

# Banking System Stability – A Guided Tour Through Networks

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Paolo Vanini

Handel Strukturierte Produkte & Cross Assets

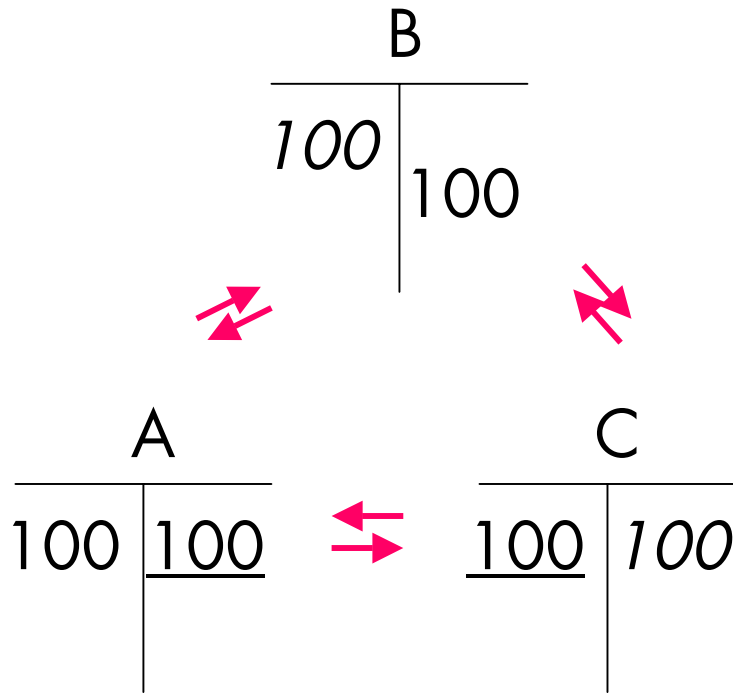
# Causes for the Crisis

- Business Models
- Incentive Schemes
- Risk Taking versus Risk Transformation
- Rating and Pricing Models
- Network of Banking System

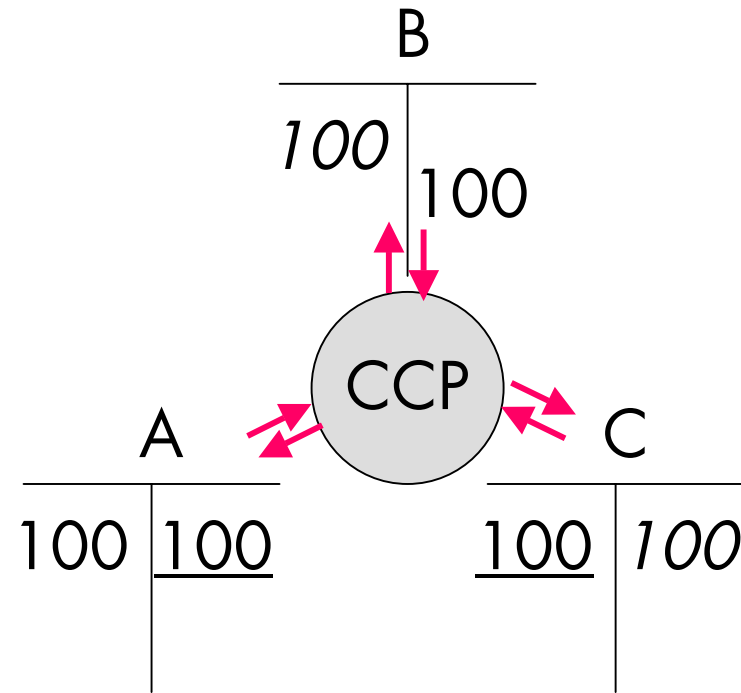
# Network of Banking System

- Highlight some aspects of banking network
- Turns out to be a fascinating and challenging task
- To my knowledge, there is no approach which consider all key aspects of a banking network:
  - Complexity (nodes and links)
  - Dynamics (evolution of nodes and links)
  - Behavior (people behind the network, not a molecular system)
- Focus on particular aspects
  - Balance sheet view (Shin)
  - Dynamics view (Redner)
  - Trust and Social Collateral (Karlan)

# Network Topology and Balance Sheets



Downgrading of C:  
Defaultchain B→A→C  
cycles



Downgrading of C:  
Default of C (unless not too  
many defaults)

# Network and Diversification Risk

- Diversification as risk measure
  - Statistical measure of dependence. Prices of assets are simple random variables
- CDOs (Networks in asset pricing)
  - A bank's assets are another bank's liabilities
  - Price of an asset is a function of trust between network agents
  - Price of an asset is a function of the network complexity – in particular if trust evaporates
  - Hence, price of an asset is not given by a set of simple random variables

# Balance Sheet View

- Two approaches
  - Mark-to-market
  - Realized values
  
- Start with mark-to-market

# Balance Sheet View

System:

- N Banks
- N+1 = Outside Sector (Households, firms, govt.)

Assets	Liabilities
Lending to firms, households, govt.	Liabilities to firms, households, govt.
Claims on Banks	Liabilities to Banks
	Equity
<b>Individual Bank</b>	

Assets	Liabilities
Total Lending to firms, households, govt.	Total debt Liabilities to firms, households, govt.
-	-
	Total equity
<b>Banking Sector</b>	

# Balance Sheet View – in a Formula

Aggregating the individual balance sheet identities leads to the system identity:

$$\underbrace{\sum_n \mathbf{y}_n}_{\text{Total Lending}} = \underbrace{\sum_n \mathbf{e}_n}_{\text{Total Equity}} + \underbrace{\sum_n \mathbf{x}_n \mathbf{z}_n}_{\text{Total Debt}}$$
$$= \underbrace{\sum_n \mathbf{e}_n}_{\text{Total Equity}} + \underbrace{\sum_n \mathbf{e}_n \mathbf{z}_n (\lambda_n - \mathbf{1})}_{\text{Total Debt}}$$

# Balance Sheet View – in a Formula

Aggregating the individual balance sheet identities leads to the system identity:

$e_n$  = equity of bank n

$y_n$  = lending of bank n to outside sector

$x_n$  = market debt value of bank n to all sectors

$\lambda_n$  = leverage of bank n (asset value/equity)

$z_n = 1 - \underbrace{\sum_i \pi_{ni}}_{\text{claim fraction of bank n hold against all other banks}} = \text{total lending of bank n to outside sector}$

claim fraction  
of bank n hold against  
all other banks  
--> Banking System

# Balance Sheet View – Conclusion from the Formula

- Total debt outside sector increases in line with household wealth: slow moving
- Ultimately, credit supply to end-users must come either from the equity of the banking system or the funding provided by non-banks.
- $\Pi$  = Matrix of interbank claims is the fundamental network system component. What happen if ...
- Three methods of regulation:
  1. Regulating leverage factor: Leverage Cap (Switzerland)
  2. Regulating equity fluctuations: Spanish Statistical Provisioning
  3. Shortening indermediation chain by issuing new products: Covered Bonds (Danish mortgage bonds, German Pfandbrief Bonds)

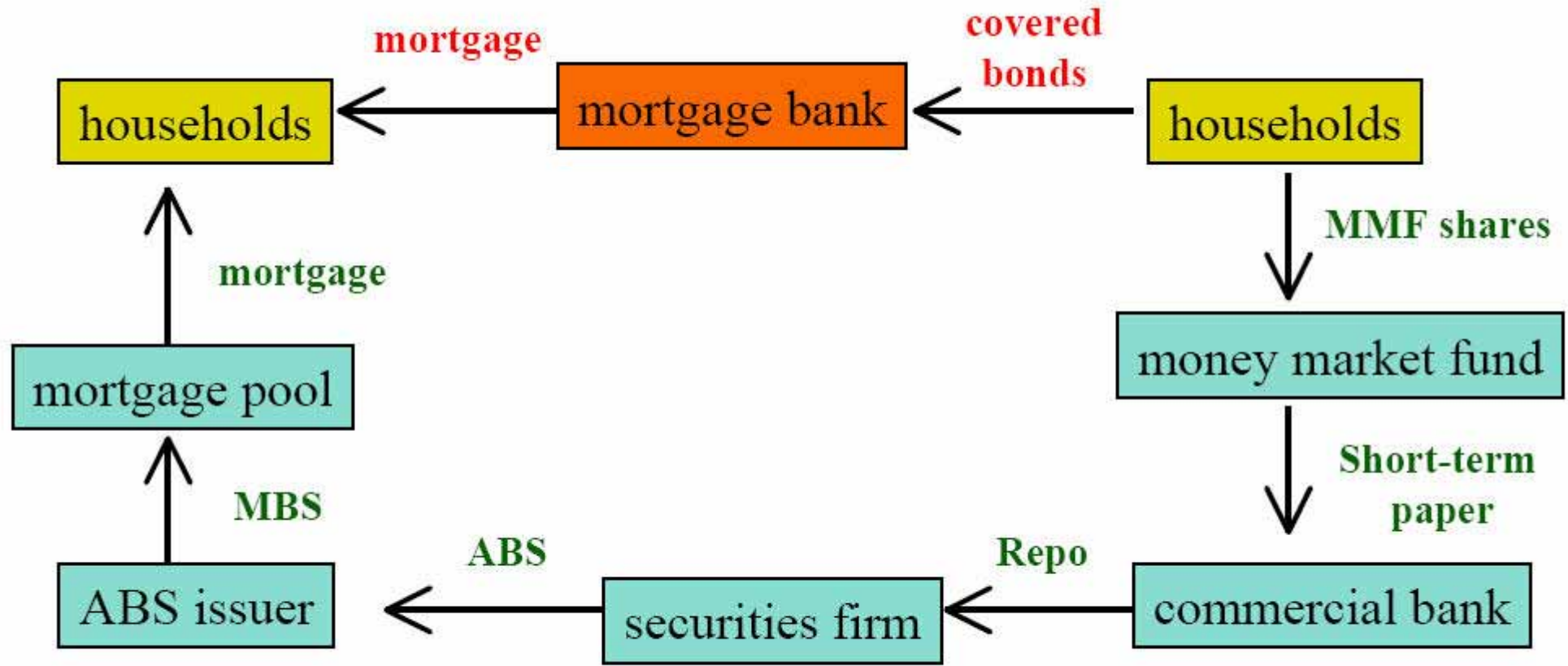
# Balance Sheet View – Conclusion from the Formula

## Capped leverage approach

- Leverage is procyclical
  - VaR of 1 CHF leads to  $\text{Equity} = \text{Asset Value} \times \text{VaR}$
  - $\text{Leverage} = \text{Asset Value} / \text{Equity} = 1 / \text{VaR}$
- Leverage of system vs. leverage of individual banks
  - Case of market values: not arbitrarily large individual leverage
  - Case of face values: no upper limits to individual leverage

# Balance Sheet View – Conclusion from the Formula

Shortening intermediation chain by issuing new products



Source: Shin 2009

# Balance Sheet View – Realized Values and Contagion

- All variables are realized values at a future date
- Banking sector with  $n$  banks only
- Balance sheet of each bank reads

$$\underbrace{\mathbf{p}_n}_{\text{illiquid asset}} + \underbrace{\mathbf{l}_n}_{\text{liquid asset}} + \underbrace{\sum_i \mathbf{x}_i \pi_{in}}_{\text{claims to other banks}} = \underbrace{\mathbf{e}_n}_{\text{equity}} + \underbrace{\mathbf{x}_n}_{\text{debt}}$$

- A bank's assets are another bank's liabilities.
- Cycles possible.

# Balance Sheet View – Realized Values and Contagion

- Banking sector: Priority of debt of equity implies

$$\mathbf{x}_1 = \min \left( \bar{\mathbf{x}}_1, \mathbf{p} \mathbf{i}_1 + \mathbf{l}_1 + \sum_i \mathbf{x}_i \pi_{i1} \right)$$

$$\mathbf{x}_2 = \min \left( \bar{\mathbf{x}}_2, \mathbf{p} \mathbf{i}_2 + \mathbf{l}_2 + \sum_i \mathbf{x}_i \pi_{i2} \right)$$

•  
•  
•

- This is the banking market clearing condition
- Does a clearing vector  $\mathbf{x}$  of debt exists?

# Balance Sheet View – Realized Values and Contagion

- Economy of banking system
  - Capital adequacy constraint

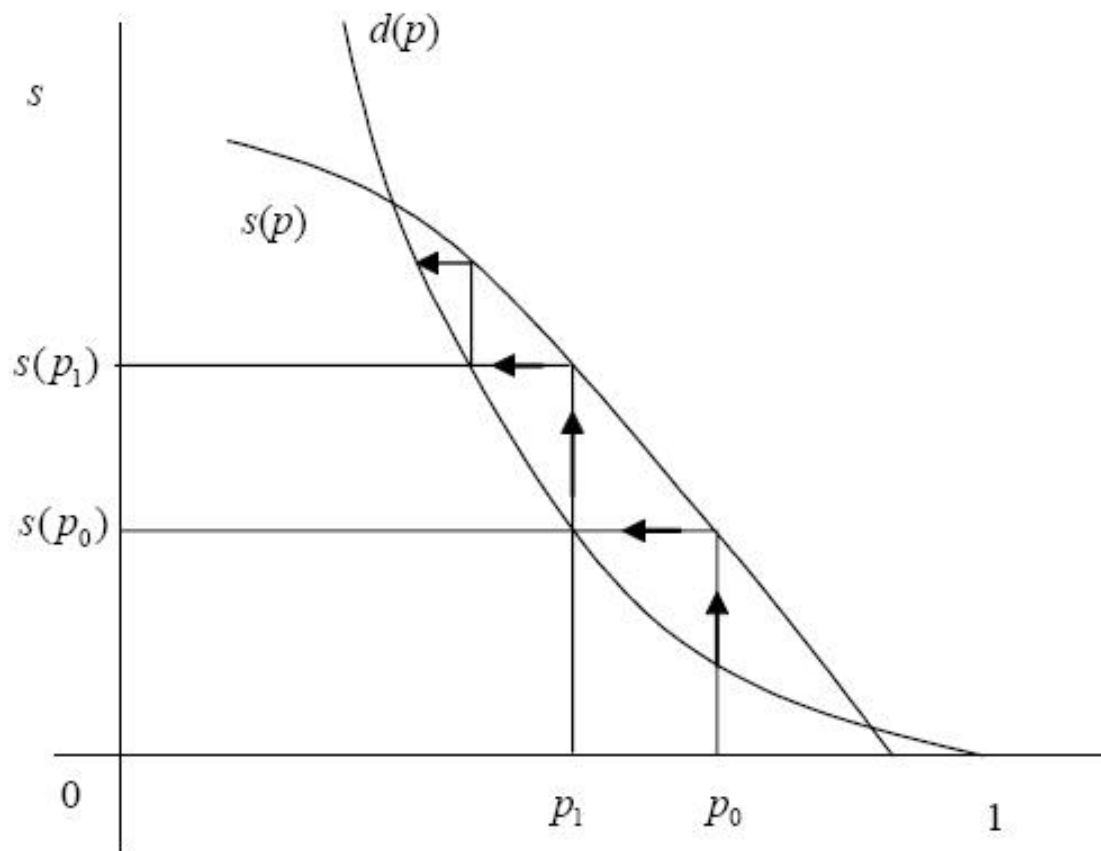
$$\frac{\text{equity value of bank n}}{\text{market value of assets of bank n}} > 8\%$$

Bank can sell liquid and illiquid asset to restore adequacy constraint

- Price  $p$  of illiquid asset: Demand equals aggregate sales
- Clearing condition of last slide
- Equilibrium
  - payments  $x$ , sale of illiquid asset, price  $p$  illiquid asset

# Balance Sheet View – Realized Values and Contagion: Result

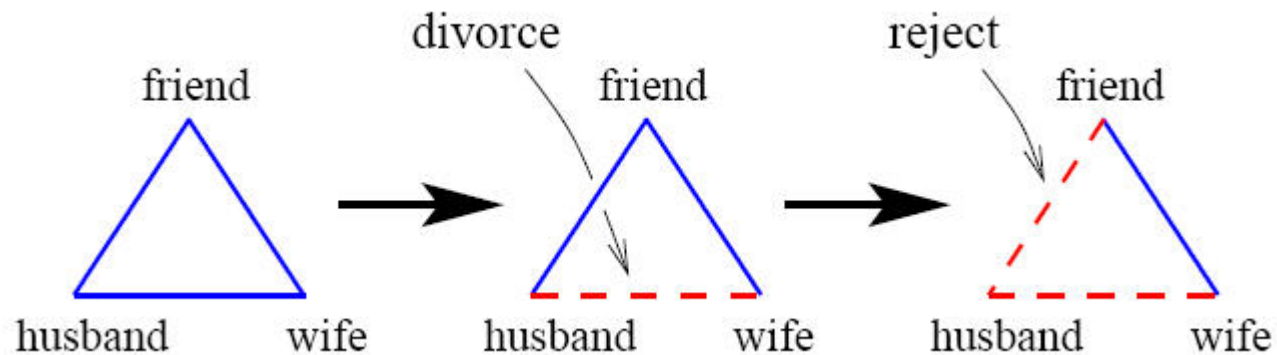
**Chart 1: Amplification of shock through asset sales**



Source: Shin 2007

# Dynamics view

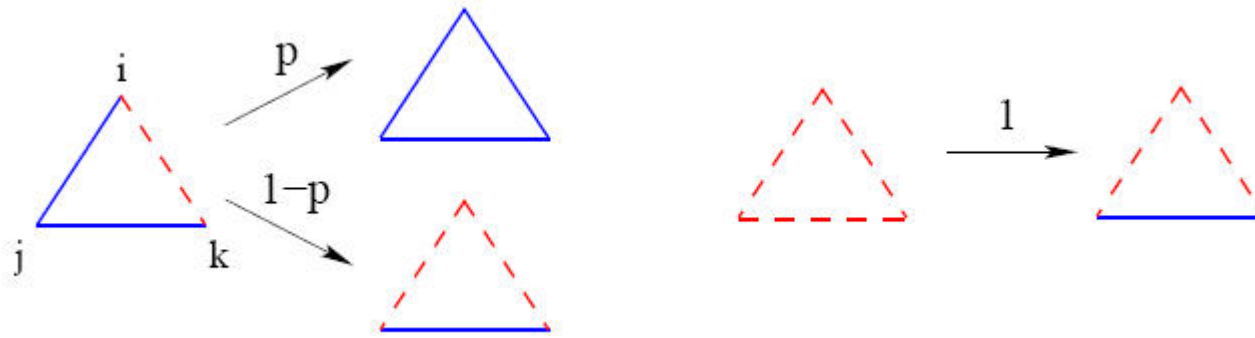
## Triad model



- Balanced and unbalanced triads
- Interbank lending
  - a friend of my friend as well as an enemy of my enemy is my friend;
  - a friend of my enemy as well as an enemy of my friend is my enemy.

# Dynamics view

## Dynamic update of friendship



- Key question
- Given  $N$  banks with an initial distribution of friendship relations. What will be the evolution of the friendship links over time?

# Dynamics view

## Stationary State

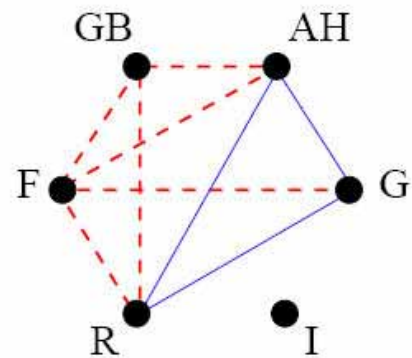
- Writing down the dynamics and considering the stationary state, it follows that the density  $r$  of friendly links satisfy

$$r = \begin{cases} \frac{1}{\sqrt{3(1-2p)} + 1}, & \text{if } p \leq 0.5 \\ 1 & , \text{ else} \end{cases}$$

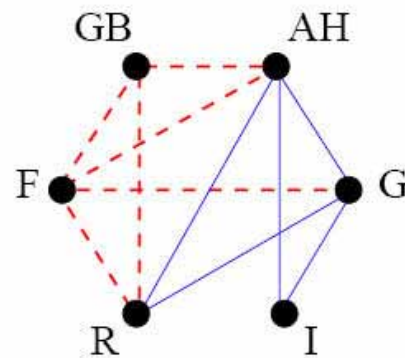
- There is a phase transition: Gas/Liquid/Solid
- Phase transitions are key in economic networks too, i.e. when the economy undergoes a qualitative change
- Little is quantitatively known about economic phase transitions – many stories in so called behavioral finance

# Dynamics view

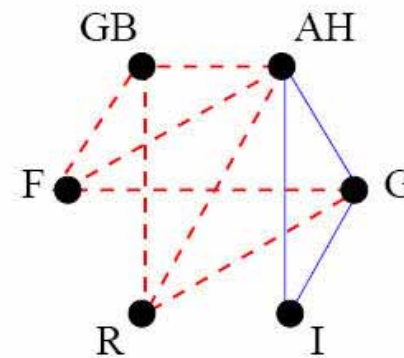
## Protagonists of World War I



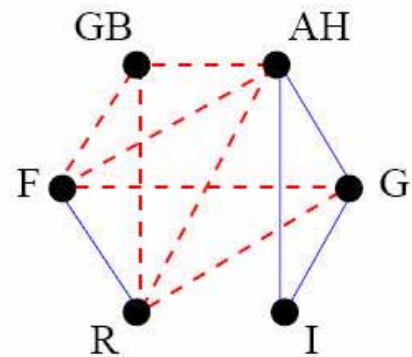
3 Emperor's league 1872-81



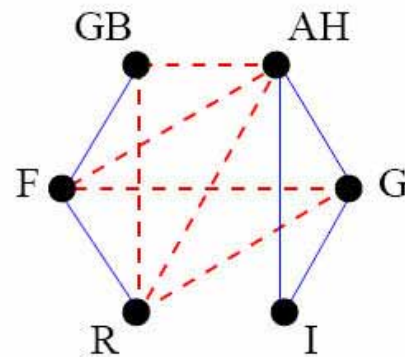
Triple Alliance 1882



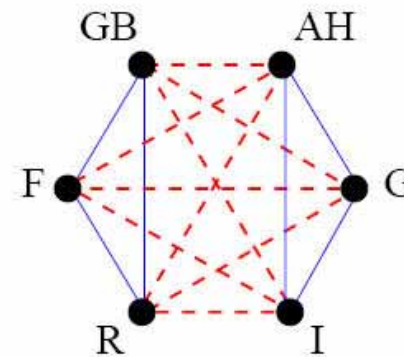
German-Russian Lapse 1890



French-Russian Alliance 1891-94



Entente Cordiale 1904



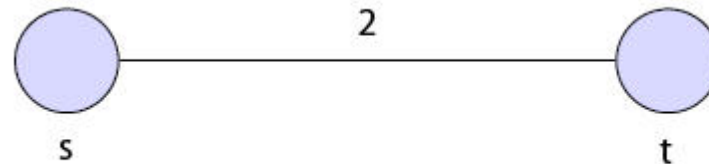
British-Russian Alliance 1907

Source: Redner 2008

# Trust and Social Collateral

- Network of agents with no formal contract enforcement
- Agents decision making:
  - Maximize individual utility
  - Economy equilibrium is a game theoretic equilibrium

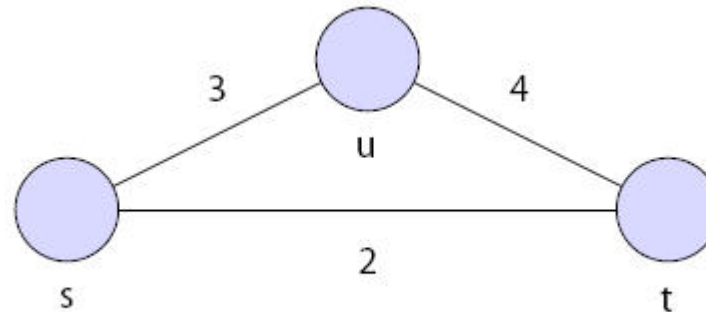
# Trust and Social Collateral



Source: Karlan 2009

- $s$  wants to borrow car from  $t$
- $2$  = value of their relationship (social value of friendship or PV of future transactions)
- Lending occurs only if value of car smaller than  $2$

# Trust and Social Collateral



Source: Karlan 2009

- u common friend
- weakest link connecting borrower and lender through u is  $3 = \min(4,3)$
- increase of borrowing limit to 5
- u acting as guarantor of loan transaction
- if s does not return car, loses u-friendship

# Trust and Social Collateral

- General result:
  - Trust = sum of weakest link values over all disjoint paths connecting borrower and lender
  - Intuition?
- Key in the proof of the result is the famous maximum flow-minimum cut theorem of computer science

# Summary

- Balance sheet view
  - fundamental economic state variables
  - no behavior
- Dynamics view
  - true dynamics
  - rule based behavior
  - no economic decision incentives
- Trust and social collateral view
  - economic incentives and strategic behavior
  - no dynamics

# Summary

## Regulation of banks

- Basel II
  - No network dependence
  - No dynamics
  - Behavior on single-bank basis
- New concepts of regulation. Understand
  - the network,
  - the dynamics of network formation,
  - the role and interplay of hard (Balance sheets) and soft (Trust) variables
  - the incentive structure not only on a micro but also on a macro level

# Literature

- Trust and Social Collateral

Dean Karlan, Markus Mobius, Tanya Rosenblat Adam Szeidl  
Quarterly Journal of Economics, 2009

- Several papers of Hyun Shin from Princeton

<http://www.princeton.edu/~hsshin/>

- Several papers of Sidney Redner from Boston University

<http://physics.bu.edu/~redner//>