Management of systemic risk

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What is a Complex System?
Co-evolving multiplex network

- Multiplex network, $M_{i,j}^{\alpha}(t)$
- 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 → 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 → 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

→ role of regulator: manage systemic risk
→ 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 → 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
→ page is important if many important pages point to it
→ number for importance → PageRank
page is **important** if many **important** pages point to it

source Wikipedia cc-license
institutions. Risky if institutions lend to it
Systemic risk factor — DebtRank $\mathcal{R}$

... 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

note: size is not proportional to systemic risk
note: core-periphery structure
Systemic risk profile

Austria

![Bar chart showing systemic risk factors for banks in Austria](chart.png)
Systemic risk profile

Mexico*

*with Serafin Martinez-Jaramillo and his team at Banco de Mexico, 2014
Daily assessment of systemic risk is possible

Mexico

Graph showing the systemic risk of all banks over time for Mexico.
Systemic risk $\rightarrow$ expected systemic loss

Expected economic loss for bank $i$ (stress testing)

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

Expected systemic loss of bank $j = p_{default}(j) \cdot \text{DebtRank}(j)$

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

→ rational decision on bailouts

• allows to compare countries

• allows to compare situation of country over time

→ 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? → increase of expected syst. loss
- ergo: restrict borrowing from those with high DebtRank

→ **tax those transactions** that increase systemic risk
Systemic risk tax

• tax transactions according to their systemic risk contribution

→ agents look for deals with agents with low systemic risk
→ liability networks re-arrange → 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

→ new equilibrium where systemic risk is distributed evenly across the network (cascading minimal)

→ self-organized critical
To test efficacy of tax: Crisis Macro-Financial Simulator (schematic)
The agents

- **firms**: ask bank for loans: random size, maturity \( \tau \), \( r^f_{\text{loan}} \)
  - firms sell products to households: realise profit/loss
  - if surplus → deposit it bank accounts, for \( r^f_{\text{deposit}} \)
  - firms are bankrupt if insolvent, or capital is below threshold
  - if firm is bankrupt, bank writes off outstanding loans

- **banks** try to provide firm-loans. If they do not have enough
  - approach other banks for interbank loan at interest rate \( r^\text{ib} \)
  - bankrupt if insolvent or equity capital below zero
  - 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 (≈ 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

![Graphs showing systemic risk factors for Austria and a model with different tax scenarios.](image-url)
Model results: Systemic risk of individual loans

Austria

Model

LOAN SIZE
SYST. RISK INCREASE

SYST. RISK INCREASE
LOAN SIZE

no tax
tobin tax
systemic risk tax
Model results: Distribution of losses

SRT eliminates systemic risk. How?
Model results: Cascading is suppressed

![Graph showing cascade sizes of defaulting banks with different taxes applied: no tax, Tobin tax, systemic risk tax. The x-axis represents cascade sizes of defaulting banks (C), and the y-axis represents frequency. The graph uses different colors to differentiate between the tax categories: red for no tax, blue for Tobin tax, and green for systemic risk tax.](image)
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 $i$ chooses 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. → apply SRT to other multiplex layers
Basel III is does not reduce SR!

(a) Frequency of total losses to banks ($L$)

(b) Frequency of cascade sizes ($C$)

(c) Frequency of transaction volume IB market ($V$)
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

\[ \Delta E L_{syst} > \Delta E L_{credit} \rightarrow \text{defaults do not affect lender only but involves third parties (all exposures 2007–2013)} \]
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**

<table>
<thead>
<tr>
<th></th>
<th>No tax</th>
<th>SRT</th>
<th>SST ($\alpha=0.1$)</th>
<th>SST ($\alpha=0.67$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output</td>
<td>128.458 ± 1.792</td>
<td>128.382 ± 2.038</td>
<td>127.506 ± 3.278</td>
<td>106.877 ± 20.706</td>
</tr>
<tr>
<td>Unemployment</td>
<td>0.0017 ± 0.0102</td>
<td>0.0020 ± 0.0121</td>
<td>0.0059 ± 0.0204</td>
<td>0.1520 ± 0.1533</td>
</tr>
<tr>
<td>Credits (firms)</td>
<td>128.174 ± 18.990</td>
<td>121.435 ± 17.303</td>
<td>120.193 ± 19.397</td>
<td>87.943 ± 29.958</td>
</tr>
<tr>
<td>Interest (firms)</td>
<td>0.0238 ± 0.0015</td>
<td>0.0243 ± 0.0016</td>
<td>0.0241 ± 0.0017</td>
<td>0.0248 ± 0.0023</td>
</tr>
</tbody>
</table>

**Output (GDP)**
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