Management of systemic risk

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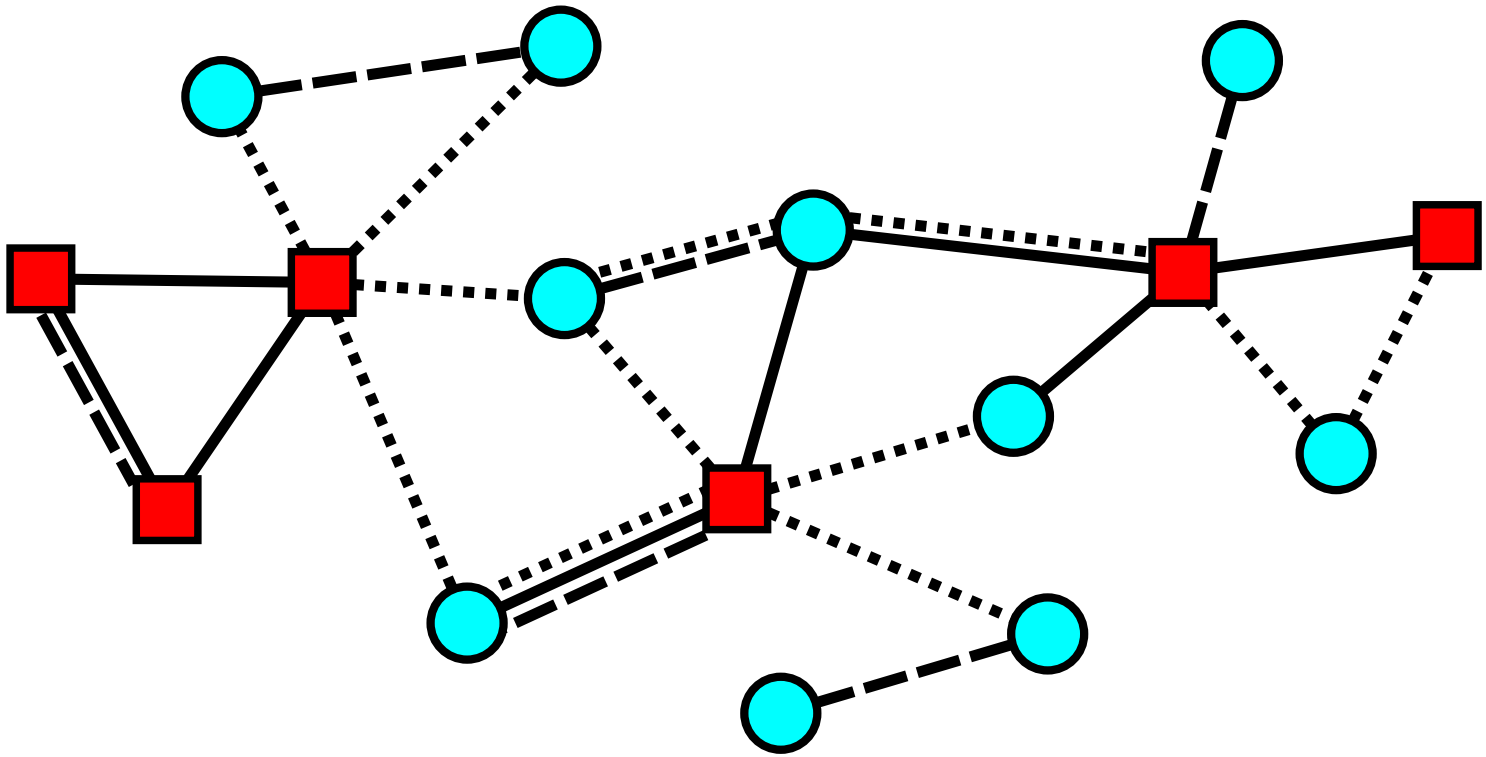
funded in part by

What is a Complex System?

Co-evolving multiplex network



- Multiplex network, $M_{ij}^{\alpha}(t)$
- Nodes i characterized by states, $\sigma_i^{\beta}(t)$

complex system = co-evolving multiplex network

$$\frac{d}{dt}\sigma_i^\alpha(t) \sim F\left(M_{ij}^\alpha(t), \sigma_j^\beta(t)\right)$$

and

$$\frac{d}{dt}M_{ij}^\alpha(t) \sim G\left(M_{ij}^\alpha(t), \sigma_j^\beta(t)\right)$$

can not **solve** this – but can observe it

- States of individuals are observable (big data)
- Networks are observable (big data)

Part I: What is systemic risk?

The three types of risk

- **economic risk:** investment in business idea does not pay off
- **credit-default risk:** you don't get back what you have lent
- **systemic risk:** system stops functioning due to local defaults and subsequent (global) cascading

Economic risk

risk that business idea does not fly – fails – investments are lost

- who takes this risk? The financial system!
- this is a service of financial system to economy
- this service should not introduce new risks: as long as it does

$\rightarrow$ financial system is ill designed

- **management:** hard to get rid of this type of risk

Credit-default risk

if I lend something – there is risk that I will not get it back

estimate for credit-worthiness: assets–liabilities

- **management:** capital requirements for lending $\rightarrow$ Basle-type regulation

Systemic risk

- risk that significant fraction of financial network defaults
- systemic risk is **not** the same as credit-default risk
- banks care about credit-default risk
- banks have no means to manage systemic risk

$\longrightarrow$ role of regulator: **manage systemic risk**
$\longrightarrow$ incentivise banks to think of SR

Two origins of systemic risk

- **synchronisation of behaviour**: fire sales, margin calls, herding including various amplification effects. May involve networks
- **networks of contracts**: this is manageable

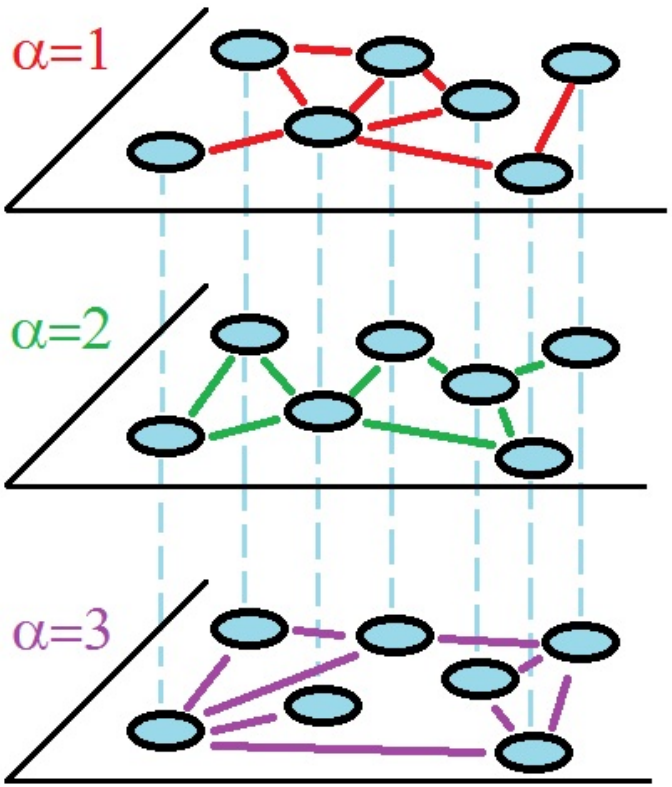
How does systemic risk spread?

on networks of contracts: **by borrowing!**

if you borrow from systemically risky nodes $\rightarrow$ you increase your systemic risk

note: credit-default risk spreads by lending

Systemic risk is a multiplex



layer 1: lending–borrowing network

layer 2: network of derivatives

layer 3: network of collateral

layer 4: network of overlapping pfolios

layer 5: network of cross-holdings

layer 6: liquidity networks

Part II: Quantification of SR

Systemic risk – quantification

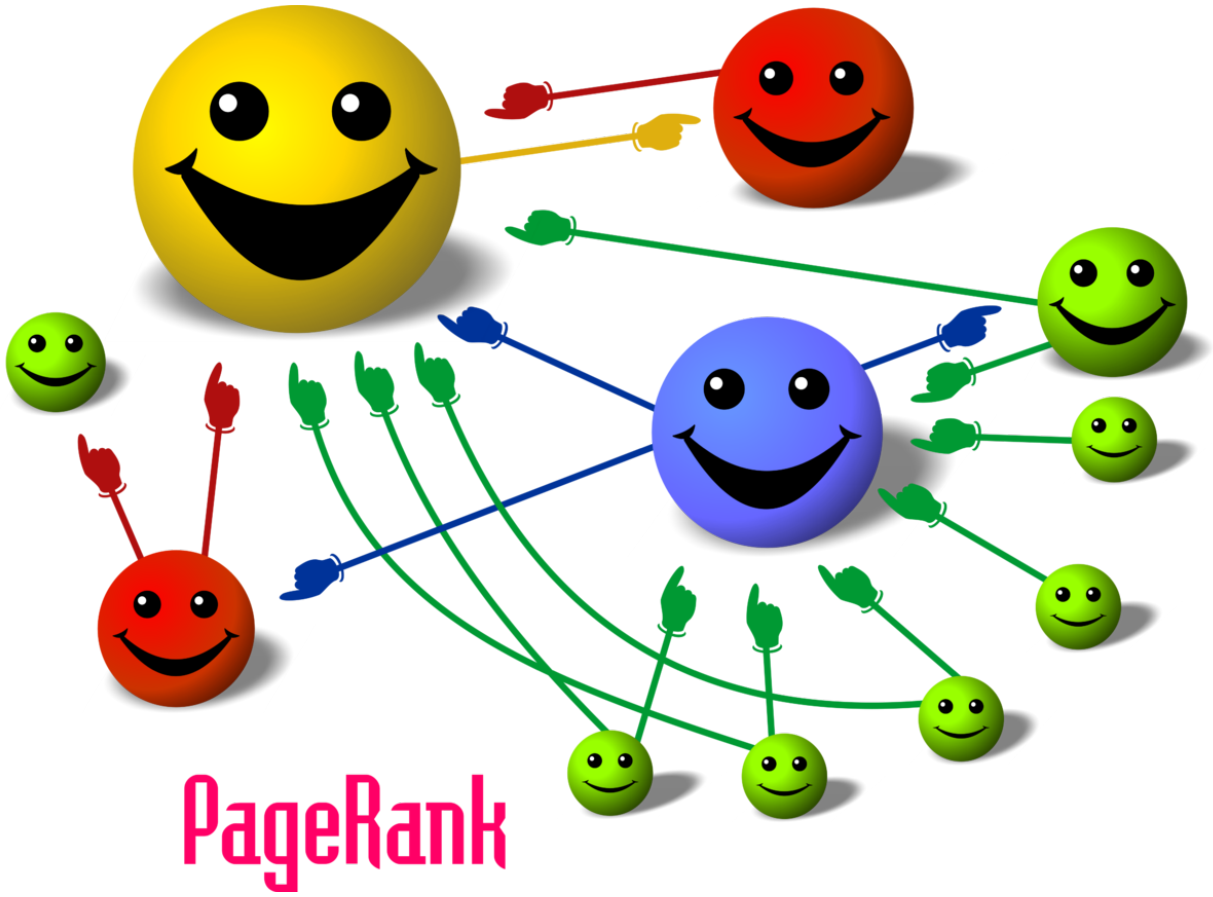
Wanted: systemic risk-value for every financial institution

Google has similar problem: value for importance of web-pages

$\rightarrow$ page is important if many important pages point to it

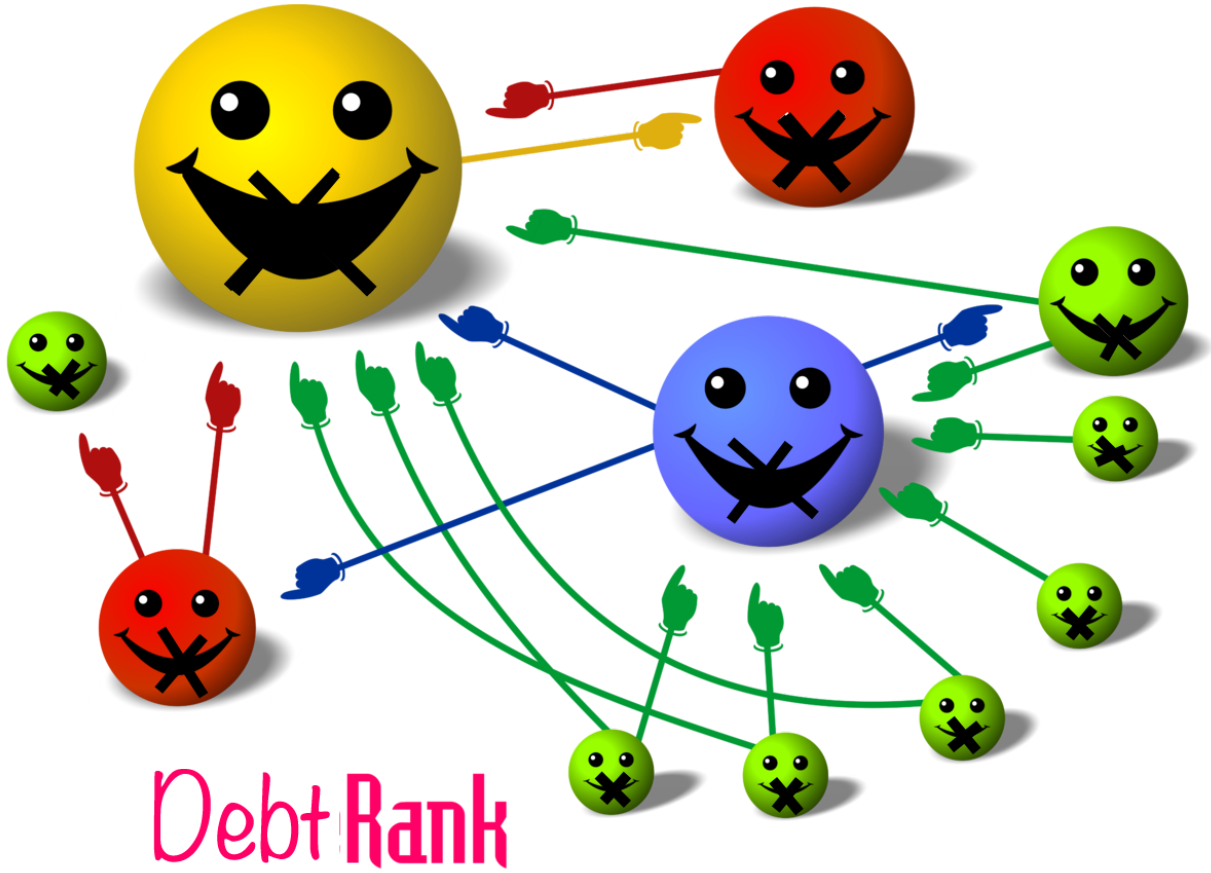
$\rightarrow$ number for importance $\rightarrow$ PageRank

page is **important** if many **important** pages point to it



source Wikipedia cc-license

institution system. risky if system. risky institutions lend to it



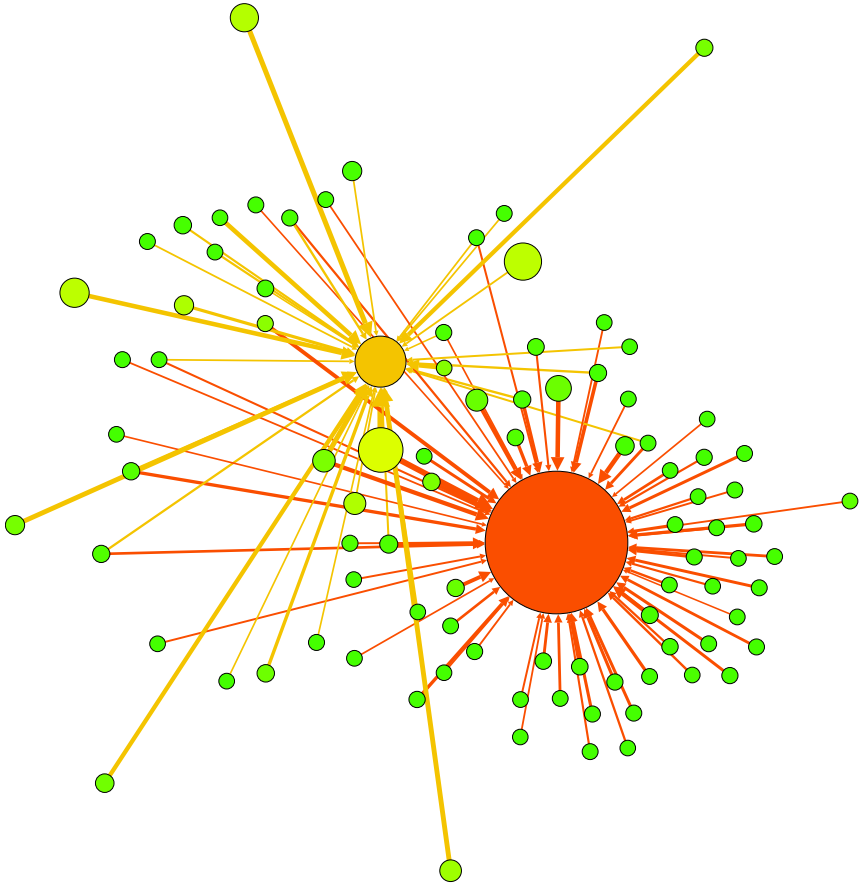
Systemic risk factor – DebtRank R

... is a "different Google" – adapted to context of systemic risk

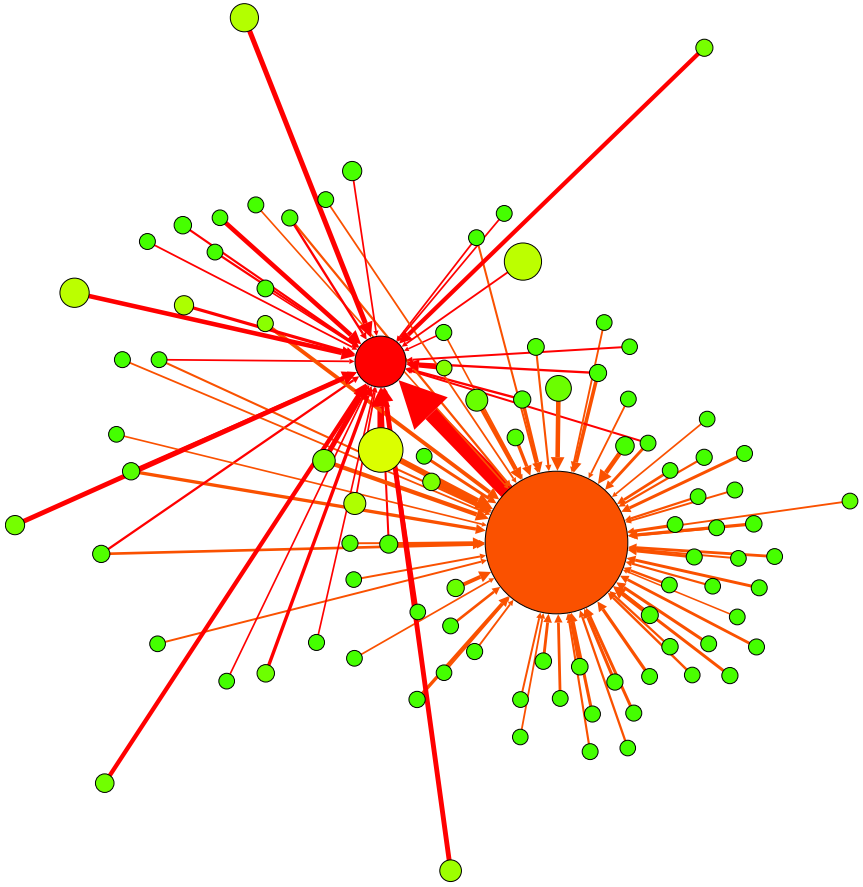
superior to: eigenvector centrality, page-rank, Katz rank ... Why?

- quantifies systemic relevance of node in financial network with economically meaningful number
- **economic value** in network that is affected by node's default
- takes capitalization/leverage of banks into account
- takes cycles into account: no multiple defaults

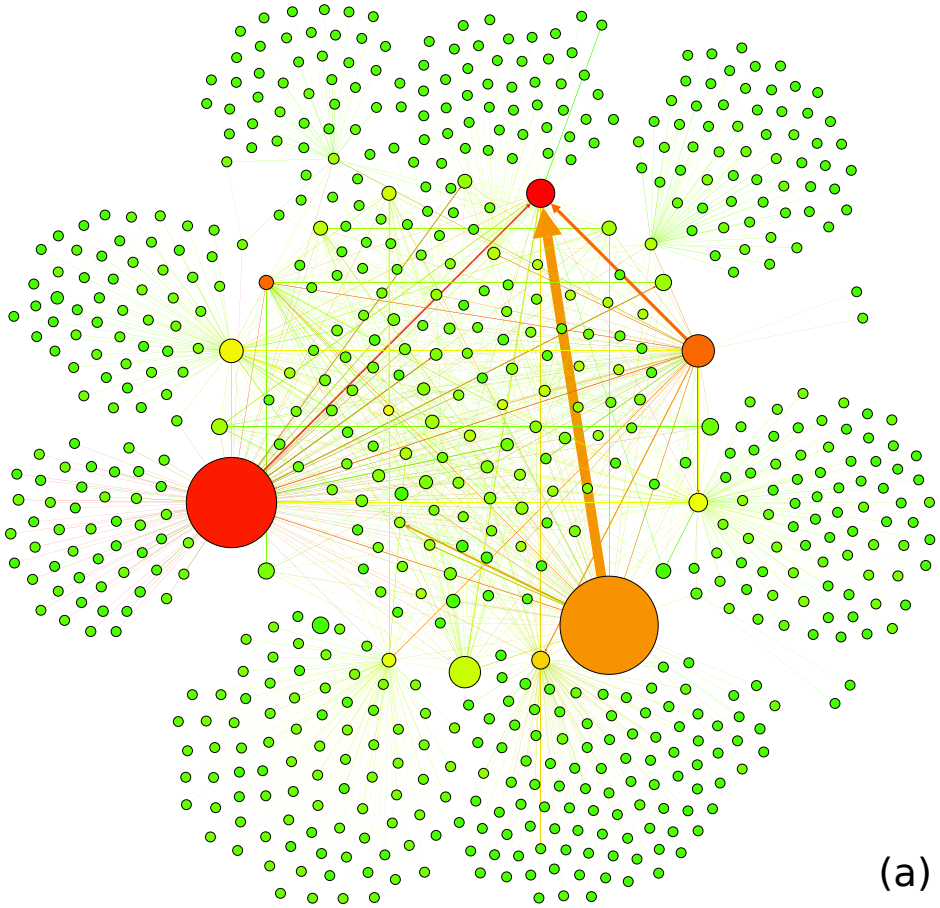
Systemic risk spreads by borrowing



Systemic risk spreads by borrowing



DebtRank Austria Sept 2009

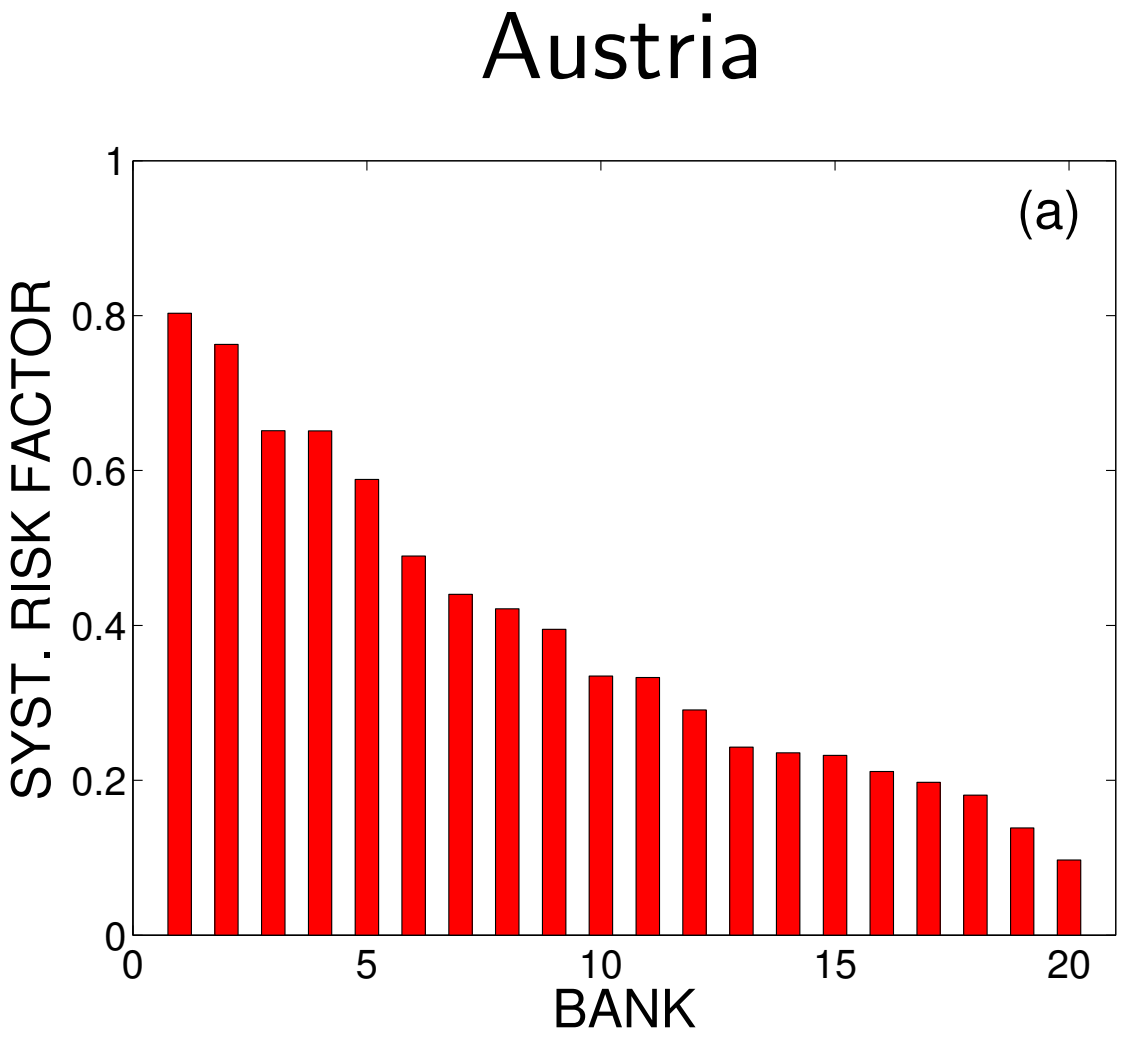


(a)

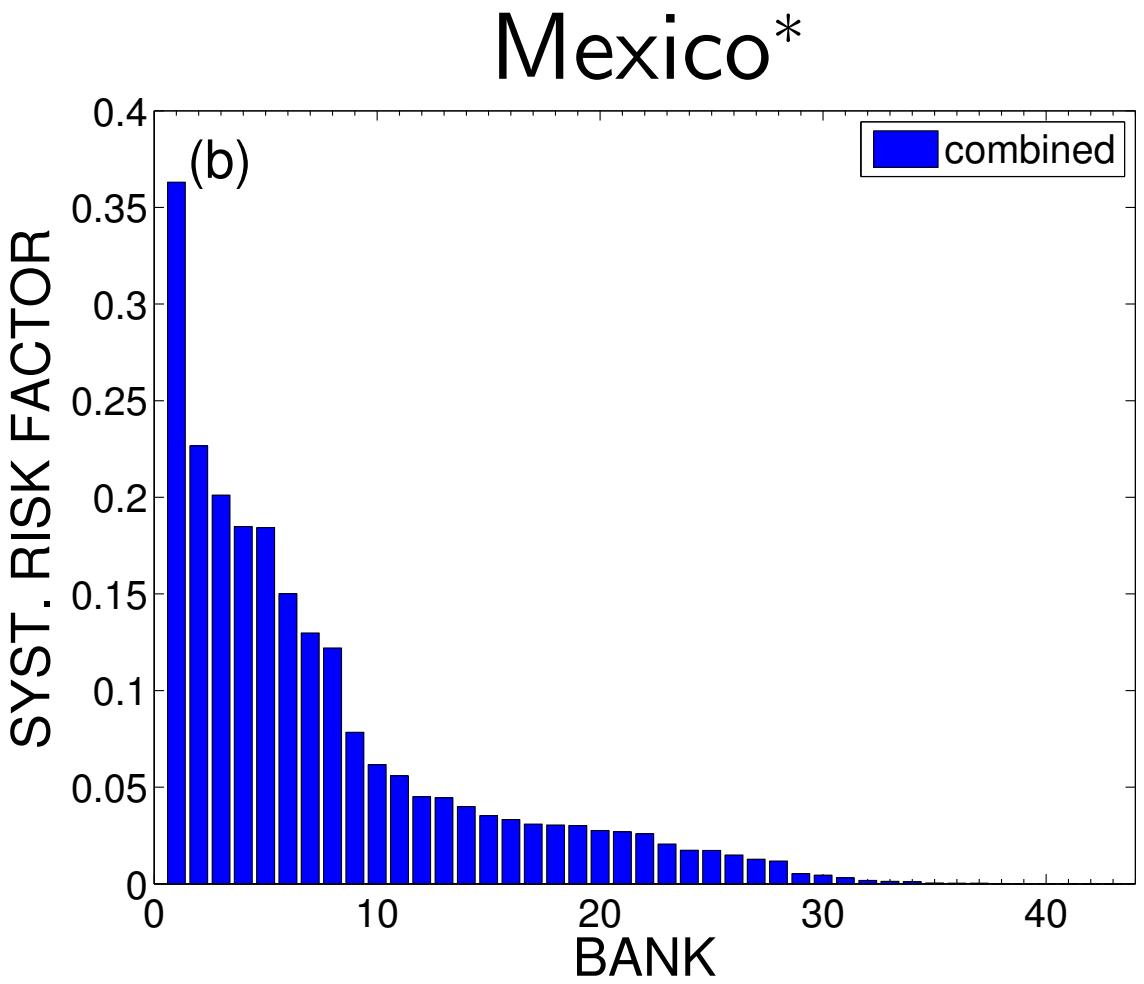
note: size is not proportional to systemic risk

note: core-periphery structure

Systemic risk profile

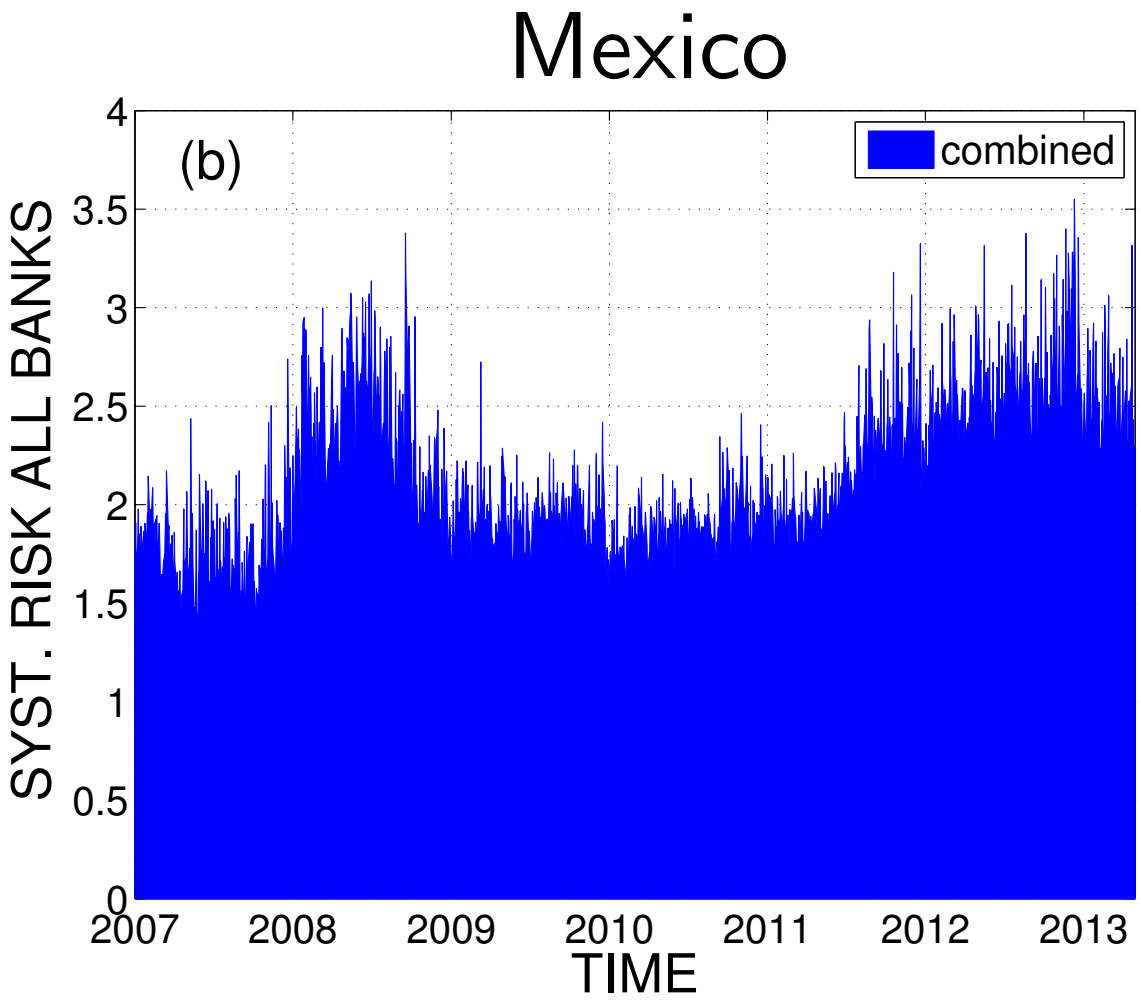


Systemic risk profile



*with Serafin Martinez-Jaramillo and his team at Banco de Mexico, 2014

Daily assessment of systemic risk is possible



Systemic risk $\rightarrow$ expected systemic loss

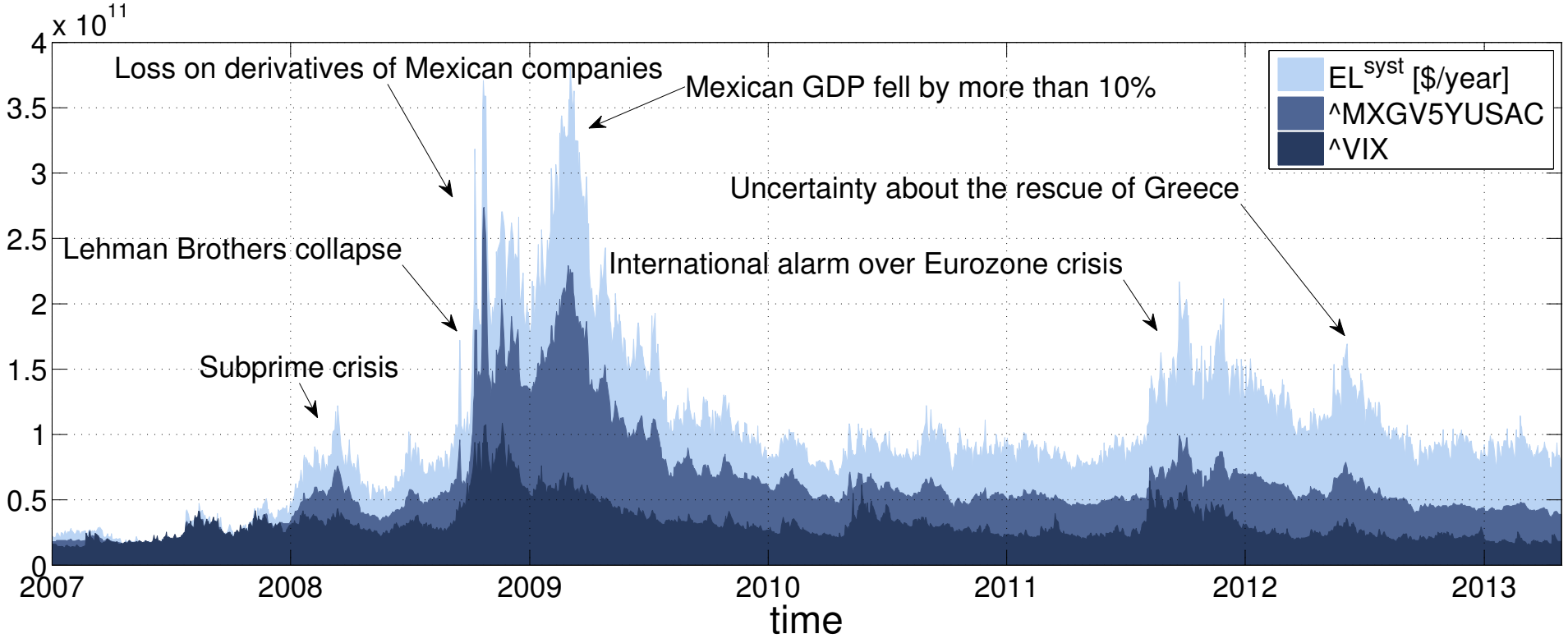
Expected economic loss for bank i (stress testing)

Expected loss(i)=$\sum_j p_{default}$(j).Loss-given-default(j).Exposure(i,j)

Expected systemic loss of bank $j = p_{default}$(j) . DebtRank(j)

units: Euro / Year

Expected systemic loss index for Mexico*



*with Serafin Martinez-Jaramillo and team at Banco de Mexico, 2014

Expected systemic loss index

- expected losses per year within country in case of severe default and NO bailout

$\rightarrow$ rational decision on bailouts

- allows to compare countries

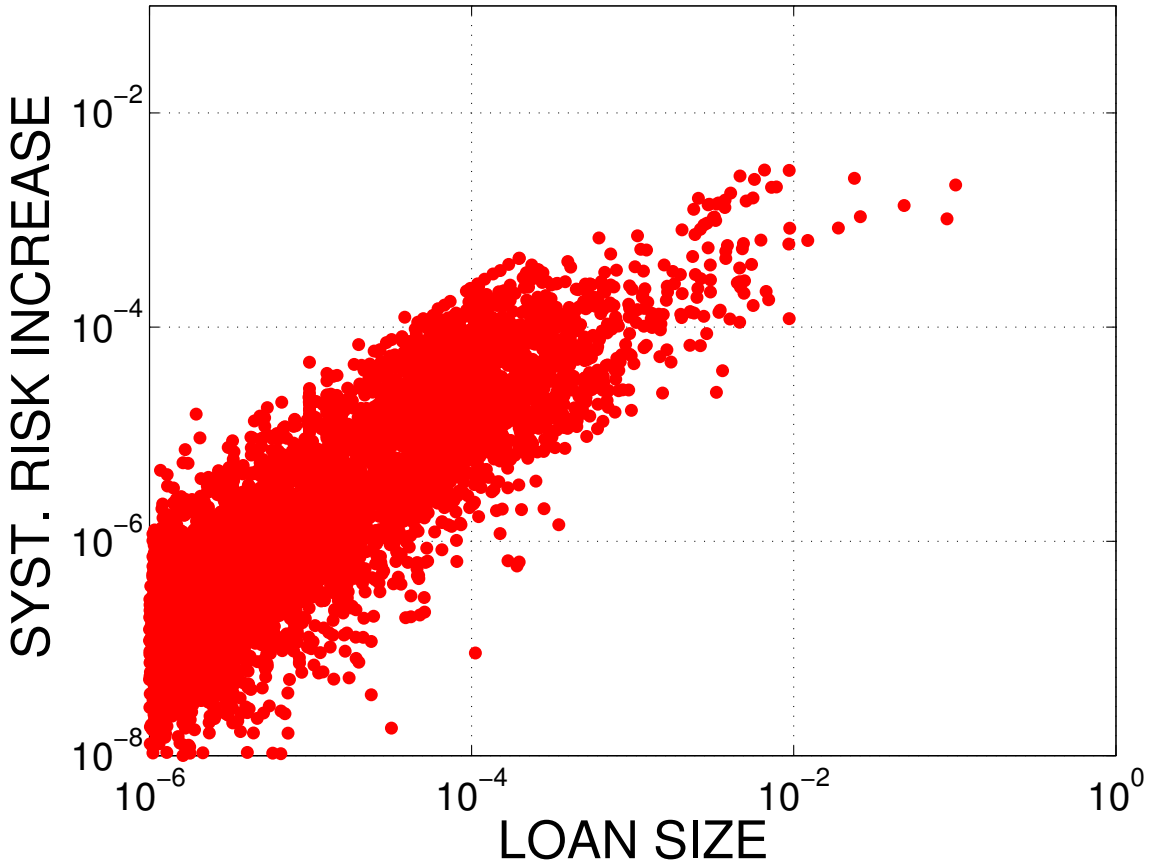
- allows to compare situation of country over time

$\rightarrow$ are policy measures taking action in Spain? in Greece?

Observation

Systemic risk of a node changes with every transaction

Austria all interbank loans



note orders of magnitude !

Management of systemic risk

- Systemic risk is a network property to large extent
- Manage systemic risk: **re-structure financial networks** such that cascading failure becomes unlikely, ideally impossible

Systemic risk elimination

- systemic risk spreads by borrowing from risky agents
- how risky is a transaction? $\rightarrow$ increase of expected syst. loss
- ergo: restrict borrowing from those with high DebtRank

$\rightarrow$ **tax those transactions** that increase systemic risk

Systemic risk tax

- tax transactions according to their systemic risk contribution

$\rightarrow$ agents look for deals with agents with low systemic risk
$\rightarrow$ liability networks re-arrange $\rightarrow$ eliminate cascading

No one should pay the tax – tax serves as incentive to re-structure networks

- size of tax = expected systemic loss of transaction (government is neutral)

- if system is risk free: no tax

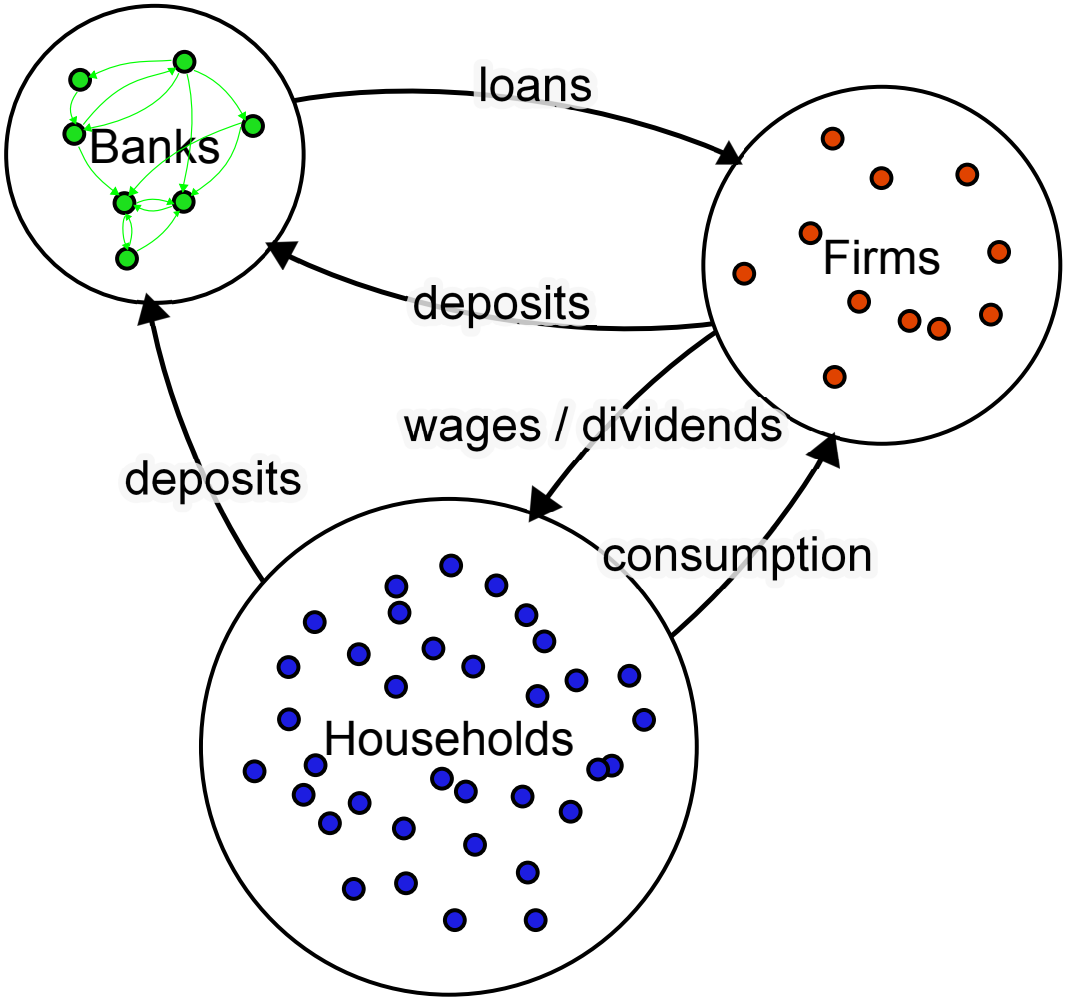
- credit volume should not be affected by tax

Self-stabilisation of systemic risk tax

- those who can not lend become systemically safer
- those who are safe can lend and become unsafer
- $\rightarrow$ new equilibrium where systemic risk is distributed evenly across the network (cascading minimal)

$\rightarrow$ self-organized critical

To test efficacy of tax: Crisis Macro-Financial Simulator (schematic)



The agents

- **firms:** ask bank for loans: random size, maturity τ, $r^{\mathrm{f-loan}}$

$\rightarrow$ firms sell products to households: realise profit/loss

$\rightarrow$ if surplus $\rightarrow$ deposit it bank accounts, for $r^{\mathrm{f-deposit}}$

$\rightarrow$ firms are bankrupt if insolvent, or capital is below threshold

$\rightarrow$ if firm is bankrupt, bank writes off outstanding loans

- **banks** try to provide firm-loans. If they do not have enough

$\rightarrow$ approach other banks for interbank loan at interest rate r^{ib}

$\rightarrow$ bankrupt if insolvent or equity capital below zero

$\rightarrow$ bankruptcy may trigger other bank defaults

- **households** single aggregated agent: receives cash from firms (through firm-loans) and re-distributes it randomly in banks (household deposits, r^{h}), and among other firms (consumption)

For comparison: implement Tobin-like tax

- tax all transactions regardless of their risk contribution
- 0.2% of transaction ($\sim$ 5% of interest rate)

Simulations: measure losses, cascades and efficiency

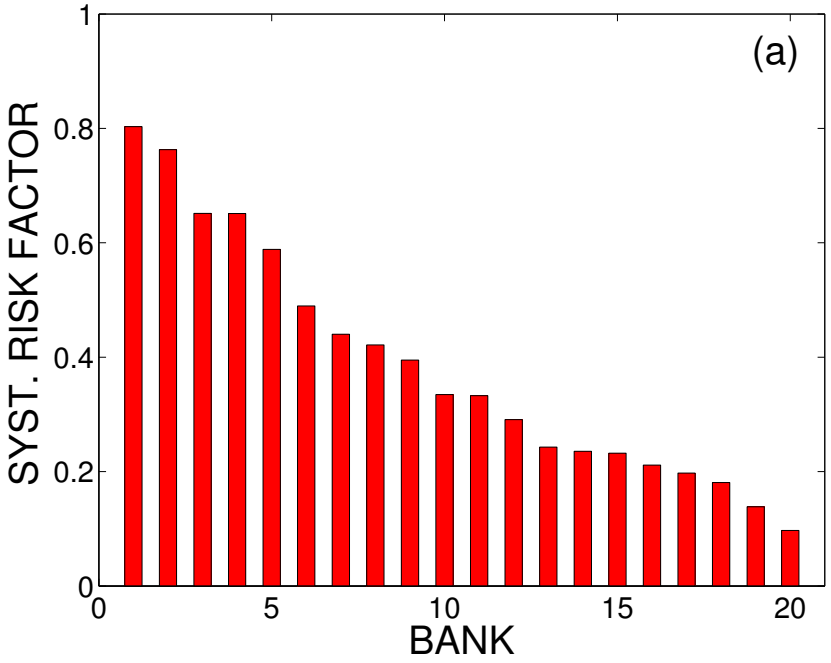
- **total losses to banks** resulting from a default/cascade
- **cascade size**: number of defaulting banks in systemic event
- **credit volume**: total credit volume in interbank market

Comparison of three schemes

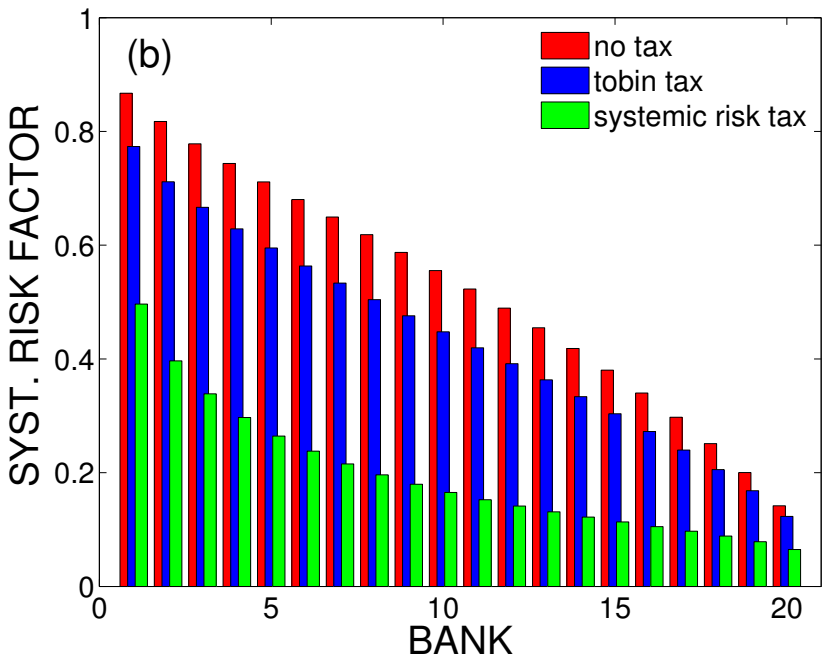
- No systemic risk management
- Systemic Risk Tax (SRT)
- Tobin-like tax

Model results: Systemic risk profile

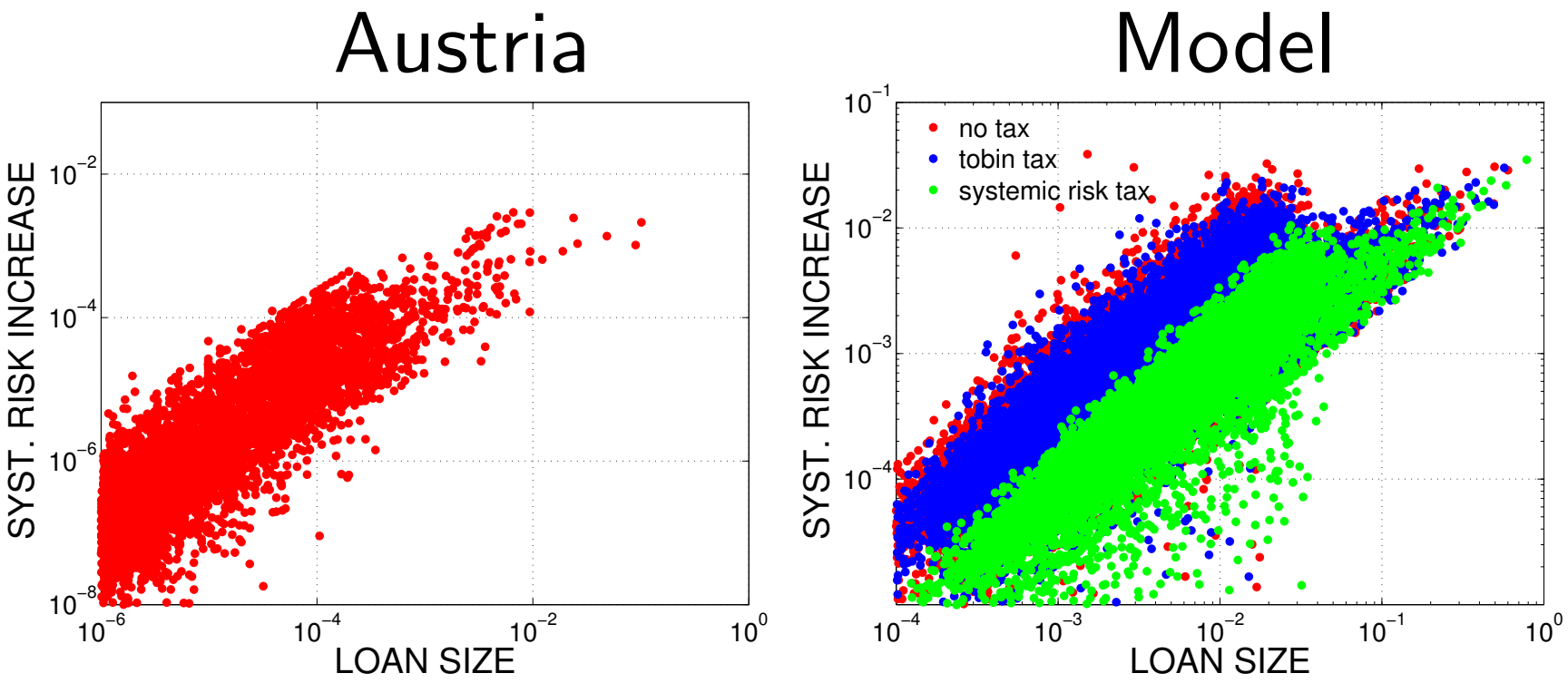
Austria



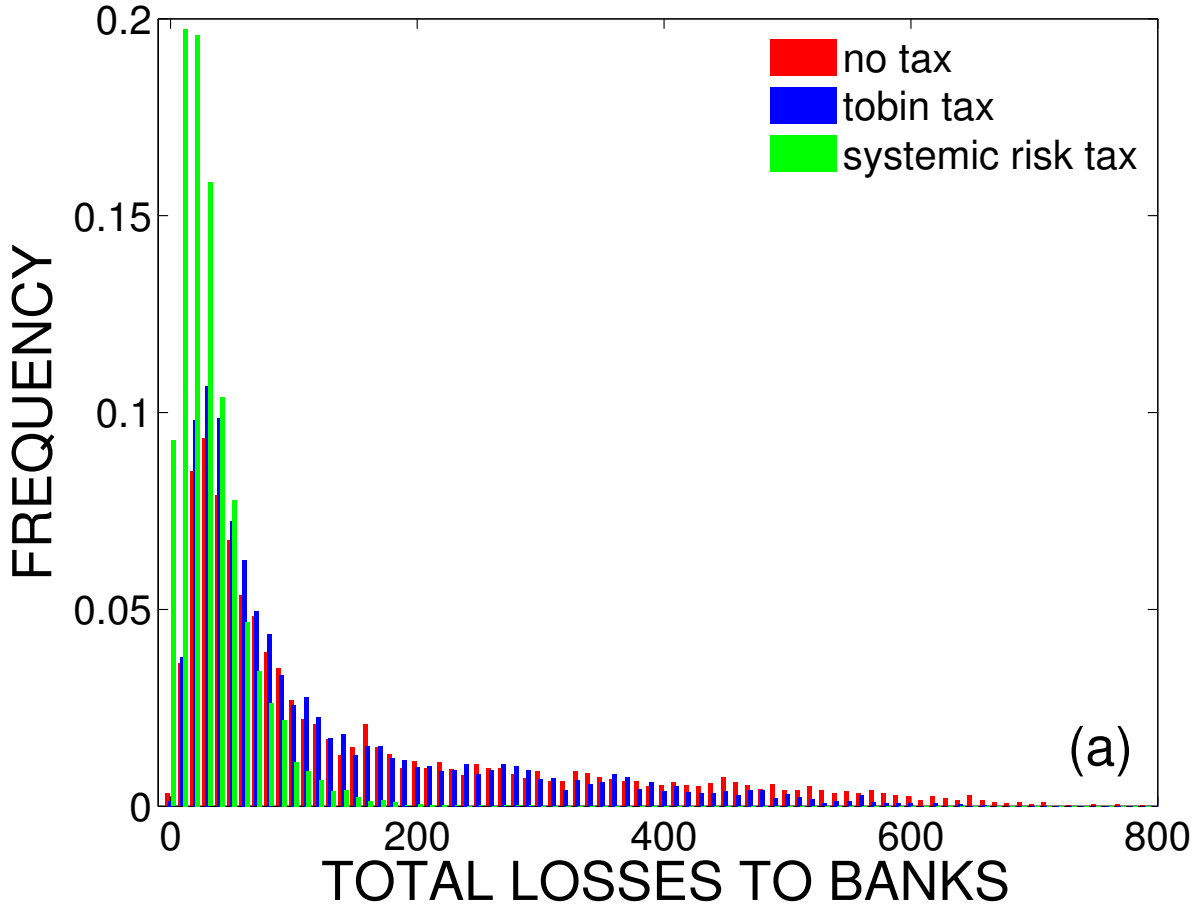
Model



Model results: Systemic risk of individual loans

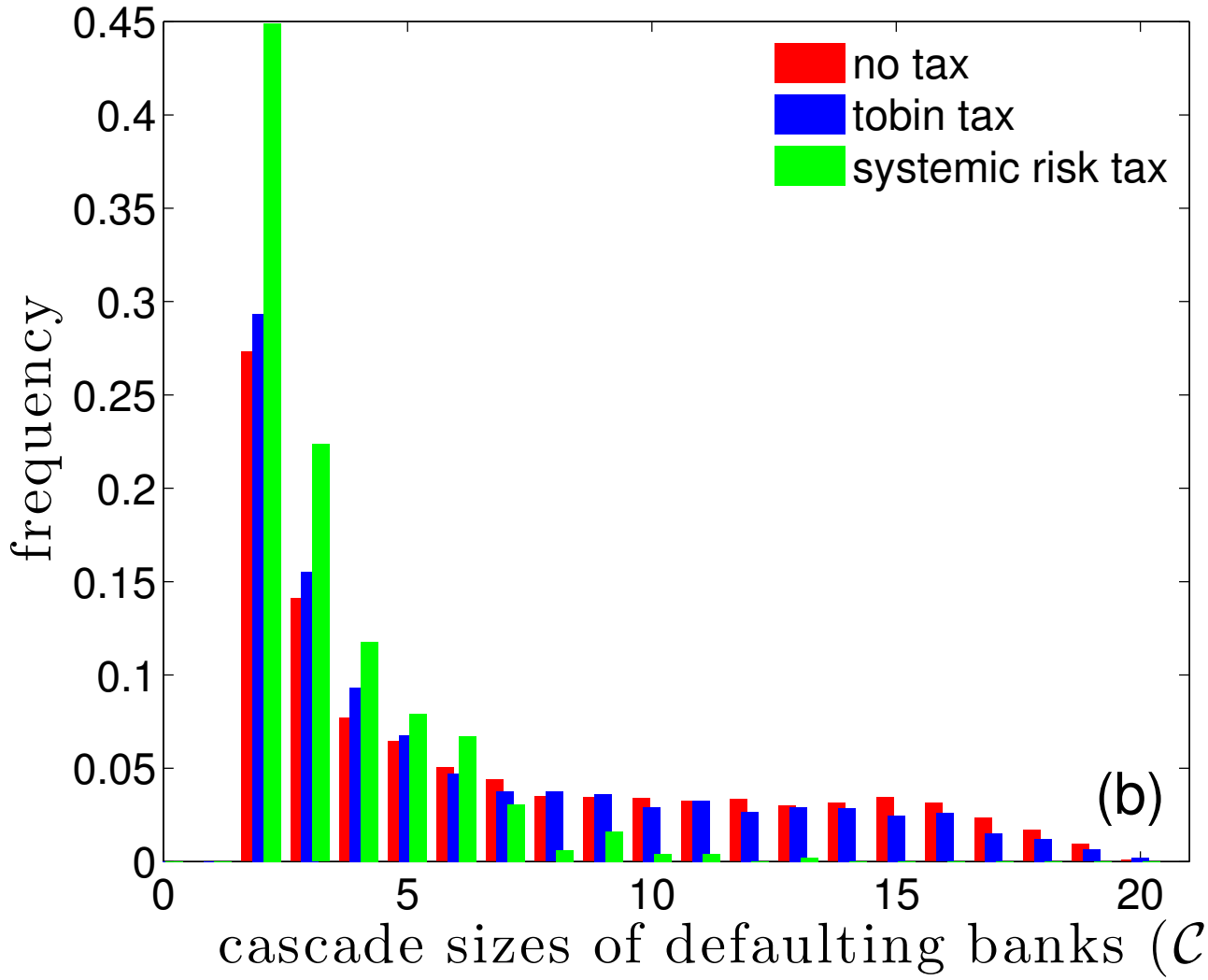


Model results: Distribution of losses

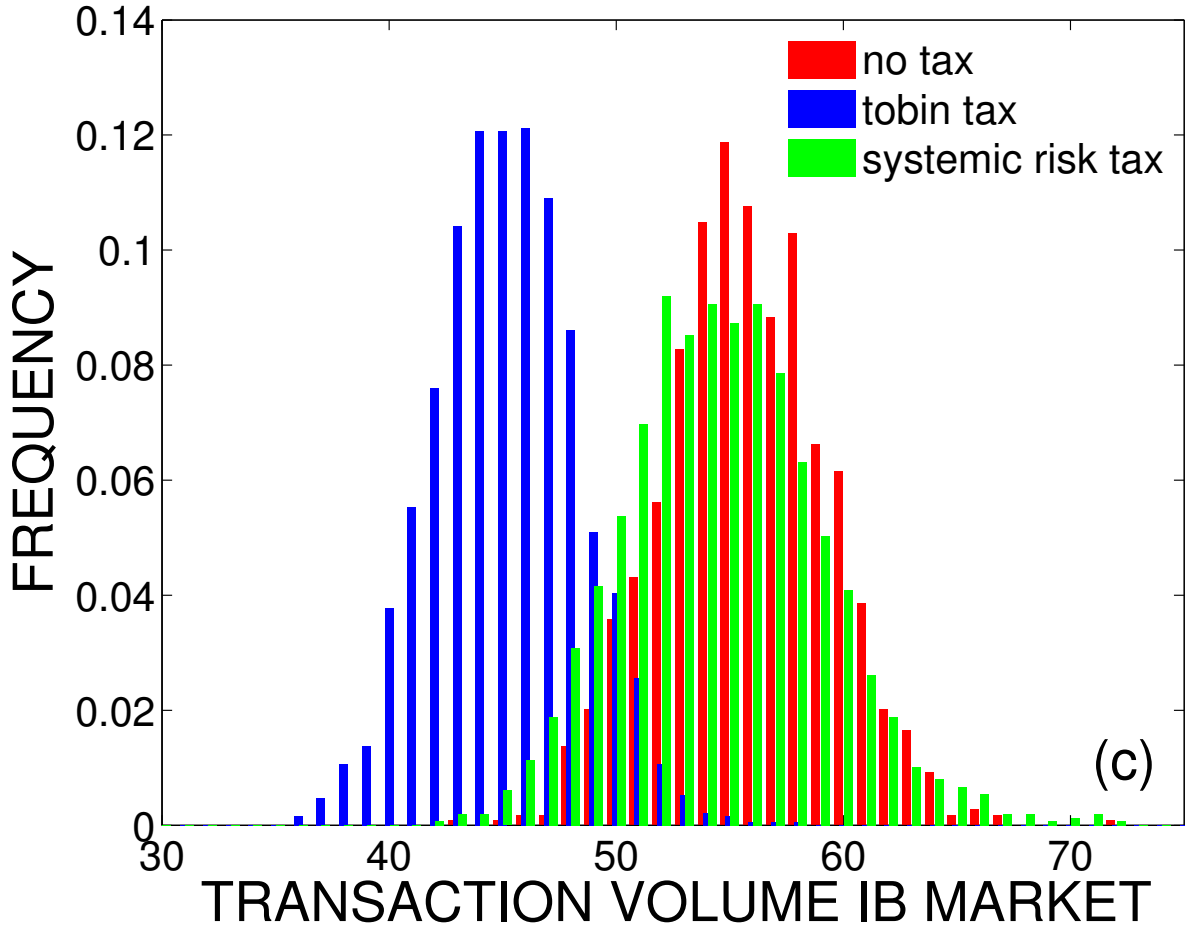


SRT eliminates systemic risk. How?

Model results: Cascading is suppressed



Model results: Credit volume



Tobin tax reduces risk by reducing credit volume

Implementation in reality

- Bank i requests loan of size L_{ij} from bank j
- Bank j provides loan for interest $I(L_{ij})$
- Central Bank computes SRT(L_{ij}) for transaction
- Cost for loan with bank j: $I(L_{ij})$+SRT(L_{ij})
- Bank i asks other bank k for same transaction $L_{ik} = L_{ij}$
- Costs for loan with bank k: $I(L_{ik})$+SRT(L_{ik})
- Bank i choses transaction partner for which costs are minimal

Challenges – what could be wrong ?

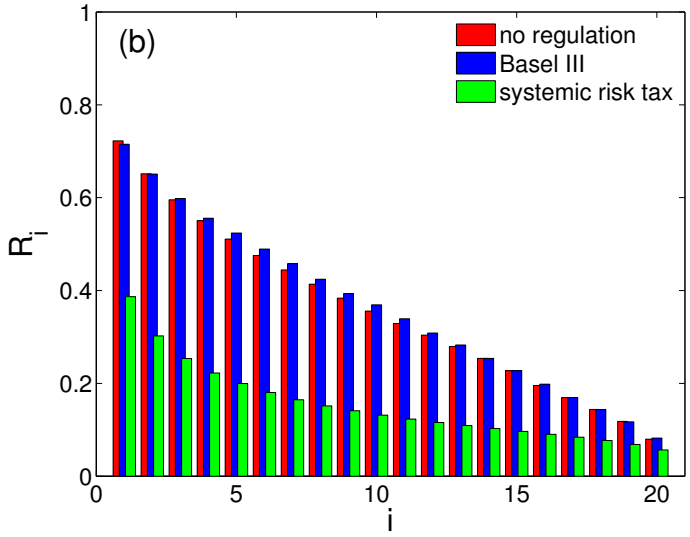
- **SRT is pro-cyclical** – feedback: SRT hits most risky banks hardest. Needed: ramp-up phase. Once system is in low-risk equilibrium, there are practically no pro-cyclical effects

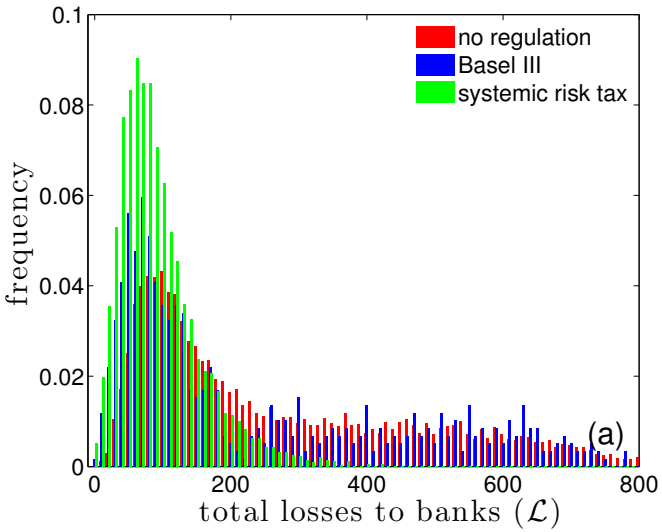
- **SRT is useless if not all countries participate** – arbitrage possibilities for non-participating countries – same as for any transaction tax

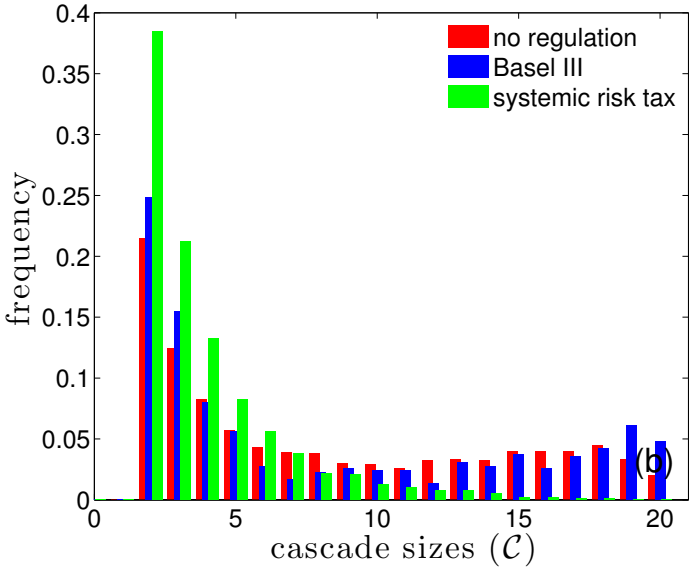
- **Basel III takes care of Systemic Risk?**

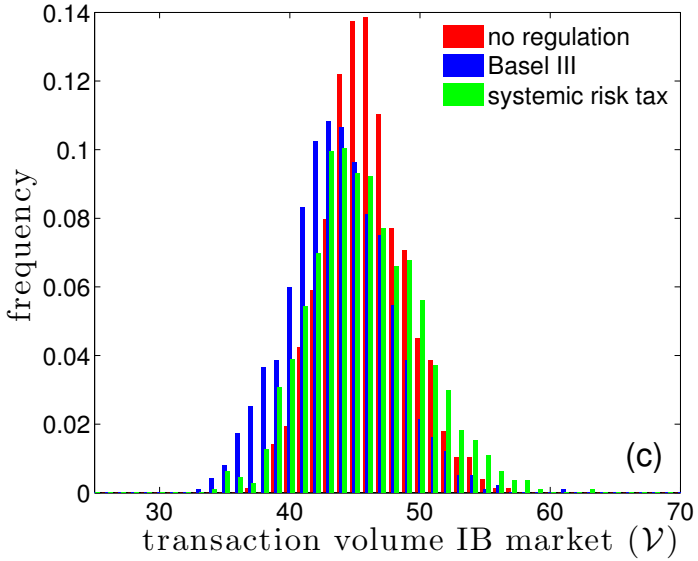
- **the interbank network is not the relevant one** – role of derivatives, mutual cross-holdings, overlapping pfs, etc. $\rightarrow$ apply SRT to other multiplex layers

Basel III is does not reduce SR !



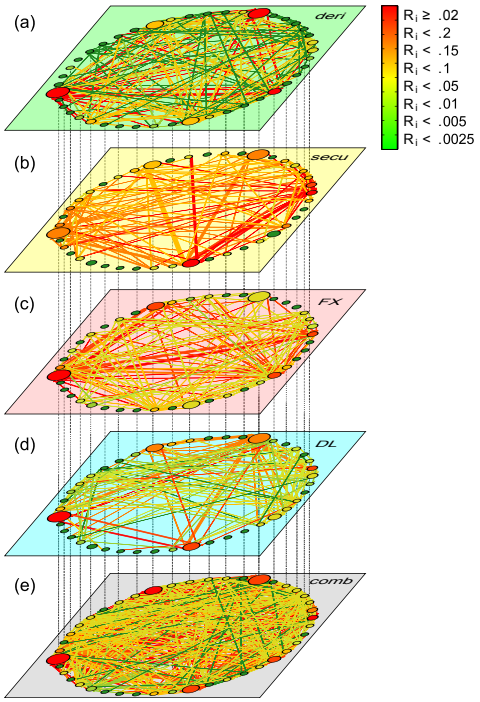






Part III: Financial multiplex networks

Systemic risk multiplex of Mexico Sep 30 2013



layer 1: derivatives network

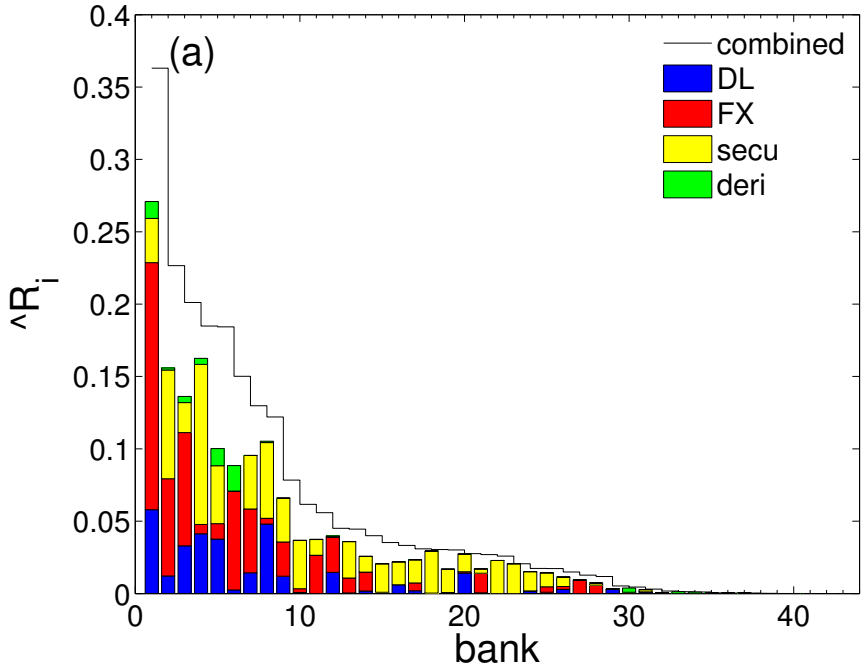
layer 2: network of cross holdings

layer 3: foreign exchange exposures

layer 4: network of deposits and loans

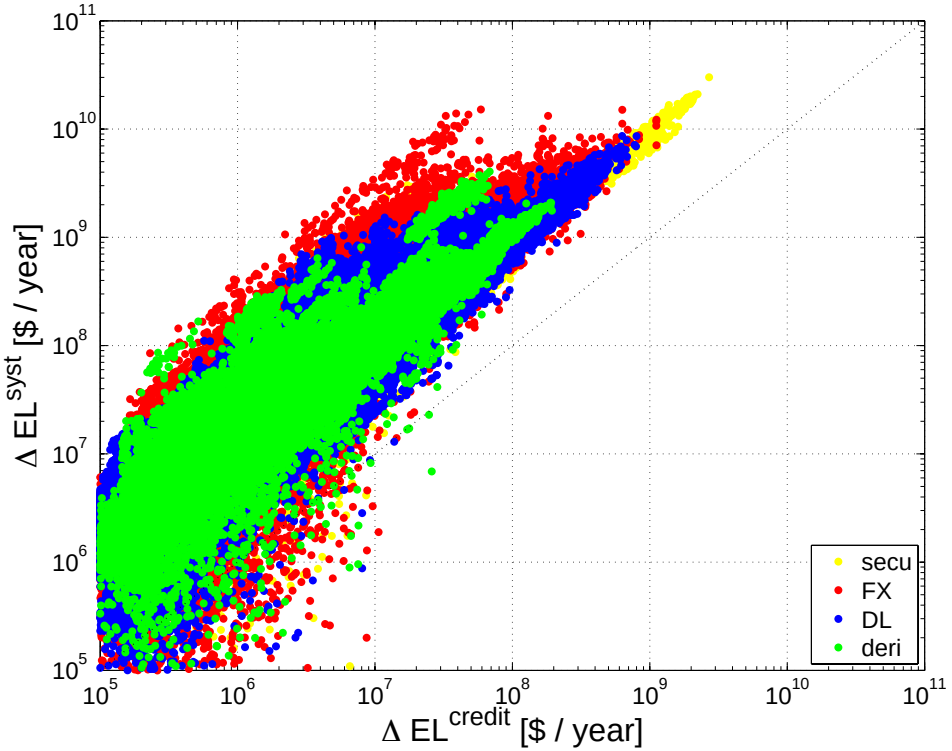
layer 5: combined exposures

Risk profile in the various layers



systemic risk profile for different layers
DebtRank $\hat{R}_i^{\alpha}$ stacked for banks. Jan 2, 2007 – May 30, 2013

Expected systemic losses for every transaction



$\Delta EL^{\text{syst}} > \Delta EL^{\text{credit}} \rightarrow$ defaults **do not affect lender only** but involves third parties (all exposures 2007–2013)

Conclusions

- systemic risk is a network property – endogenously created
- can be measured for each institution / transaction: DebtRank
- can be eliminated by SRT; networks don't allow for cascading
- SRT should **not be payed!** – evasion re-structures networks
- SRT does not reduce credit volume; re-ordering transactions
- Basel III as planned does not work – 3 fold works – costly
- SR requires a multiplex network framework
- Expected Systemic Loss Index: compare countries, over time
- SR tax is technically feasible

Mexican data collaborators

Sebastian Poledna
Peter Klimek
Serafin Martinez-Jamarillo
Jose-Luis Molina Balboa
Marco van der Leij

Alternatives to systemic risk tax

- Markose: taxes banks – not transactions – according to eigenvalue centrality

Problem 1 eigenvector is not economically reasonable number

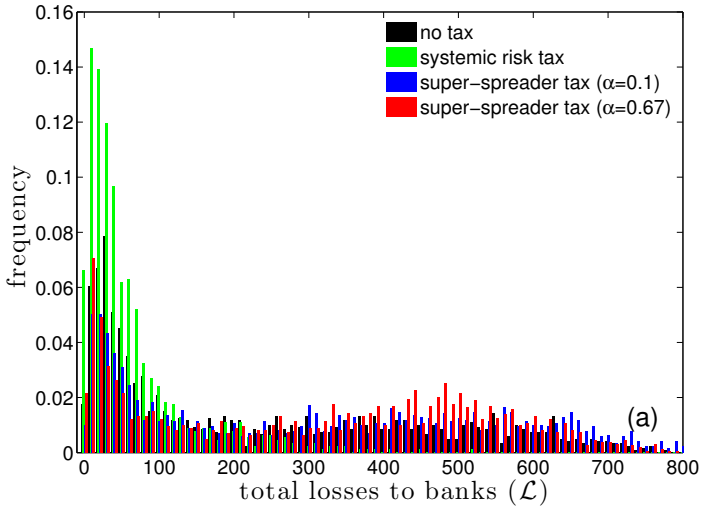
Problem 2 blind to cycles in contract networks

Problem 3 absurd size (up to 30% of capital)

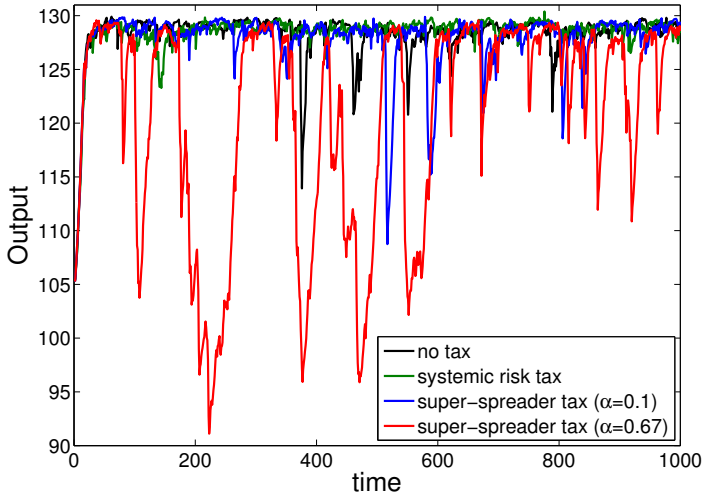
- Tax size: misses small SR institutions, SR improvement at tremendous economic cost

Markose proposal in macro-financial ABM

Losses



Output (GDP)



	No tax	SRT	SST (α=0.1)	SST (α=0.67)
Output	128.458 ± 1.792	128.382 ± 2.038	127.506 ± 3.278	**106.877 ± 20.706**
Unemployment	0.0017 ± 0.0102	0.0020 ± 0.0121	0.0059 ± 0.0204	**0.1520 ± 0.1533**
Credits (firms)	128.174 ± 18.990	121.435 ± 17.303	120.193 ± 19.397	**87.943 ± 29.958**
Interest (firms)	0.0238 ± 0.0015	0.0243 ± 0.0016	0.0241 ± 0.0017	**0.0248 ± 0.0023**

Statistical measures

- CoVAR: descriptive – not predictive!
- SES, SRISK: related to leverage and size
- DIP: market based – markets do not see NW-based SR

pro data publicly available, easy to implement

contra 'conditional' hard to define without knowledge of networks, descriptive, non-predictive