Computing the impact of central clearing on systemic risk

A Generative Approach

Nikolai Nowaczyk
joint work with Sharyn O'Halloran

QuantMinds 21/11/2024 London

The views expressed in this presentation are those of the author alone.

mail@nikno.de
https://uk.linkedin.com/in/niknow
https://github.com/niknow

Content

The 07/08 Financial Crisis

- The 07/08 crisis challenged the fundamental assumption that **banks cannot fail**.
- Various big **regulatory changes** have been implemented such as collateralization and **central clearing**.

The 07/08 Financial Crisis

- The 07/08 crisis challenged the fundamental assumption that **banks cannot fail**.
- Various big **regulatory changes** have been implemented such as collateralization and **central clearing**.
- **Are we any safer today?**

The 07/08 Financial Crisis

- The 07/08 crisis challenged the fundamental assumption that **banks cannot fail**.
- Various big **regulatory changes** have been implemented such as collateralization and **central clearing**.
- **Are we any safer today?**
- **How do we know that?**

Empirical Data Analysis

- Now that the regulation has been implemented, an obvious approach to its evaluation is to **study empirical data ex-post**, e.g.:

Empirical Data Analysis

- Now that the regulation has been implemented, an obvious approach to its evaluation is to **study empirical data ex-post**, e.g.:
- S. Ghamami and P. Glasserman. *Does OTC Derivatives Reform Incentivize Central Clearing?*. Journal of Financial Intermediation 32 (2017), pp. 76–87.
  - “Our dataset has reports from **five** of the ten largest U.S. banks ... We also have data on initial margin and guarantee fund contributions made by each bank **to 17 CCPs.**”
  - uses a macro-economic model
  - calibrated to empirical data

Evaluating the Impact of a Regulation

by empirical means

has the big

- **upside** that this is obviously of very **high practical relevance**.
- **downside** that empirical data is **invariably confounded** by many other factors.

by a generative approach

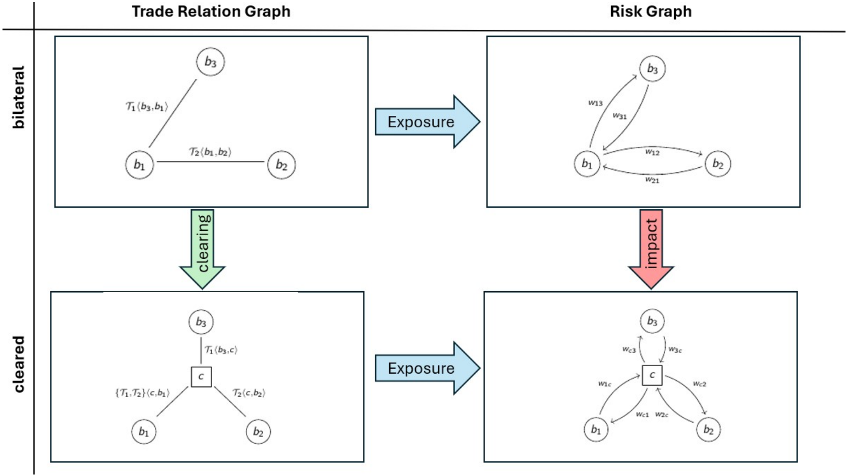
allows us to

- **compute the isolated impact** of a regulation before implementation.
- **model trade and risk relations** in a **clean graph model bridging the gap** between micro- and macro-economics.
- **illustrate** key drivers of impact in stylized case studies.
- **generate entire financial systems and compare impact**.

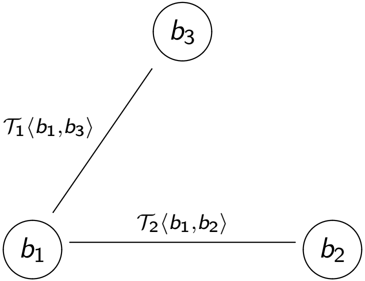
Content

Content

Key Idea of Graph Model

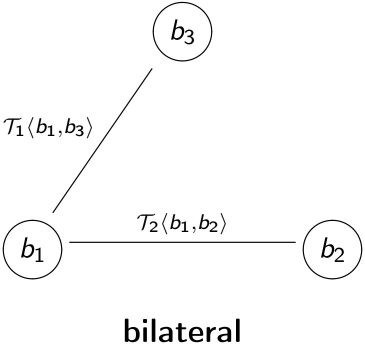


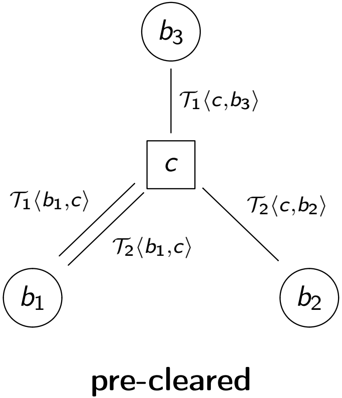
1. Pre-clearing



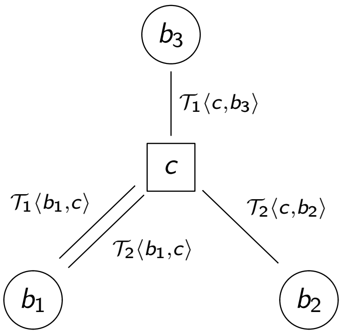
bilateral

1. Pre-clearing



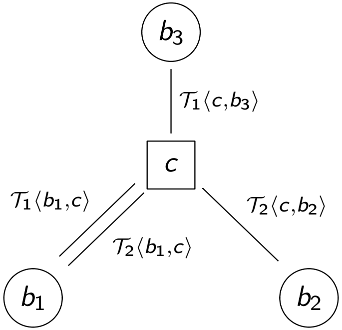


2. Compression

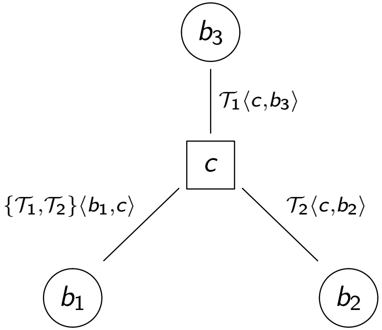


pre-cleared

2. Compression



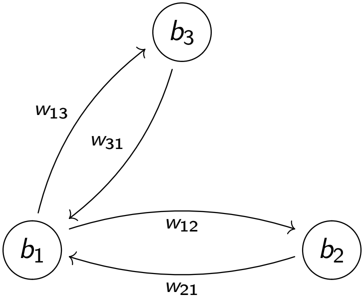
pre-cleared



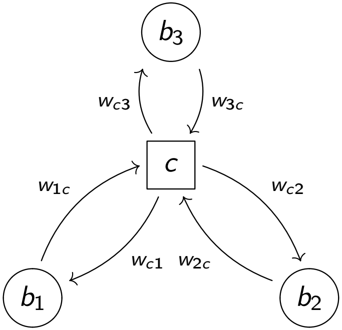
cleared

Content

Impact on Risk Graph



bilateral



cleared

Impact on Total Systemic Risk

#	operation	preserves netting	preserves adjacency	effect on system exposure
1.	pre-clearing	✓	✗	⬆·2
2.	compression	✗	✓	⬇·[0, 1]

- **Total effect on total levels of exposure** is interplay between **competing effects** of pre-clearing and compression.
- Hence, **total effect is not obvious a priori**.

Lower and upper bounds

Theorem

Let $\mathrm{FS}_{\mathrm{bil}}$ *be a bilateral financial system and* $\mathrm{FS}_{\mathrm{clear}}$ *be the cleared system with a single CCP. Let*

- w_{bil} *be the total sum of all exposures in the bilateral system and*
- w_{clear} *be the total sum of all exposures in the cleared.*

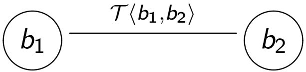
Then the cleared system has at most twice as much as the bilateral system:

$$0 \leq w_{\mathrm{clear}} \leq 2w_{\mathrm{bil}}$$

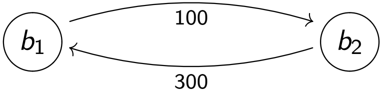
Content

Case: Two Banks: Double Exposure

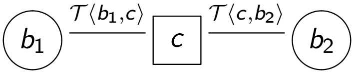
Trade Relation Graph FS (bilateral)



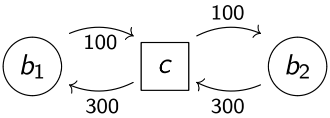
Risk Graph RG (bilateral)



Trade Relation Graph $\overline{\text{FS}}$ (cleared)



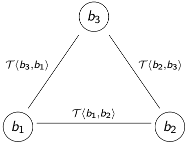
Risk Graph $\overline{\text{RG}}$ (cleared)



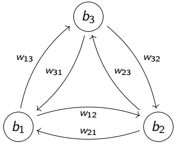
$$w_{\text{clear}} = 2w_{\text{bil}}$$

Case: Three Banks with a daisy chain: No Exposure

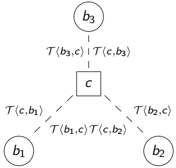
Trade Relation Graph FS (bilateral)



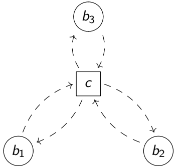
Risk Graph RG (bilateral)



Trade Relation Graph $\overline{\text{FS}}$ (cleared)



Risk Graph $\overline{\text{RG}}$ (cleared)



$$w_{\text{clear}} = 0$$

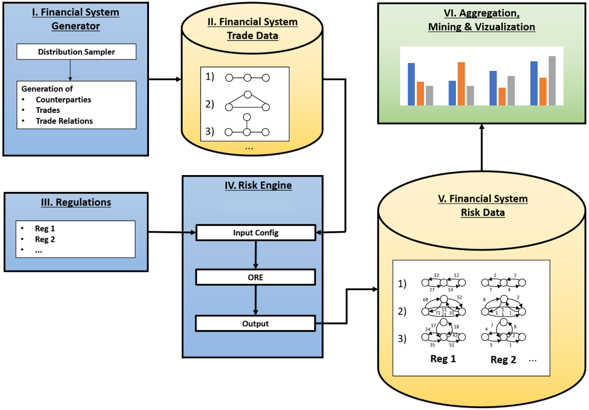
Content

Content

The case for generative models

- **Real world impact** will be a mix of these stylized situations.
- Use of **real trade data is tempting** methodologically, but **impossible to carry out in practice**.
- Should the question whether or not a regulation has the desired impact **really depend on the precise trade data** as of today?
- **No!** We want the **impact of a regulation** to be **very robust** under many different scenarios (**avoid overfitting** regulation to current market).
- $\Longrightarrow$ Can use a **generative model** to **create synthetic data** of entire financial systems instead.

Generative Model: Impact of Regulation on Systemic Risk

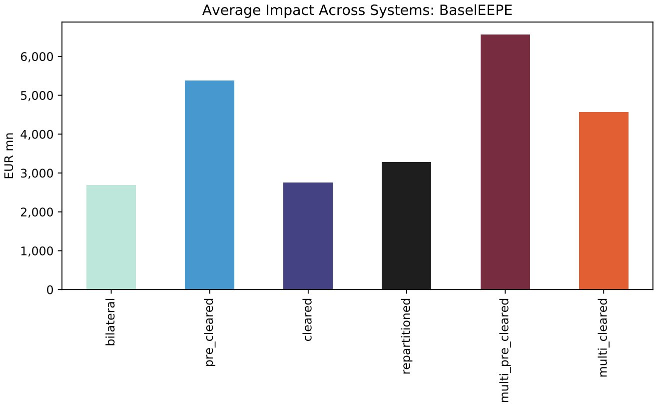


Technology Stack

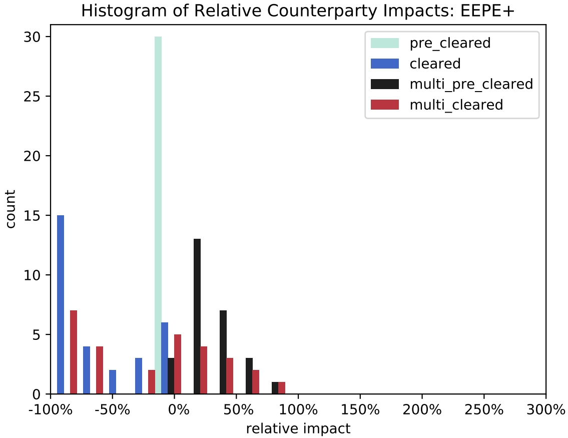
- Python: `lxml`, `numpy`, `networkx`, `pyvizjs`, `bqplot`, `matplotlib` `seaborn`, `panadas`,`json`, `jupyter`
- C++: `boost`, `QuantLib`, `Open Source Risk Engine`

Content

Average Impacts across Systems (EEPE)

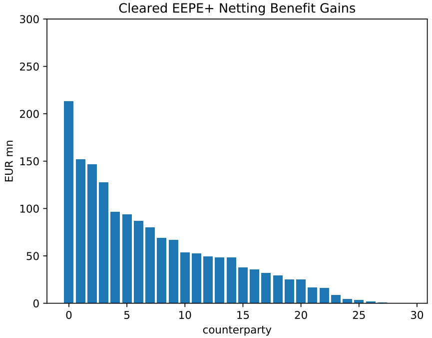


Histogram of Counterparty Impacts (EEPE)

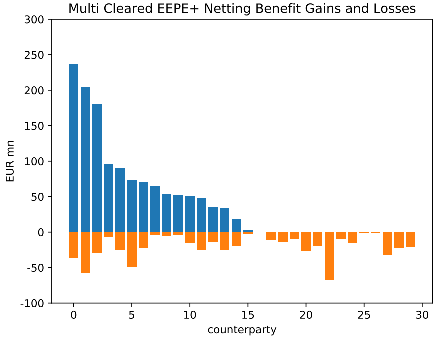


Netting Benefits (EEPE)

Single CCP



Multiple CCPs



Conclusion

- **Simulation case study** based on **generated financial systems confirms qualitative effects** derived from theory and stylized case studies.
- Central clearing through single counterparty reduces exposure, but **total impact of clearing through multiple CCPs is not unambiguously risk reducing**.
- **Results from abstract theory, stylized case studies, generative simulation case study and empirical research are broadly in line.**
- Makes the case for the **use of generative AI in financial regulation** to
  - **gauge impact of a regulation before implementation**,
  - **optimize** existing or future regulation,
  - **understand** impacts on a large scale.

References

Thank you!

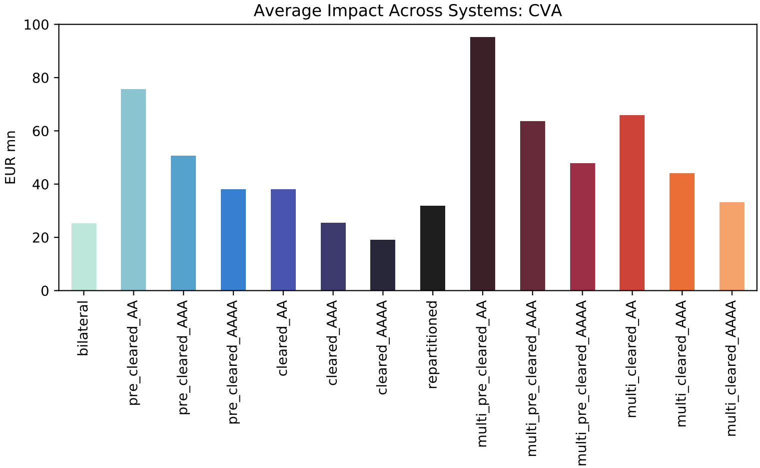
- **Central Clearing:** Nowaczyk, Nikolai. O'Halloran, Sharyn. *Computing the impact of central clearing on systemic risk*. Front. Artif. Intell., 21 February 2024 https://doi.org/10.3389/frai.2024.1138611
- **Collateralization:** O'Halloran, Sharyn; Nowaczyk, Nikolai. *An Artificial Intelligence Approach to Regulating Systemic Risk*. Front. Artif. Intell., 29 May 2019 https://doi.org/10.3389/frai.2019.00007

mail@nikno.de
https://uk.linkedin.com/in/niknow
https://github.com/niknow

Content

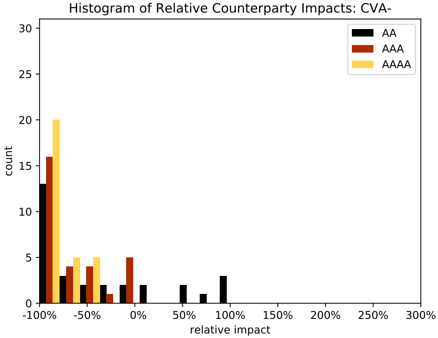
Content

Average Impacts across Systems (CVA)

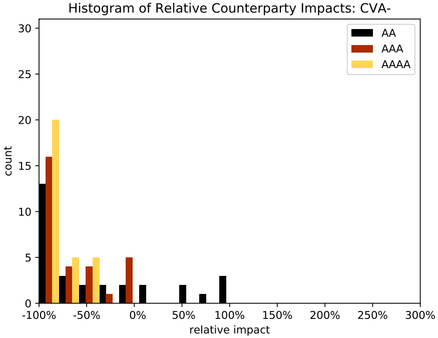


Absolute Impacts per Counterparty in System (CVA)

Single CCP

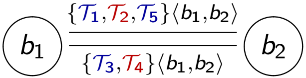


Multiple CCPs



Content

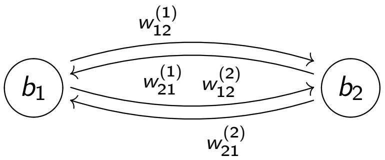
Trade Relation Graph



We model a financial system $\text{FS} = (B, \mathcal{L}, \tau)$ as an undirected *trade relation graph*.

- The nodes B represent the banks.
- The multiset $\mathcal{L}$ of all links $\{b_1, b_2\}$ represents the netting sets of all trade relations between them.
- The portfolio of trades $\tau(\ell)\{\mathcal{T}_1, \mathcal{T}_2, \ldots, \mathcal{T}_n\} < b_1, b_2 >$ between b_1, b_2 is attached to the link $\ell = \{b_1, b_2\}$ and the color coding represents the asset classes of the trades.

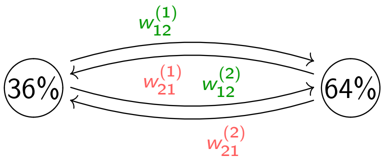
Risk Graph



The *risk graph* $\text{RG} = (B, A, w)$ of a trade relation graph $\text{FS} = (B, T, \tau)$ is a directed graph.

- The nodes B represent the same banks.
- Each undirected trade relation in ℓ is replaced by two arrows in A between the same nodes in opposite directions.
- $w : A \to \mathbb{R}^k$ is a weight function representing the risk induced from the tail to the head of an arrow, e.g. $w = \text{EEPE}$ or $w = \text{CVA}$.

Risk Aggregation



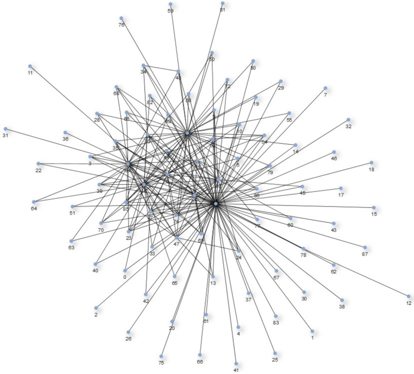
Using a weighted out-/in-degree the information in a *risk graph* $\mathrm{RG} = (B, A, w)$ can be aggregated from the arrows $a \in A$ to the nodes $b \in B$

$$w^{+/-}(b) := \sum_{\substack{a \in A \\ a \text{ starts / ends at v}}} w(a)$$

and expressed as a percentage of the total of the weight $w(\mathrm{RG}) := \sum_{a \in A} w(a)$ via

$$\rho^{+/-}(b) := \frac{w^{+/-}(b)}{w(\mathrm{RG})}.$$

Random Graph Generation



- We start from empirically gained insight that node degree of financial systems is Pareto distributed (core-periphery model).[a]
- Generating random graphs with pre-scribed distribution of the node degrees is a difficult problem in discrete mathematics.
- We just use the `configuration_erase` factory from `networkx` for now.

[a] e.g. Cont. Cont, R., Moussa, A., and Santos, E. B. (2013). *Network structure and systemic risk in banking systems* in Handbook on Systemic Risk, eds J. Fouque, and J. Langsam (Cambridge: Cambridge University Press), 327–368.

Model Choices

#	aspect	in model
1	repartitioning	✓
2	**pre-clearing**	✓
3	**compression**	✓
4	collateral/margining	✗
5	default fund	✗
6	CCP fund	✗
7	non clearing members	✗

- In reality clearing trades does much more than just re-routing them through the CCP.
- We deliberately include only the minimum necessary to study the original idea of central clearing.
- This is to avoid confounding the effects with regulation that could (and sometimes has been) introduced by other means, e.g. collateralization.