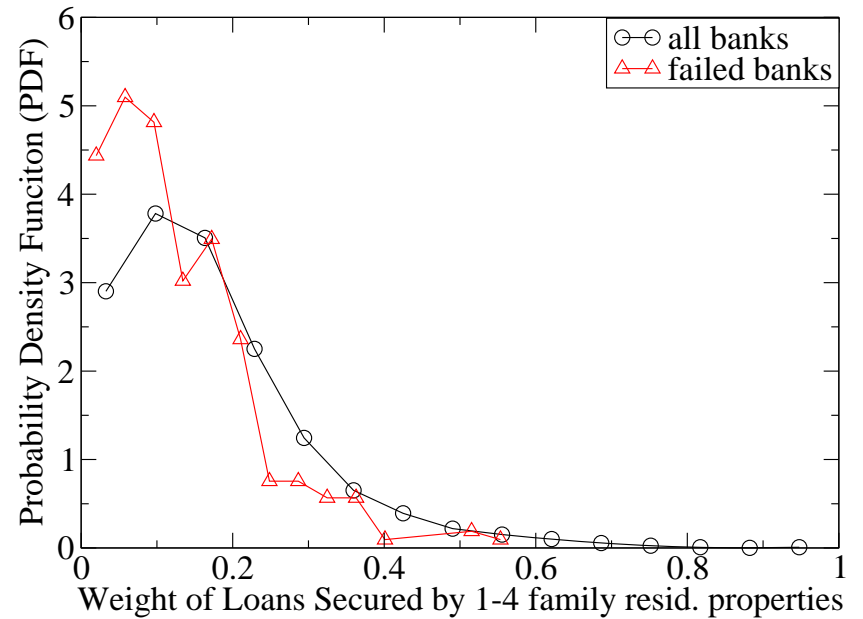
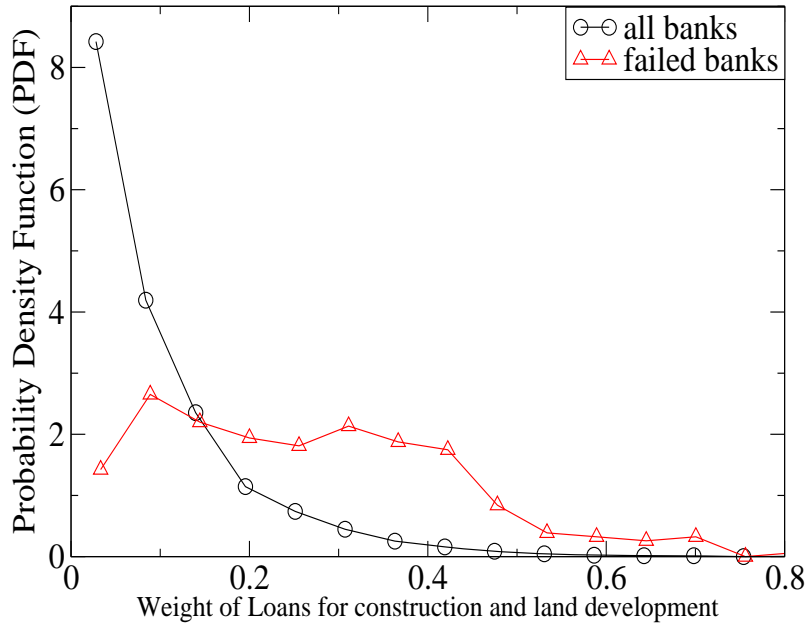


- Analyze the properties of the defaulted vs. survived banks during the 2007-12 financial crisis
- Study cascading failure of banks to show that the complex network method captures important features of the financial system
- Examine banks' balance sheets to assess current stability of the financial system and attempt to forecast future network behavior
- Test the model using 2007 data from the FDIC failed bank list

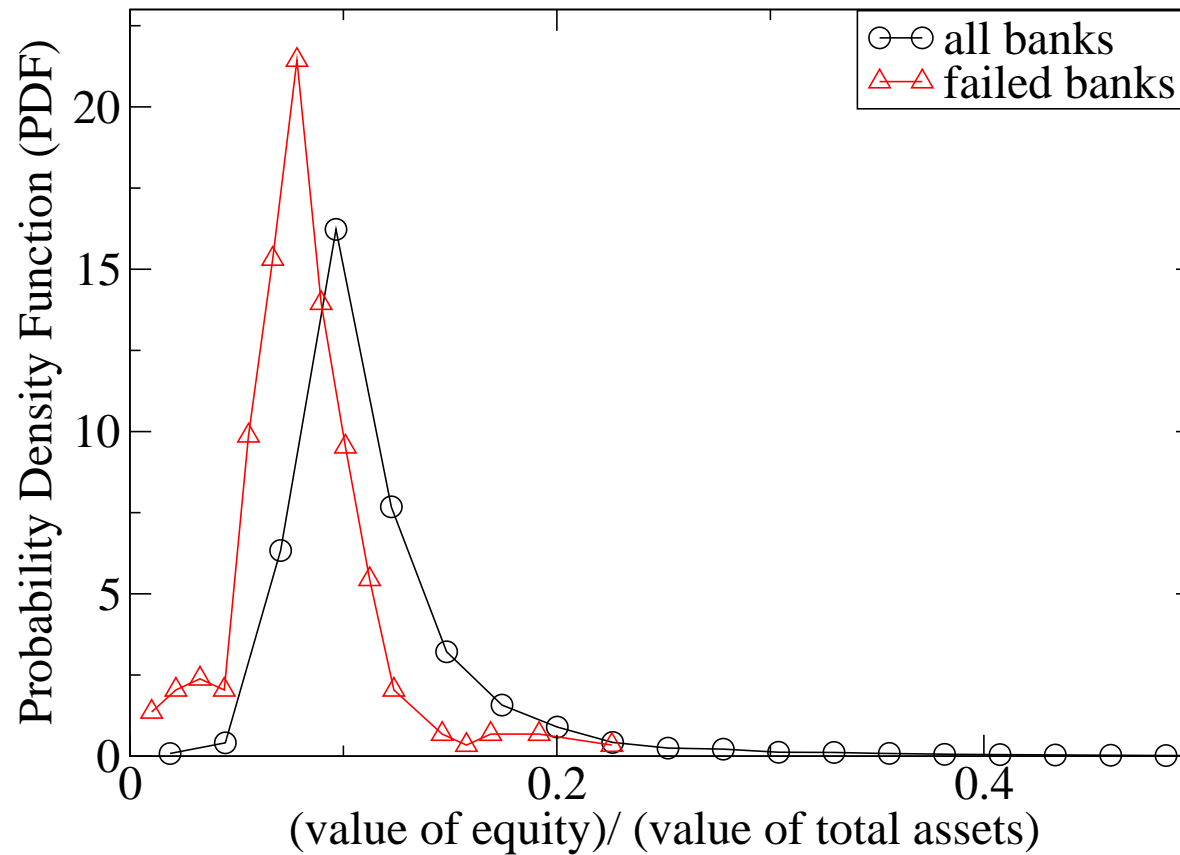
Bank-Asset Bipartite Network



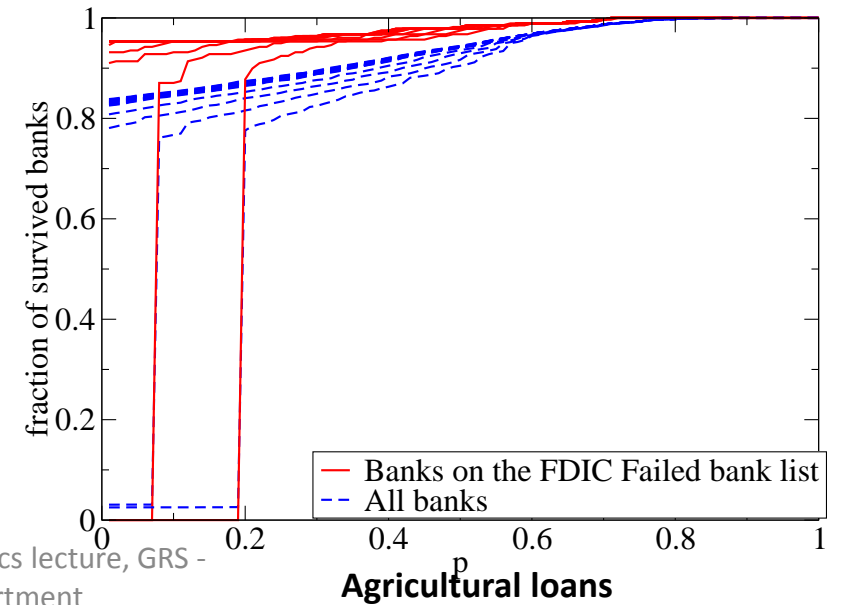
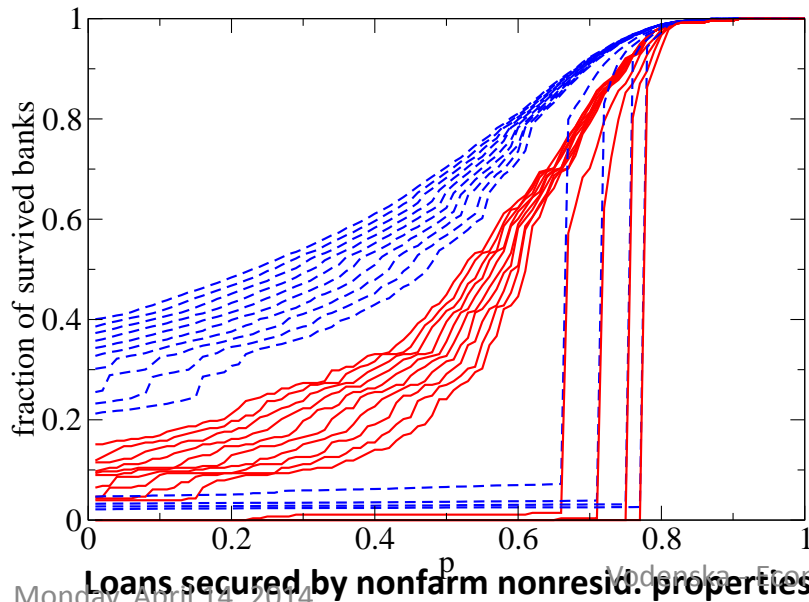
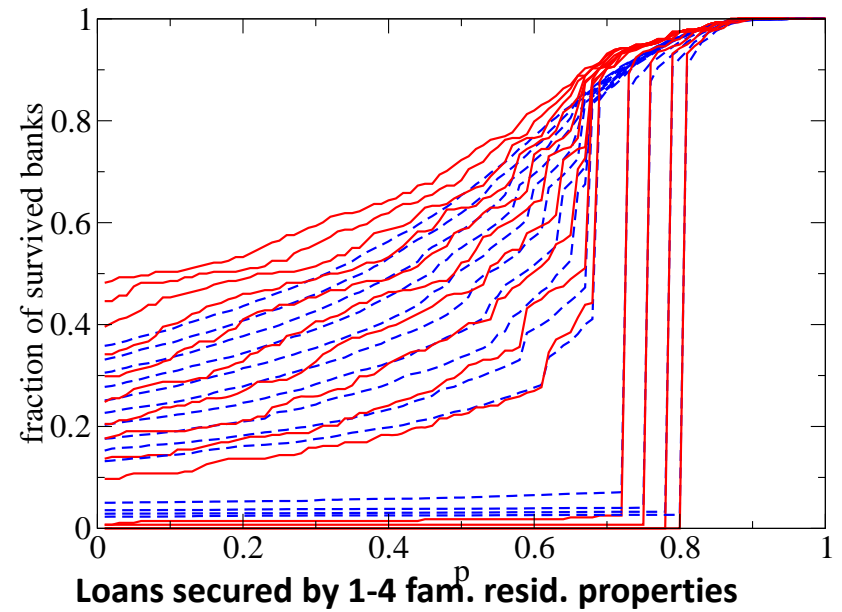
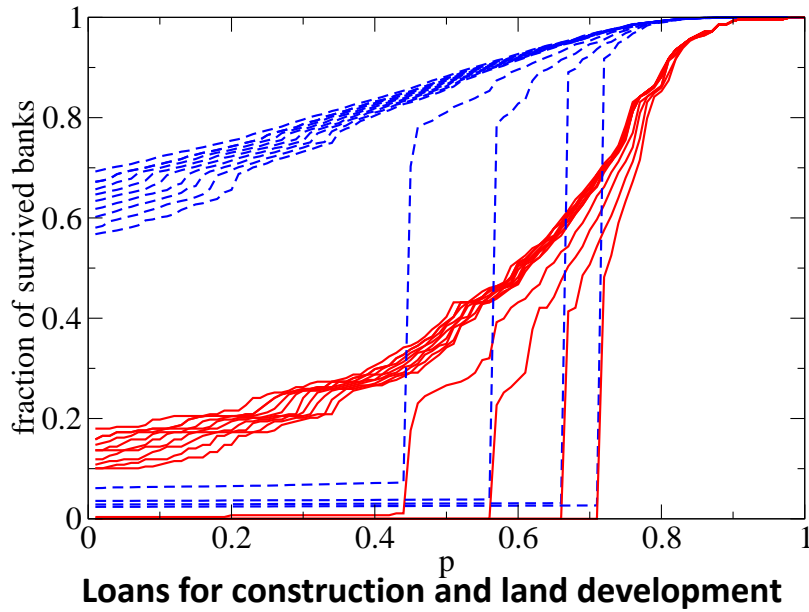
Distributions of typical bank assets



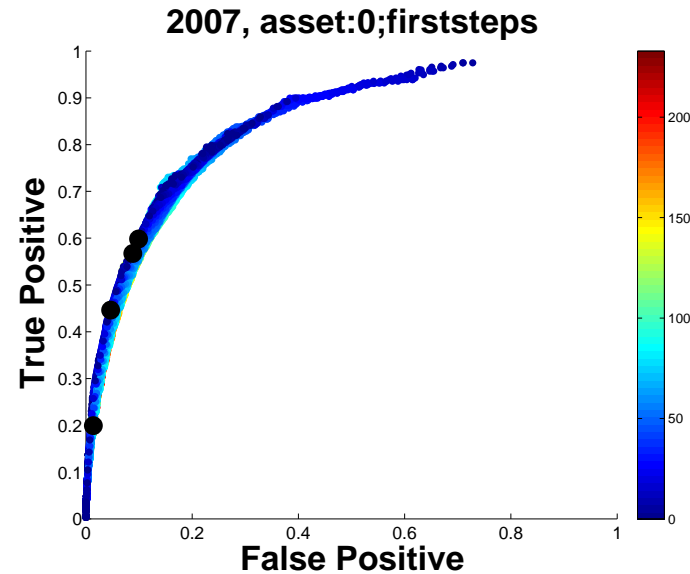
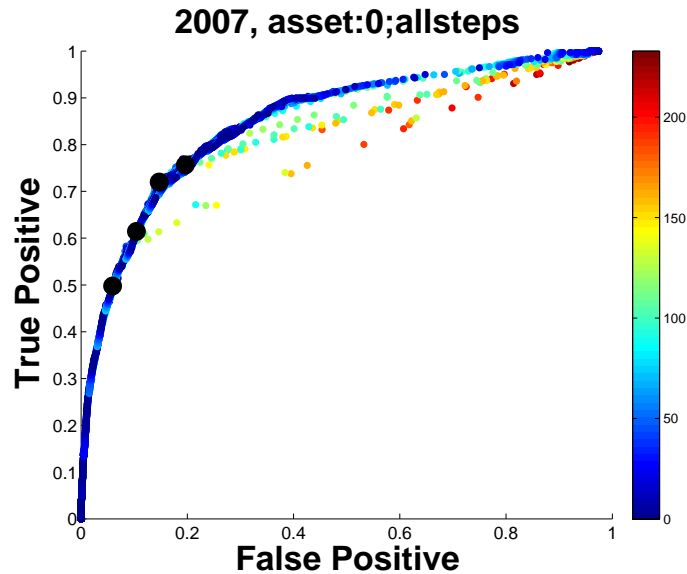
Distribution of leverage (equity/assets) ratios



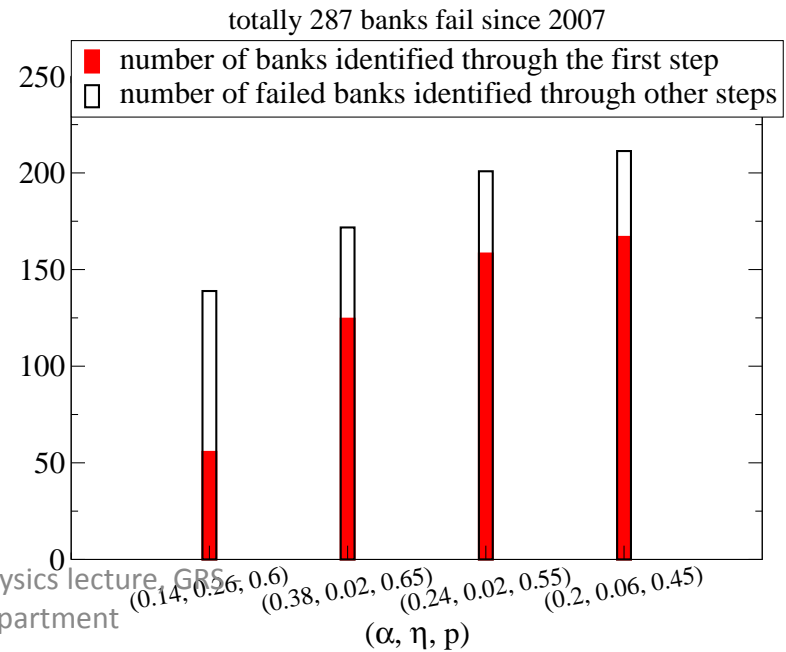
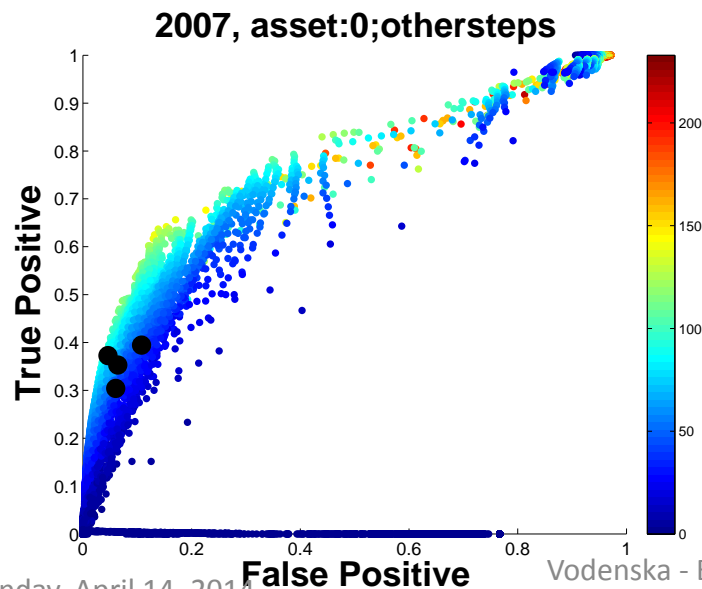
Fraction of survived banks after cascading failures



ROC curves of bank failure prediction



Loans for construction and land development



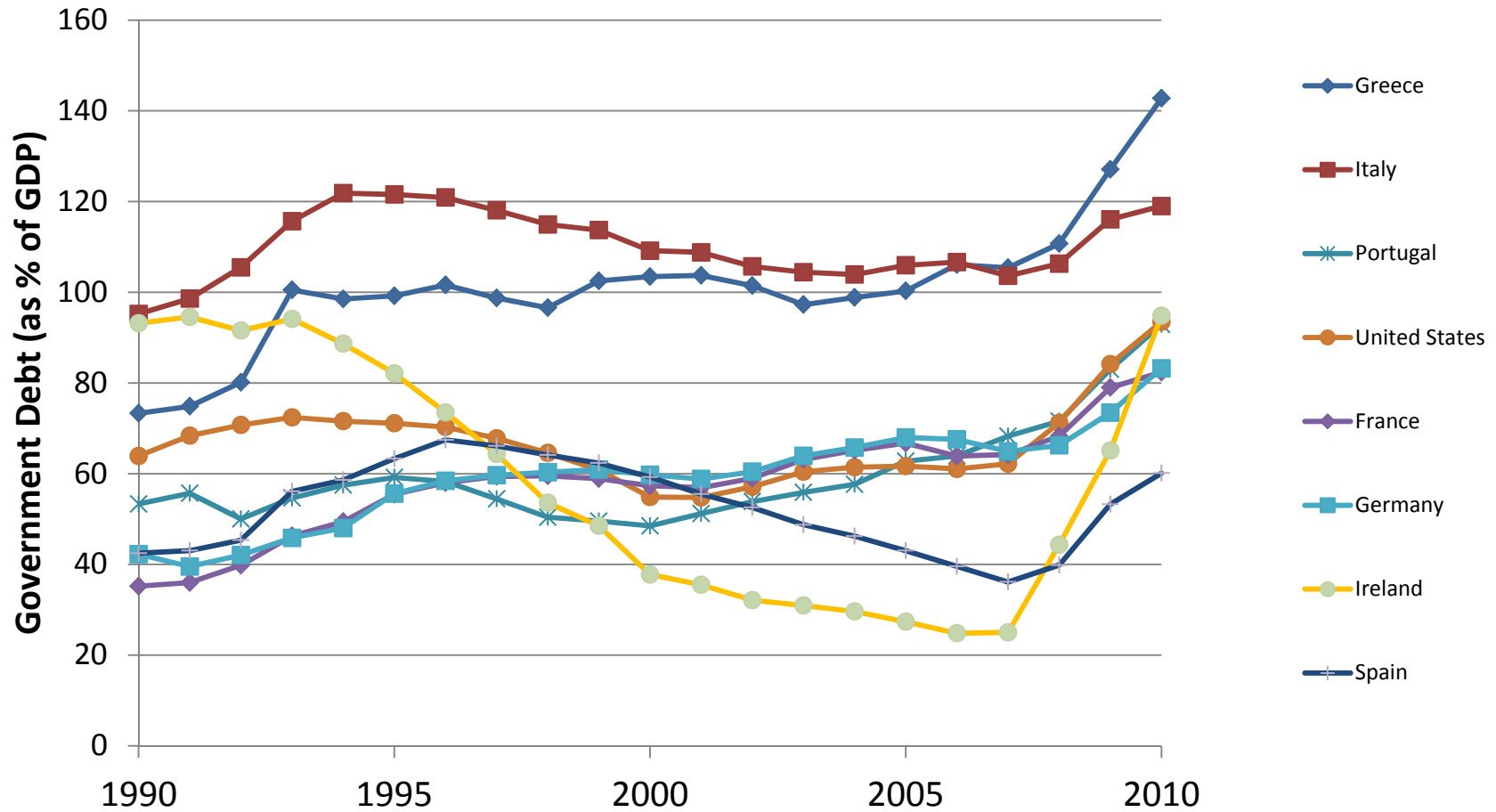
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Government Debt for the PIIGS countries, Germany, France and the United States



The case of Greece

from Boomerang by Michael Lewis

- Greece – nation of about 11 million people
- Had roughly \$400 billion outstanding debt
- And owed another \$800 billion in pensions
- So, \$145 billion bailout was ... a gesture
- Greek railroad annual revenues are €100 million with annual wages of €400 million and €300 million in other expenses
- Average railroad employee earns €65,000/y

Greek Tragedy (or Mystery)

from Boomerang by Michael Lewis

- In October 2009, estimated budget deficit was 3.7% (**George Papaconstantinou** – new minister of finance had just took office)
- Couple of weeks later, the budget deficit was revised to 12.5% and eventually turned out to be 14%
- **In 2009, the tax collection collapsed** because it was an election year (usual election year practice)
- **Approx. 30-40% of taxes are typically not paid**
- It takes about **15 years to resolve tax cases**, so people prefer to go to court rather than pay taxes

On the Ground in Ireland

from Boomerang – by M. Lewis

- In 2008 Irish politicians made a decision to **guarantee the debts of the largest Irish banks**
- In 2010 **Anglo Irish Bank declared €34 billion in losses** – on total loan amount of €72 billion
- **2006 unemployment rate was 4%, 2010 – 11%**
- **2007 Ireland had budget surplus and by 2010 its deficit was 32% of the country's GDP**
- Since 2000, **lending to construction and real estate has increased from 8 % to 28%** - roughly all Irish deposits have been handed over to the commercial property developers

Sovereign Debt Crisis

- Selected Eurozone countries considerably increased their borrowing to **unsustainable central government debt to GDP ratios**:
 - The Greek and the Irish debt crisis only a wake-up call for the EU



- **Greek GDP - \$300 billion**
- **Irish GDP - \$200 billion**
- Combined, smaller than the GDP of Pennsylvania.

– **Italy and Spain** – much larger economies -> bigger problems



- **Italy** has close to **€2 trillion debt** outstanding with 50 percent financed externally
- **Spain** has over **€700 billion** of public debt outstanding and **unemployment rate of 22 percent** (Federal Reserve Bank of St. Louis, 2011).



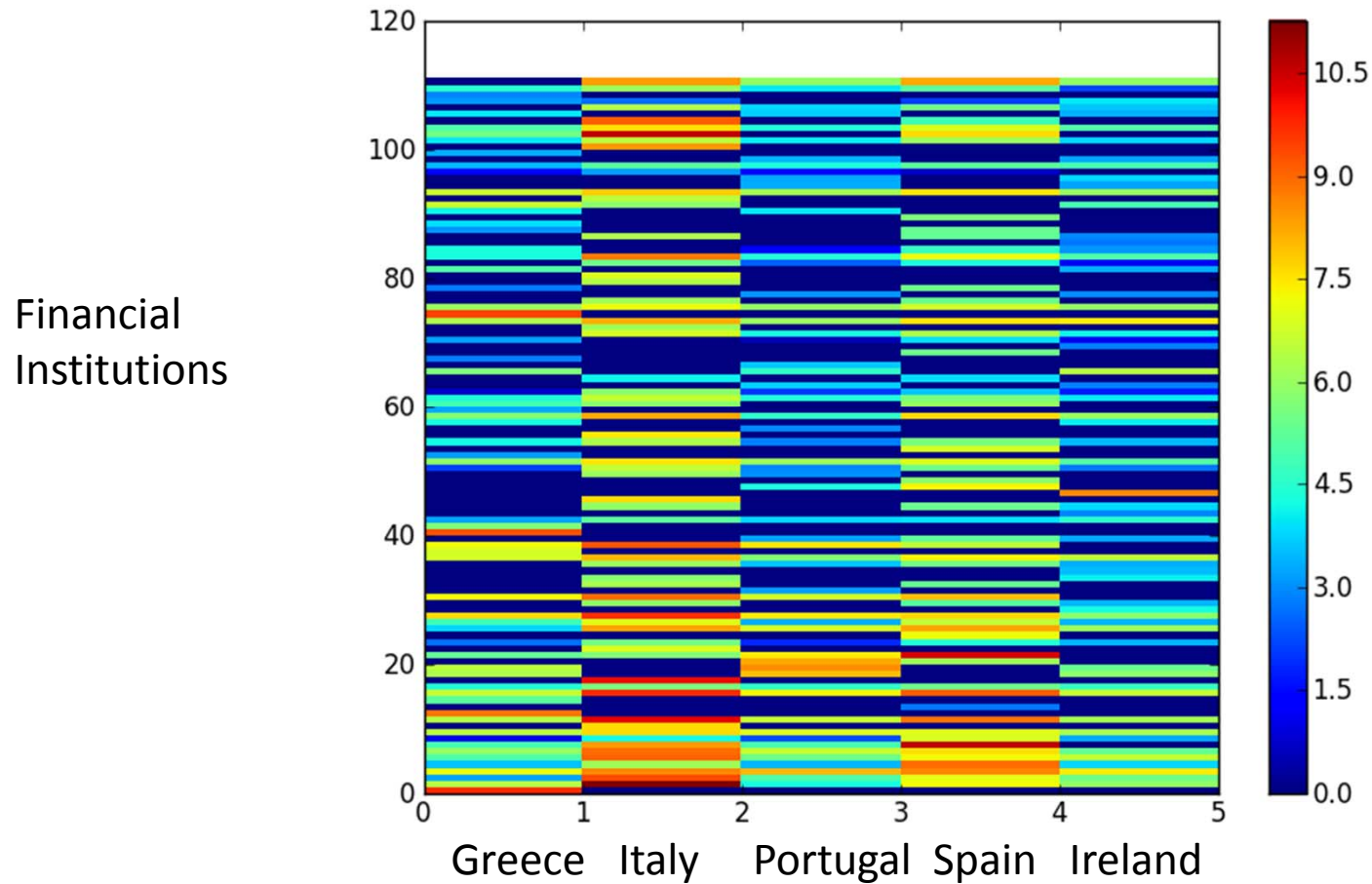
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European Sovereign Debt



- In light of the sovereign debt challenges faced by the Eurozone countries:
 - In December 2011, the European Central Bank committed to provide €1 trillion of funds for the European banks for up to three years in attempt to stem the effects of the most recent financial crisis
 - ECB – lender of last resort and principal regulator of more than 6,000 European Banks

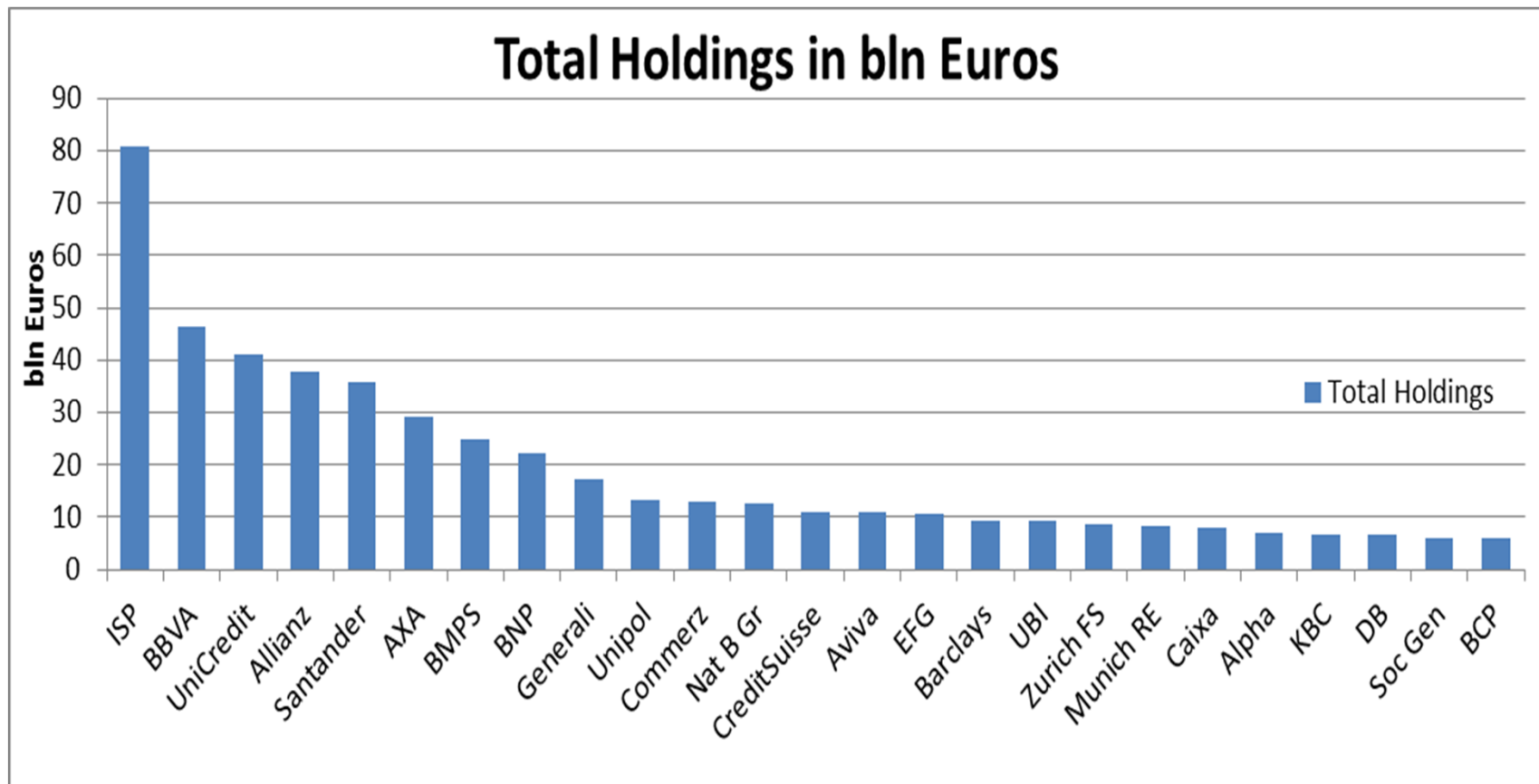
Sovereign Debt Holdings of Financial Institutions (log+1)



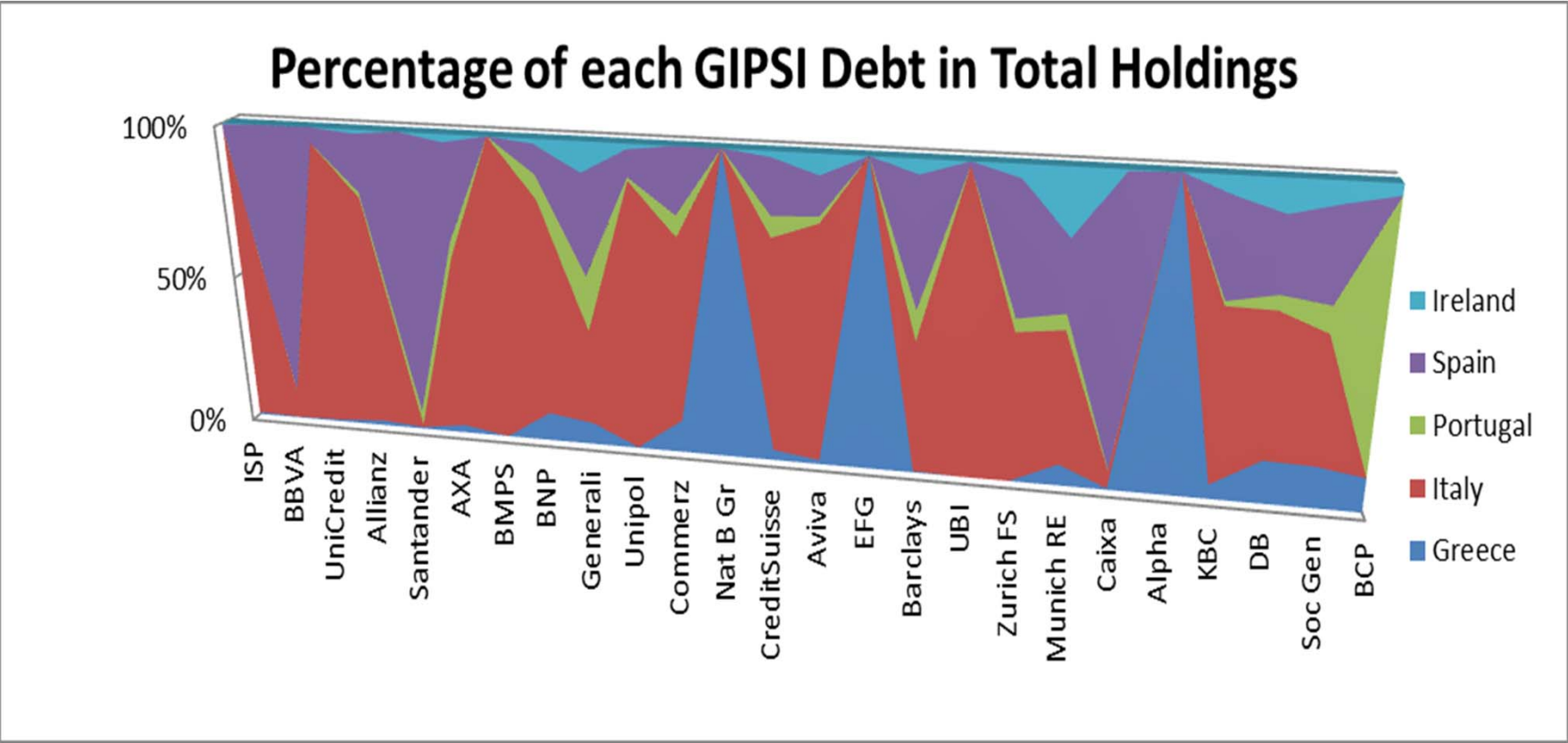
GIIPS Sovereign Debt Holdings in 2011

	Greece	Italy	Portugal	Spain	Ireland
Total (mlnEuros)	64,849	330,376	30,628	151,153	18,410
% in Banks	23.67	20.13	23.81	21.81	20.55

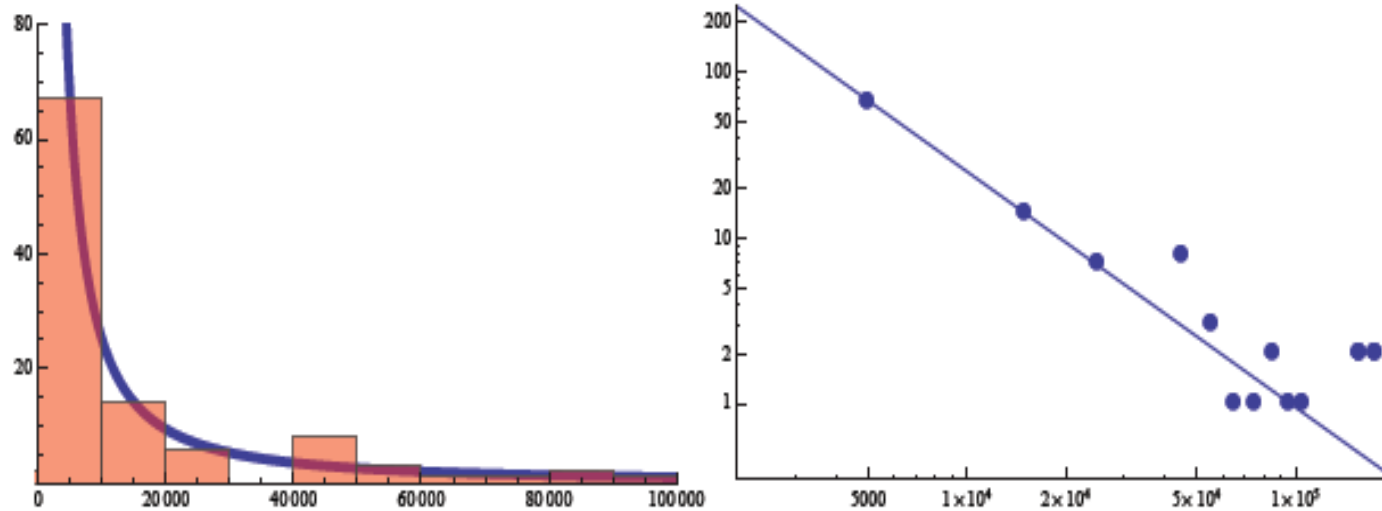
GIIPS Sovereign Debt Holdings by Individual Banks



Breakdown of GIIPS Debt holdings in Individual Banks' portfolios

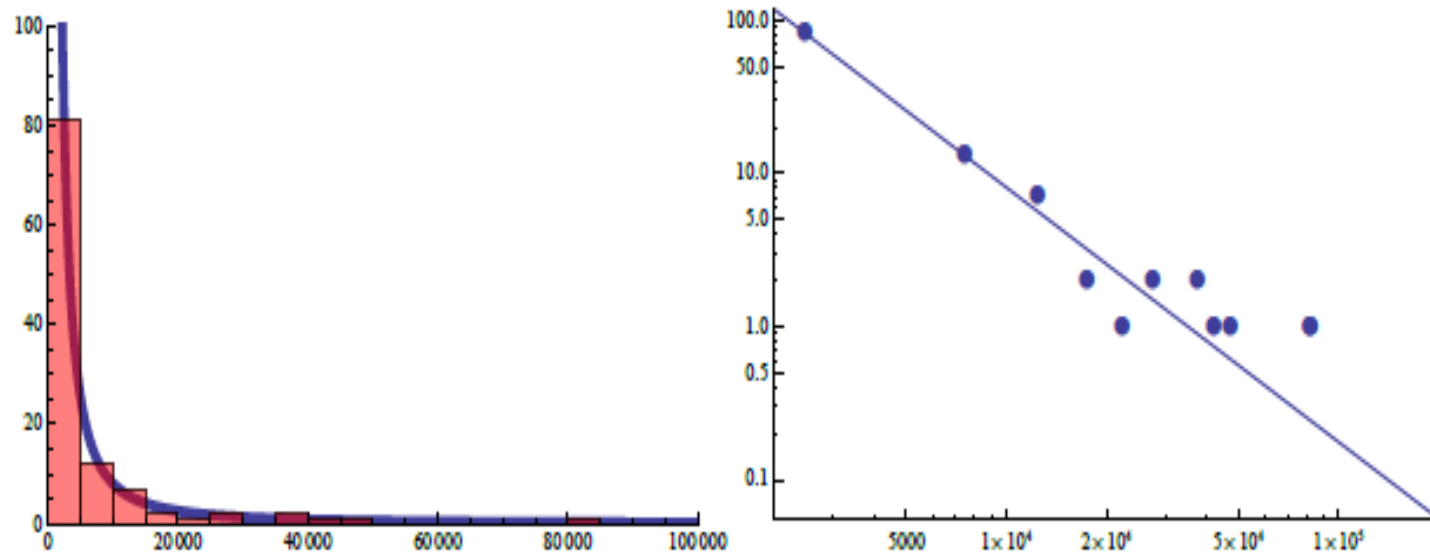


Banks' equity level distribution



(Left) A histogram of the Equity superimposed on its power-law fit with equation $y = \frac{1.21 \cdot 10^7}{x^{1.42}}$. (Right) the same plot in Log-Log scale showing how the power-law fit fits the data.

Distribution of Banks' holdings in GIIPS Sovereign Debt



(Left) A histogram of the Holdings superimposed on its power-law fit with equation $y = \frac{3.62 \cdot 10^7}{x^{1.67}}$. (Right) the same plot in Log-Log scale showing how the power-law fit fits the data.

Distress propagation model

$A_{i\mu}(t)$	Holdings of bank i in asset μ at time t
$p_\mu(t)$	Normalized price of asset μ at time t ($p_\mu(0) = 1$)
$E_i(t)$	Equity of bank i at time t .
β	Investor's "Panic" factor.
α	"Market sensitivity" factor of price to a sale.

$$E_i = \sum_{\mu} A_{i\mu} p_{\mu} + \underset{\text{Cash}}{C_i} - \underset{\text{Liability}}{L_i}$$

if : $E_i = 0 \rightarrow$ Bank i fails.

$$c_i \equiv C_i - L_i$$

Distress Propagation Model (cont.)

$$V_i \equiv \sum_{\mu} A_{i\mu} p_{\mu}, \quad A_{\mu} \equiv \sum_i A_{i\mu}$$

$$\delta p_{\mu}(t) = \alpha \frac{\delta A_{\mu}(t)}{A_{\mu}(t)} p_{\mu}(t - 1)$$

$$\delta A_{i\mu}(t) = \beta \frac{\delta E_i(t)}{E_i(t)} A_{i\mu}(t - 1)$$

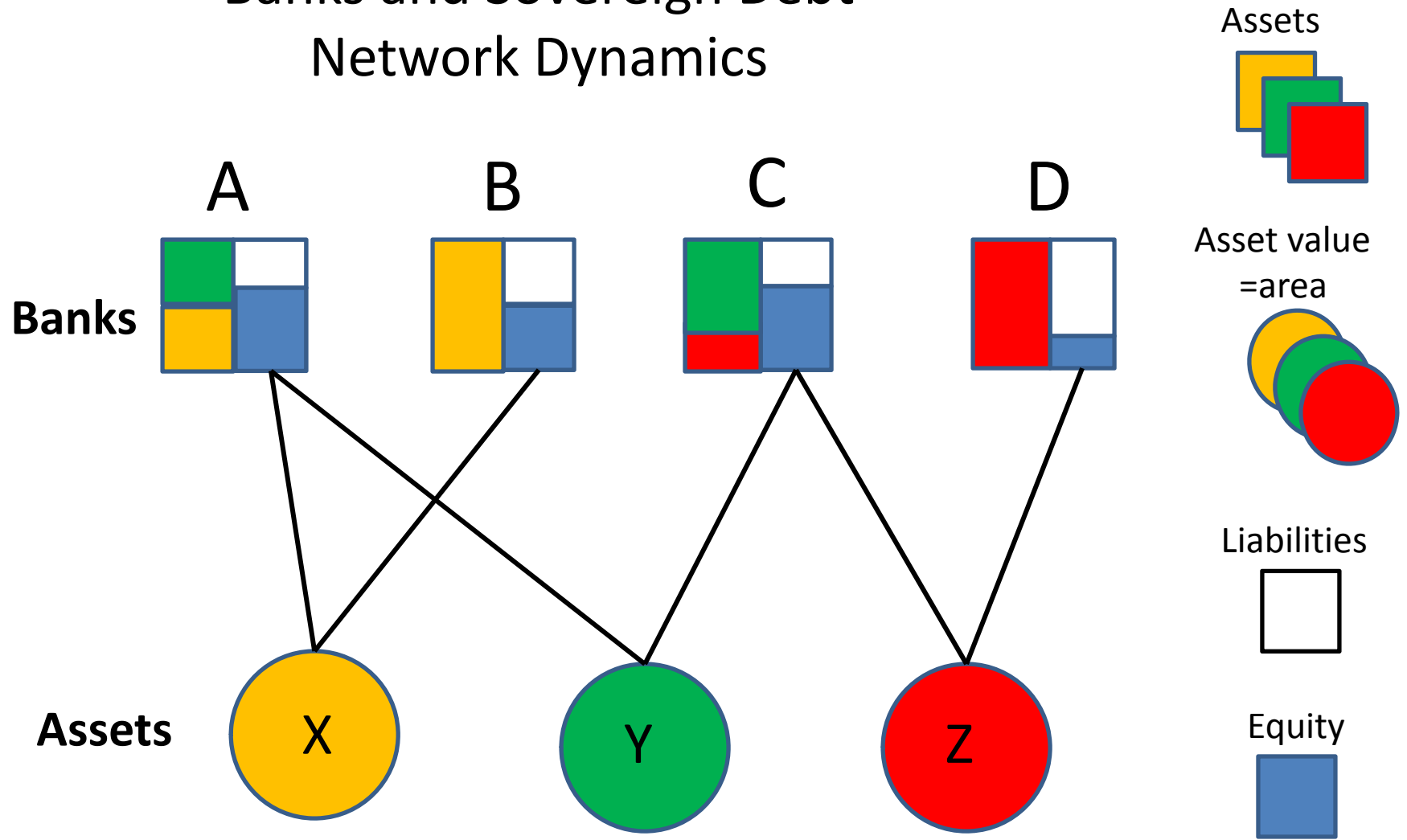
$$\delta E_i(t) = \sum_{\mu} A_{\mu}(t) \delta p_{\mu}(t)$$

Distress Propagation Model (cont.)

$$\delta A_{i\mu} \equiv \psi_i A_{i\mu}, \quad \psi_i = \beta \frac{\delta E_i}{E_i}$$

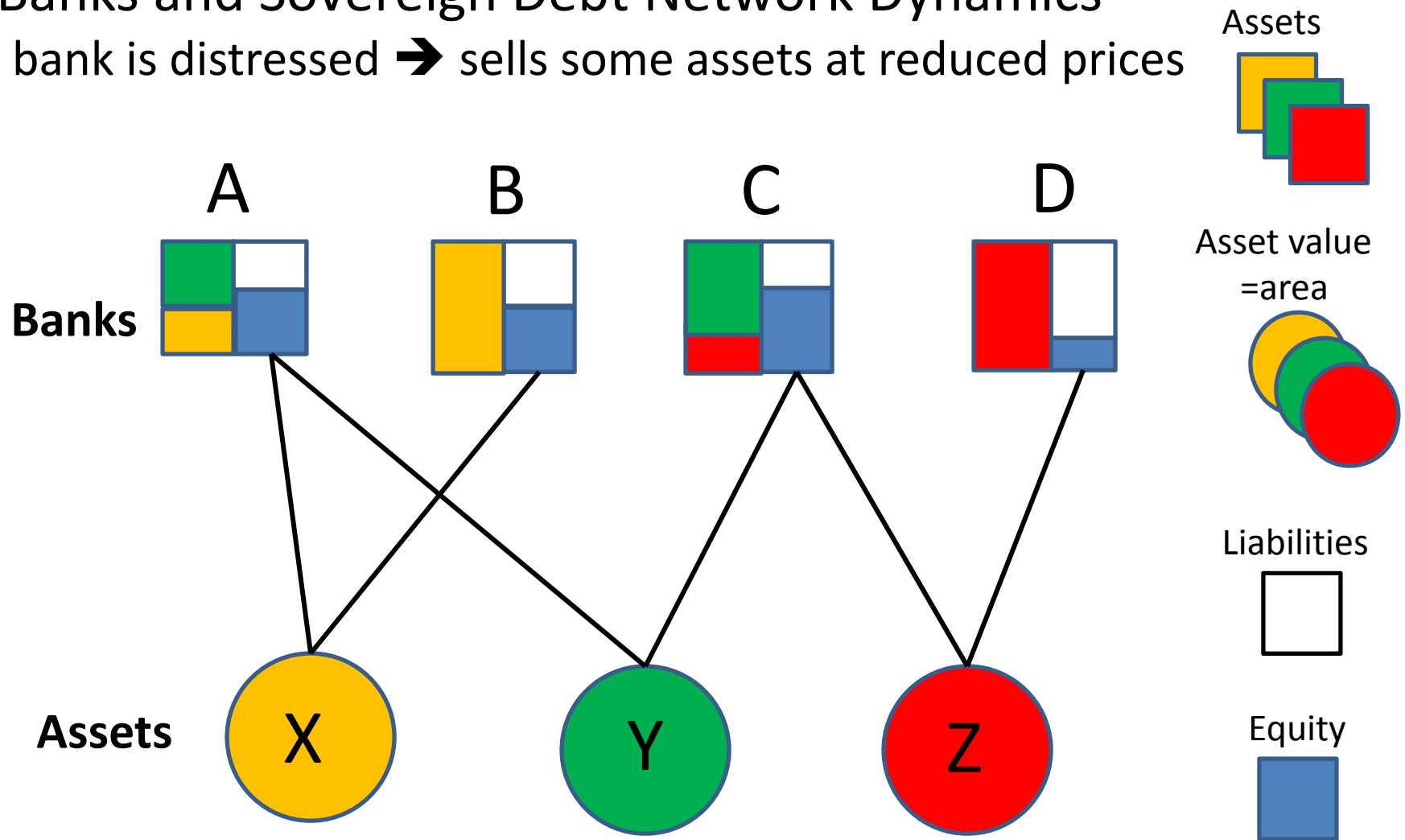
$$D_i = \sum_{\mathbf{k}} \psi_{\mathbf{k}}^{(i)} V_{\mathbf{k}}(\mathbf{0})$$

Banks and Sovereign Debt Network Dynamics



Banks and Sovereign Debt Network Dynamics

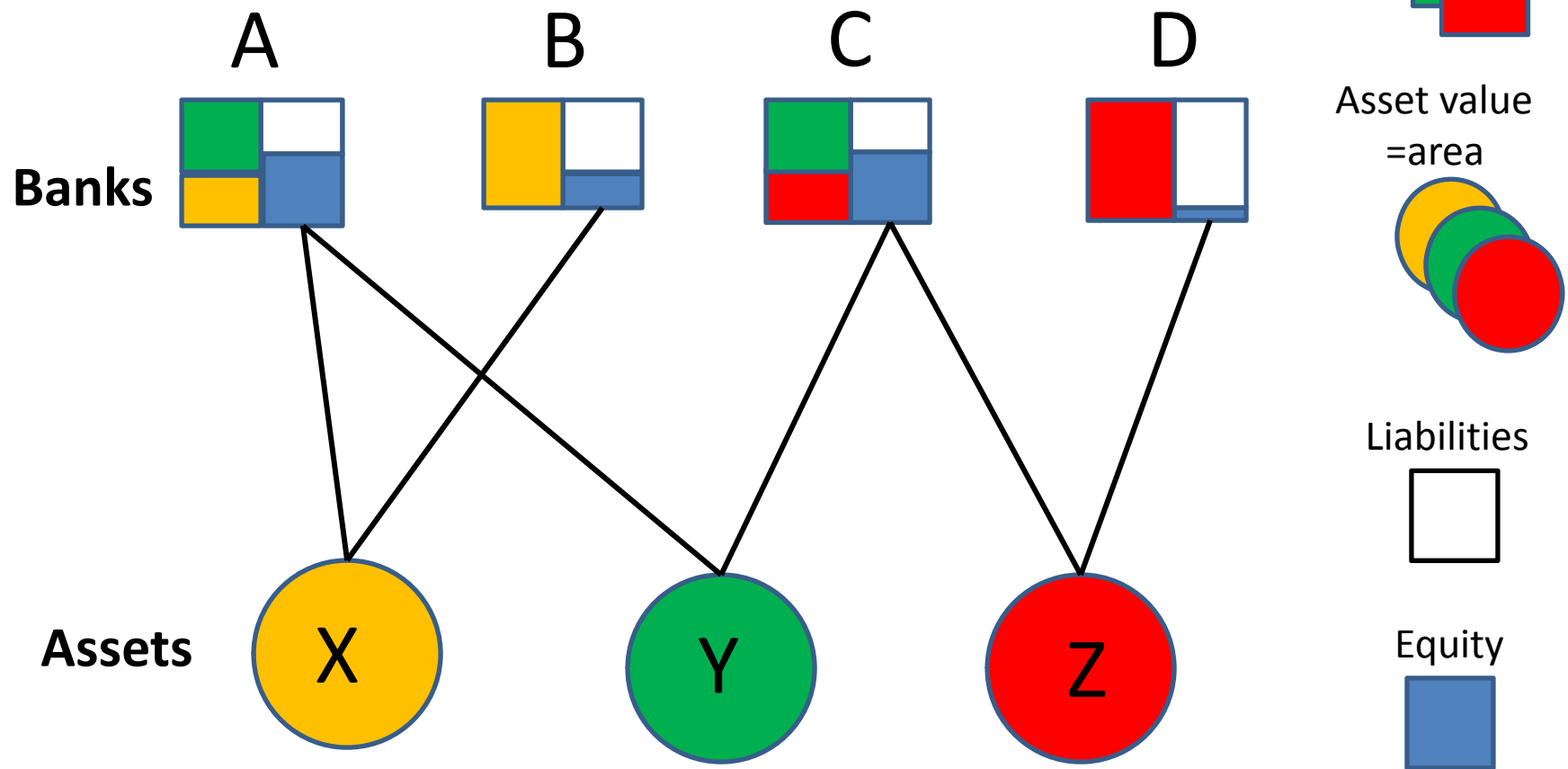
One bank is distressed → sells some assets at reduced prices



Banks and Sovereign Debt Network Dynamics

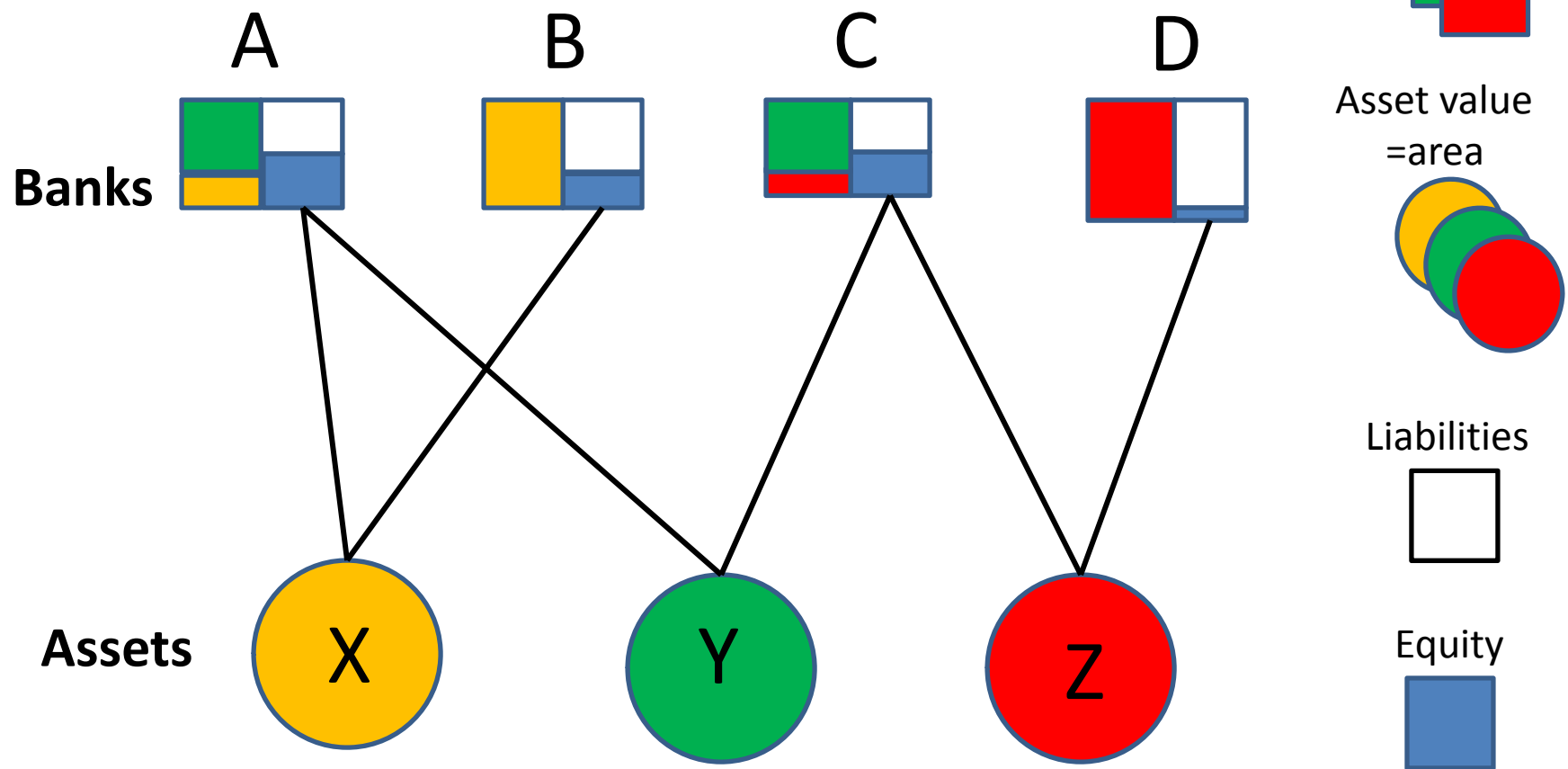
Sales affect asset values of other banks →

Banks' equity shrinks



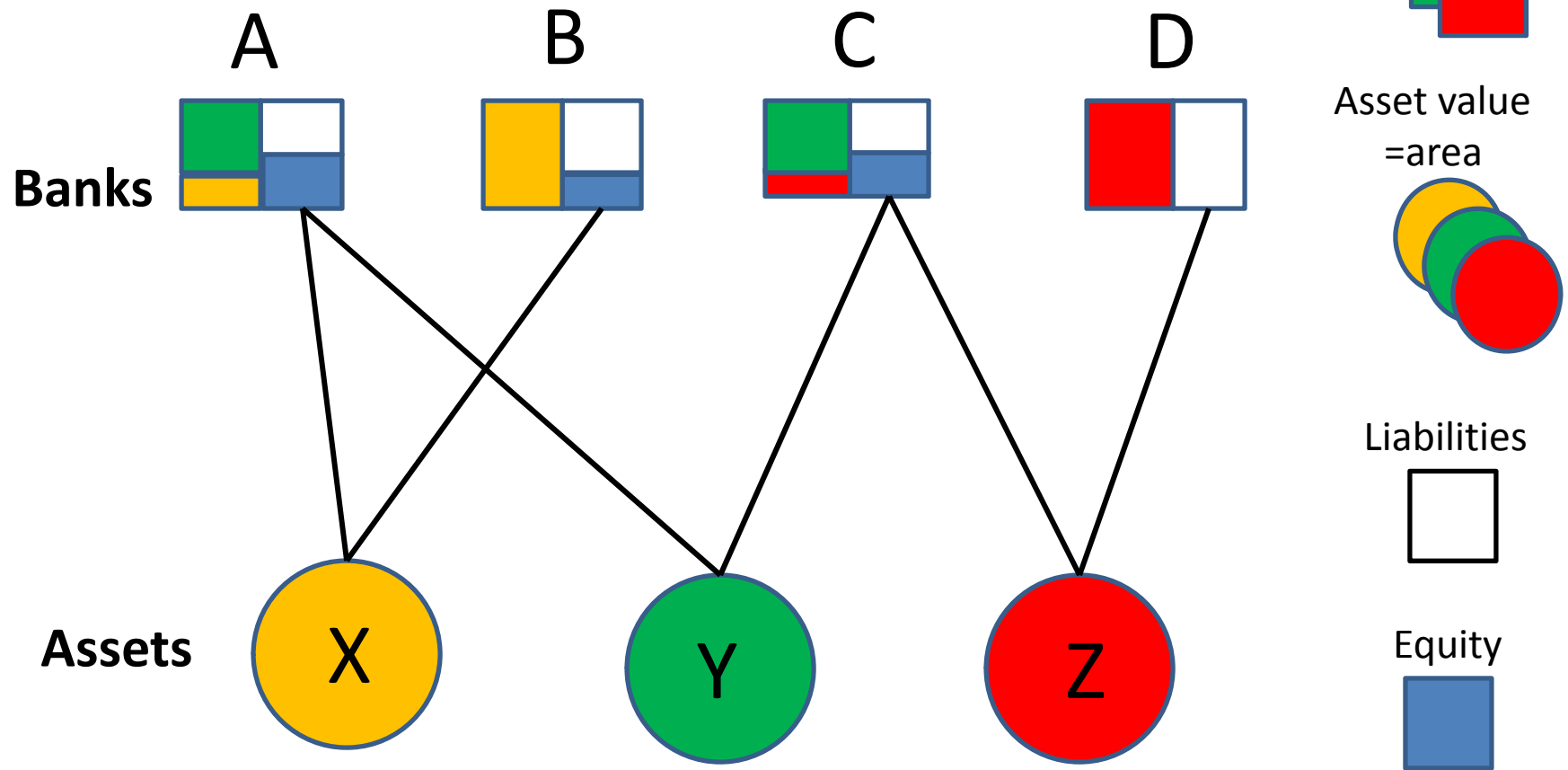
Banks and Sovereign Debt Network Dynamics

Banks get distressed → sell more assets



Banks and Sovereign Debt Network Dynamics

Equity of Bank D goes to zero → Bank D defaults



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Systemic Risk



- **Global financial crisis of 2007-2012**
- Considered to be the worst crisis since the Great Depression of the 1930s
- Propagated value deterioration of most financial markets around the world
- **Contributed to potential complete collapse of major financial institutions**
- **Involved national governments in bailing out too-big-to-fail banks (SIFIs)**

Systemic Risk



- Adversely affected the **housing market** and real estate prices globally
- Contributed to **increased unemployment** rates and prolonged workforce unemployment
- Significantly **reduced consumer wealth** and quenched appetite for spending
- **Contributed to the European sovereign-debt crisis**

Lehman Brothers

- What happened to Lehman Brothers?
 - High level of leverage, increase from 24:1 in 2003 to 31:1 in 2008
 - Heavily invested in real estate market, making the banks vulnerable to any decline in this sector
 - Large positions in subprime and other lower-rated mortgages
 - In August, 2013 news that Korea Development Bank was going to purchase Lehman Brothers propped the stock up
 - Early September news that KDB has put the talks on hold hurt Lehman, and
 - On September 15, 2013, Lehman Brothers declared bankruptcy

Investment lessons from the Lehman Brothers blow-up

by John Wasik, Sept. 16, 2013 (Reuters)

- **Gravity is stronger than diversification** – In global meltdown, there are few (if any) safe heavens - **PowerShares DB Commodity Index Tracking Fund down 5% on average in the last 5 years** as global commodity demand decreased
- **Staying on course is no sin** – **Riding the S&P 500** for the last 5 years would have rendered on average **8% return annually**
- **Boring bonds still make sense** – **iShare Core Total US Bond Market ETF averaged 4% in the last 5 years**

AIG and the CDS Market

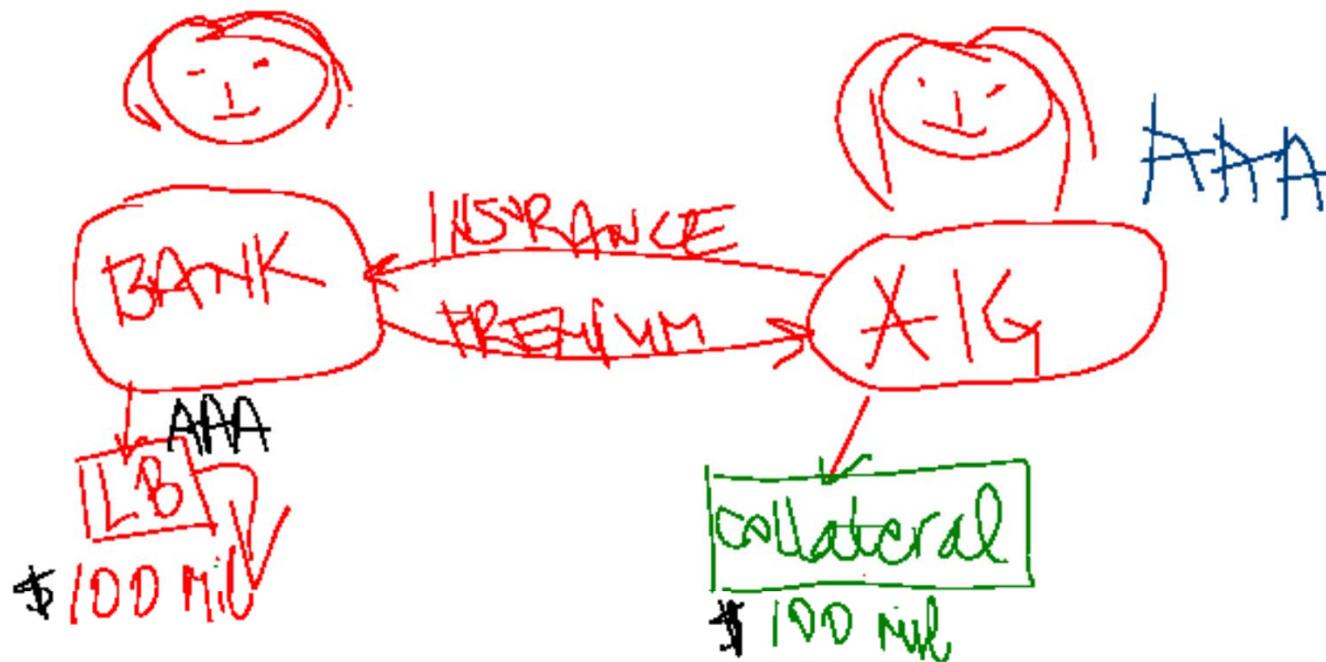
Wikipedia: AIG

- In 2008, AIG had sold credit default swaps (CDSs) on \$441 billion worth of securities (CDOs)
- CDOs (Collateralized debt obligations), originally rated AAA, but had declined in value.
- Out of these securities, \$57.8 billion were structured debt securities backed by subprime loans
- “Federal Reserve Bank s created a secured credit facility of up to \$85 billion” to prevent the company's collapse
- The taxpayers enabled AIG to deliver additional collateral to its credit default swap trading partners

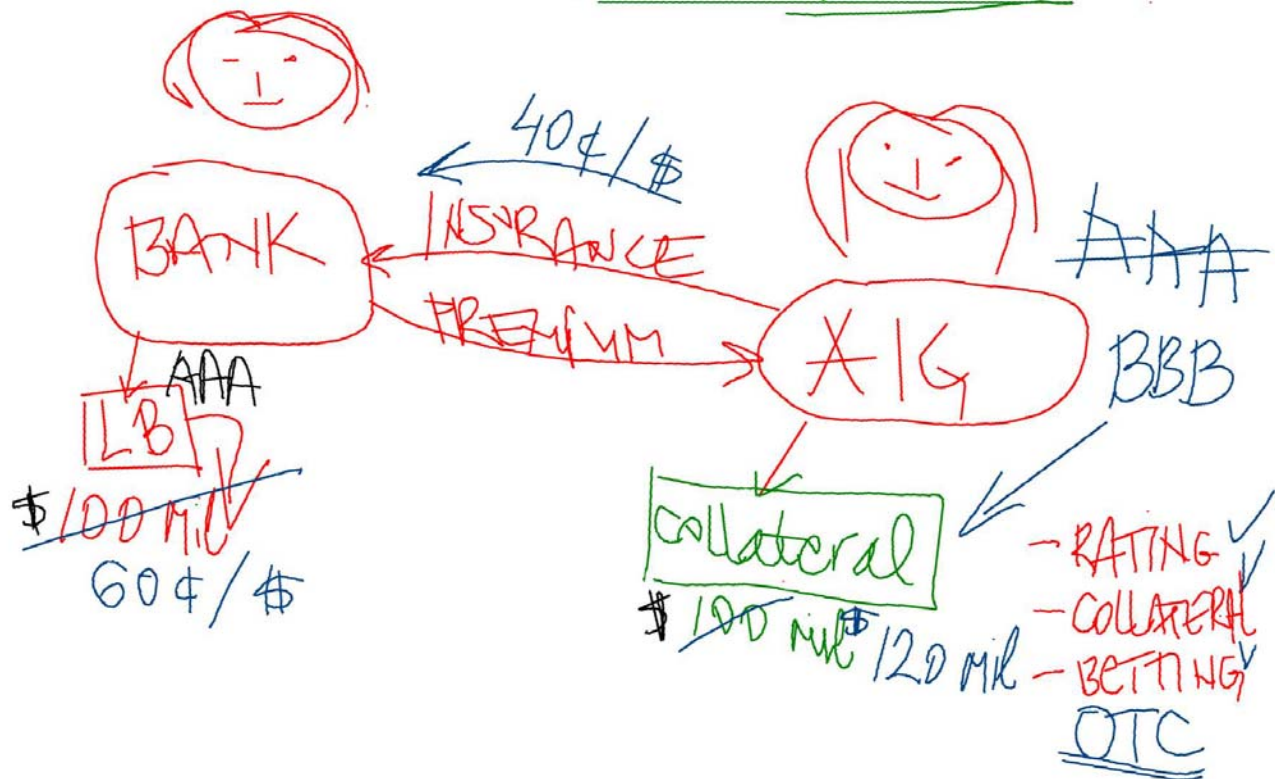
Credit Default Swaps – What are they?

A *credit default swap (CDS)* is a financial swap agreement that the seller of the CDS will compensate the buyer in the event of a loan default or other credit event.

CDS REVEALED



CDS REVEALED



Money Market Funds

- A **money market fund** (also known as **money market mutual fund**) is an **open-ended** mutual fund that invests in short-term debt securities such as US Treasury bills and commercial paper.^[1]
- **Money market funds are widely** (though not necessarily accurately) **regarded as being as safe** as bank deposits yet providing a higher yield.
- **Regulated in the US under the Investment Company Act of 1940**, money market funds are important providers of liquidity to financial intermediaries.^[2]

•^[1] [U.S. Securities and Exchange Commission on Money Funds](#)

•^[2] See Markus K. Brunnermeier, Deciphering the 2007-08 Liquidity and Credit Crunch, Journal of Economic Perspectives (May, 2008)

Reserve Primary Fund

- [Reserve Primary Fund](#) (traded below \$1/share at 97 cents) and
- Became the first money-market fund (in 14 years) to expose investors to losses after writing off \$785 million of debt issued by bankrupt Lehman Brothers Holdings Inc.
- The fund's assets plunged more than 60 percent (to \$23 billion) in two days
- Lehman Brothers losses forced the net value of Reserve Primary Fund assets to drop below \$1 a share, breaking the buck.
- Reserve Primary, the oldest money fund in the nation, suspended redemptions for as long as seven days.

- *By Christopher Condon - September 16, 2008 21:41 EDT (Bloomberg News)*

Community Bankers Mutual Fund

- The **only other money-market fund to break the buck** was the \$82.2 million **Community Bankers Mutual Fund in Denver**, which **liquidated in 1994** because of investments in interest-rate derivatives.
 - **Interest-rate derivatives** – allow swapping of variable to fixed interest rate payment **or vice versa**
 - **Commercial Paper** - An **unsecured**, short-term **debt instrument** issued by a corporation, typically for the financing of short-term liabilities.

Securities and Exchange Commission: Money Market Fund Reform

- Proposed Rules:

- “The first alternative proposal would require money market funds to sell and redeem shares based on the current market – based value of the securities in their underlying portfolios, rounded to the fourth decimal place (e.g., \$1.0000), i.e., transact at a floating net asset value per share (“NAV”).”
- “The second alternative proposal would require money market funds to impose liquidity fee (unless the fund’s board determines that it is not in the best interest of the fund) if a fund’s liquidity levels fell below a specified threshold and would permit the funds to suspend redemptions temporarily, i.e., to “gate” the fund under the same circumstances.”

- » Securities and Exchange Commission: June 2013
- » 17 CFR Parts 210, 230, 239,270,274 and 279
- » Release No. 33-9408, IA-3616; IC-30551;
- » File No. S7-03-13RIN 3235-AK61

“No financial market, no financial product, no financial player will escape efficient rules and oversight.” European commissioner Michel Barnier, recently unveiled a [set of new rules](#) to regulate the so-called shadow banking sector - By Jason Karaian, Quartz, September 6, 2013



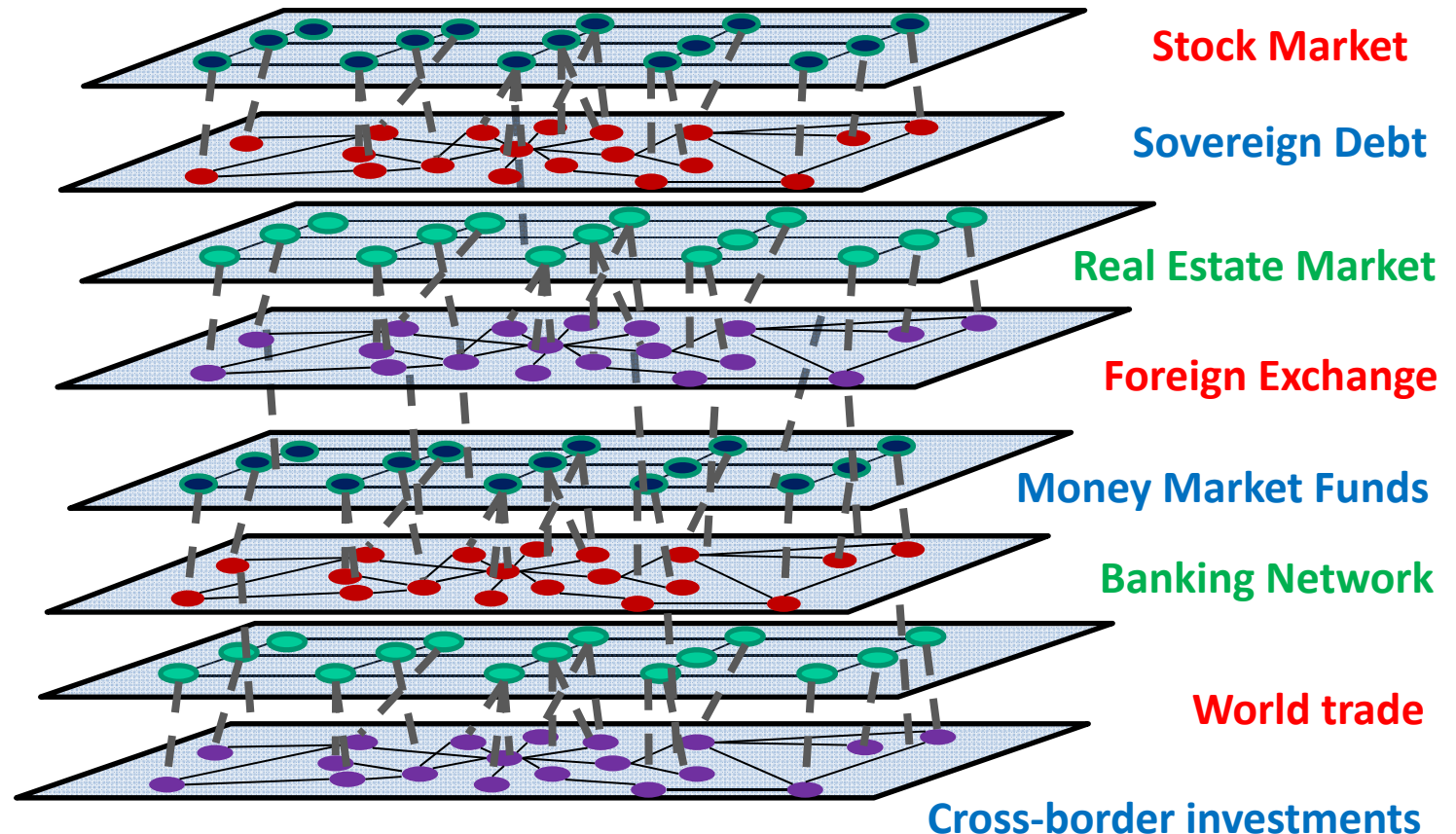
“The EU commission wants to force the MMFs to stand on their own; Under the new rules, constant NAV funds will be required to set aside 3% of their assets as a cash buffer. If they can’t, or won’t, their NAV must float according to underlying asset values, like any other investment fund. - By Jason Karaian, Quartz, September 6, 2013

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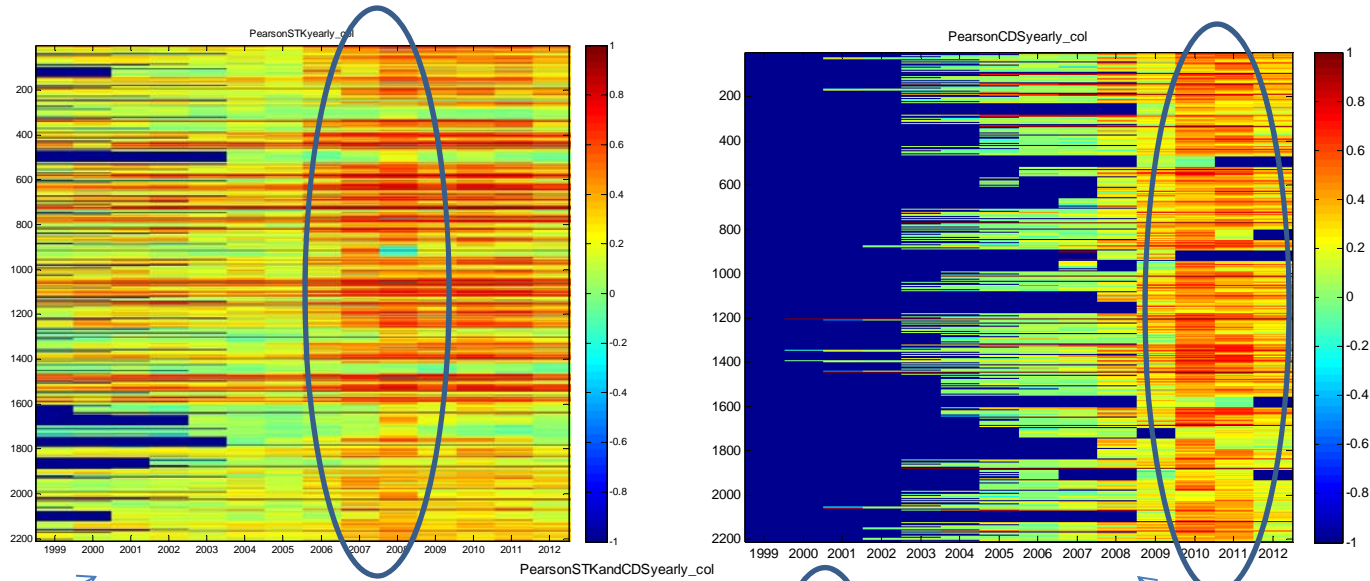
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Examples of Economic Interdependent Networks

* Different types of networks and inter-connections
* Study of real multi-connected economic networks

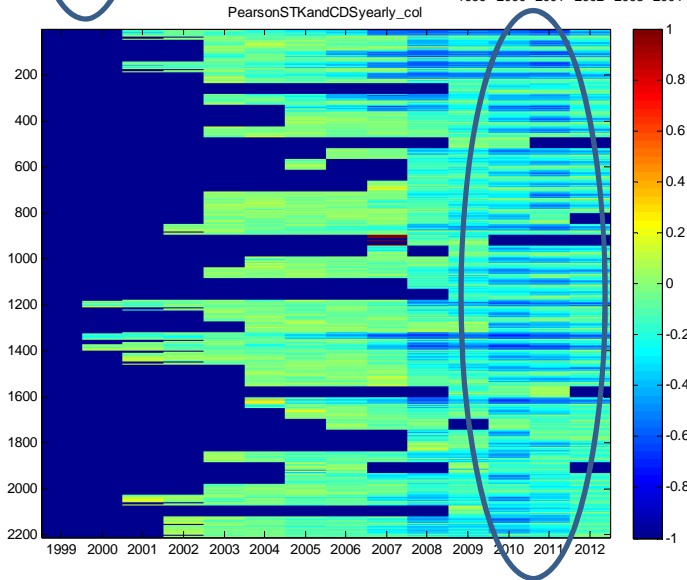


Sovereign debt effect on global financial markets

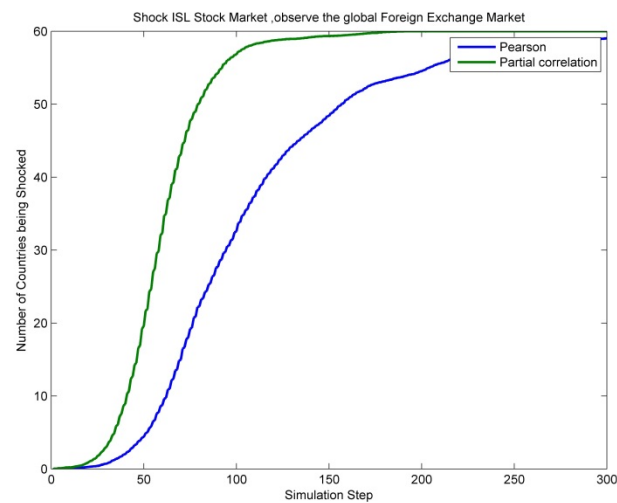
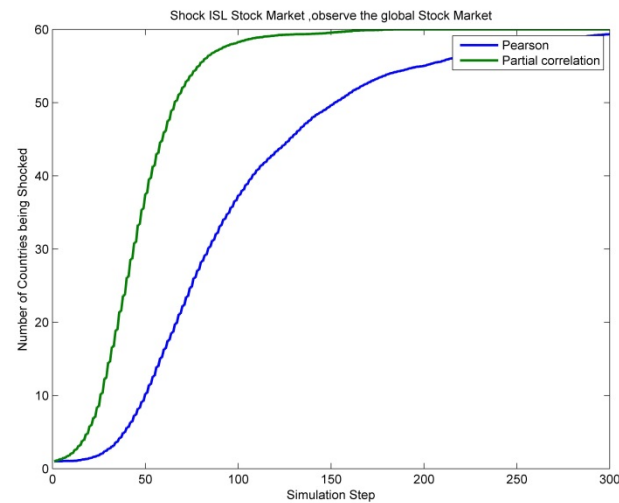
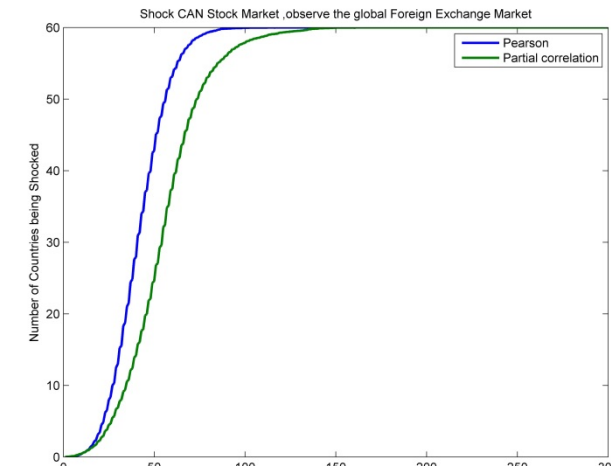
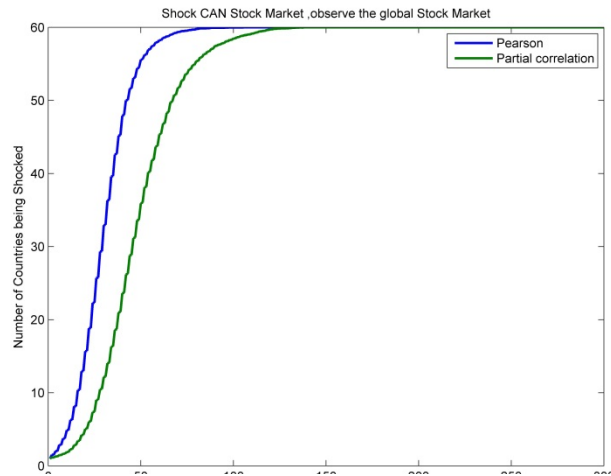


Stock Market Correlations

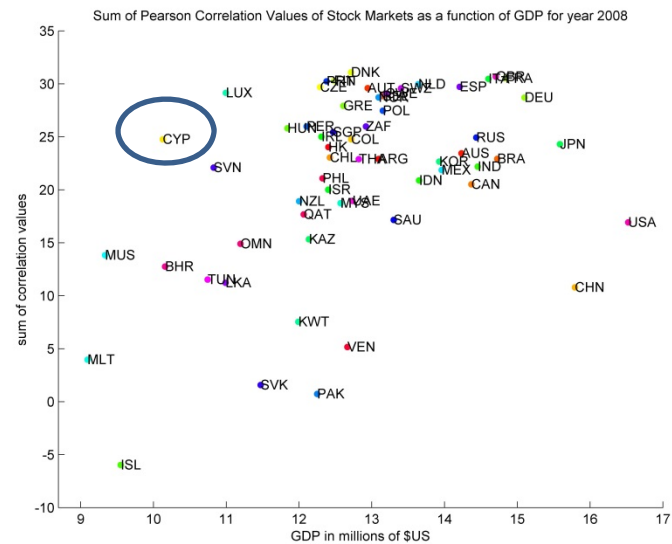
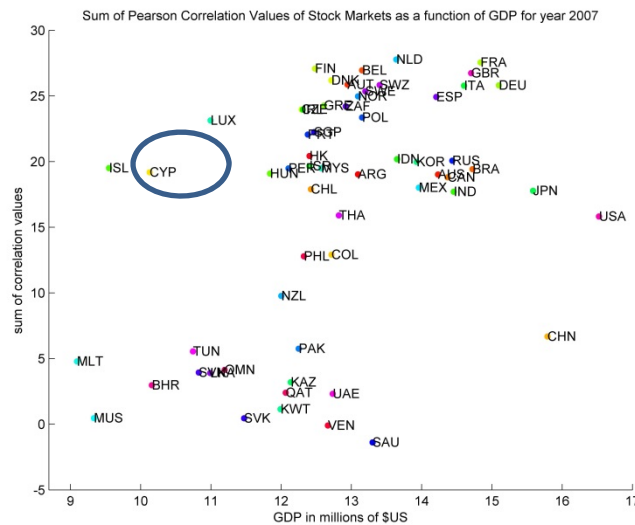
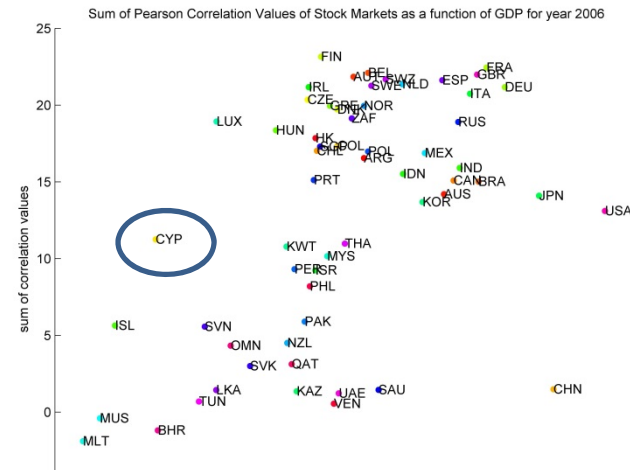
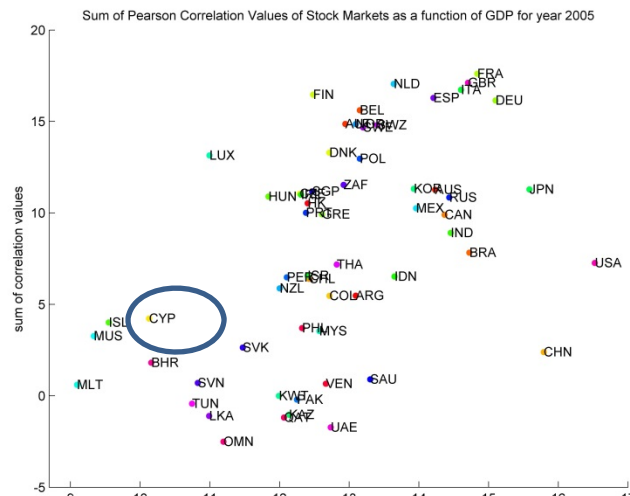
CDS Market Correlations



Networks effect of distress propagation measured by Pearson and partial correlations



Sum of Pearson correlation values of stock markets as function of GDP for 2005-2008



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Discussion

- We study systemic risk propagation through interdependent financial networks
- Focus on the challenges of financial and economic system dynamics as strongly related networks
- How to transform global economic networks into more resilient systems to shocks?
- Do crisis have common ingredients?
- Can we apply proposed methods and models universally?

Thank You!

Questions?

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