Structural changes in the interbank market across the financial crisis from multiple core-periphery analysis

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(Preprint arXiv:1802.05139)

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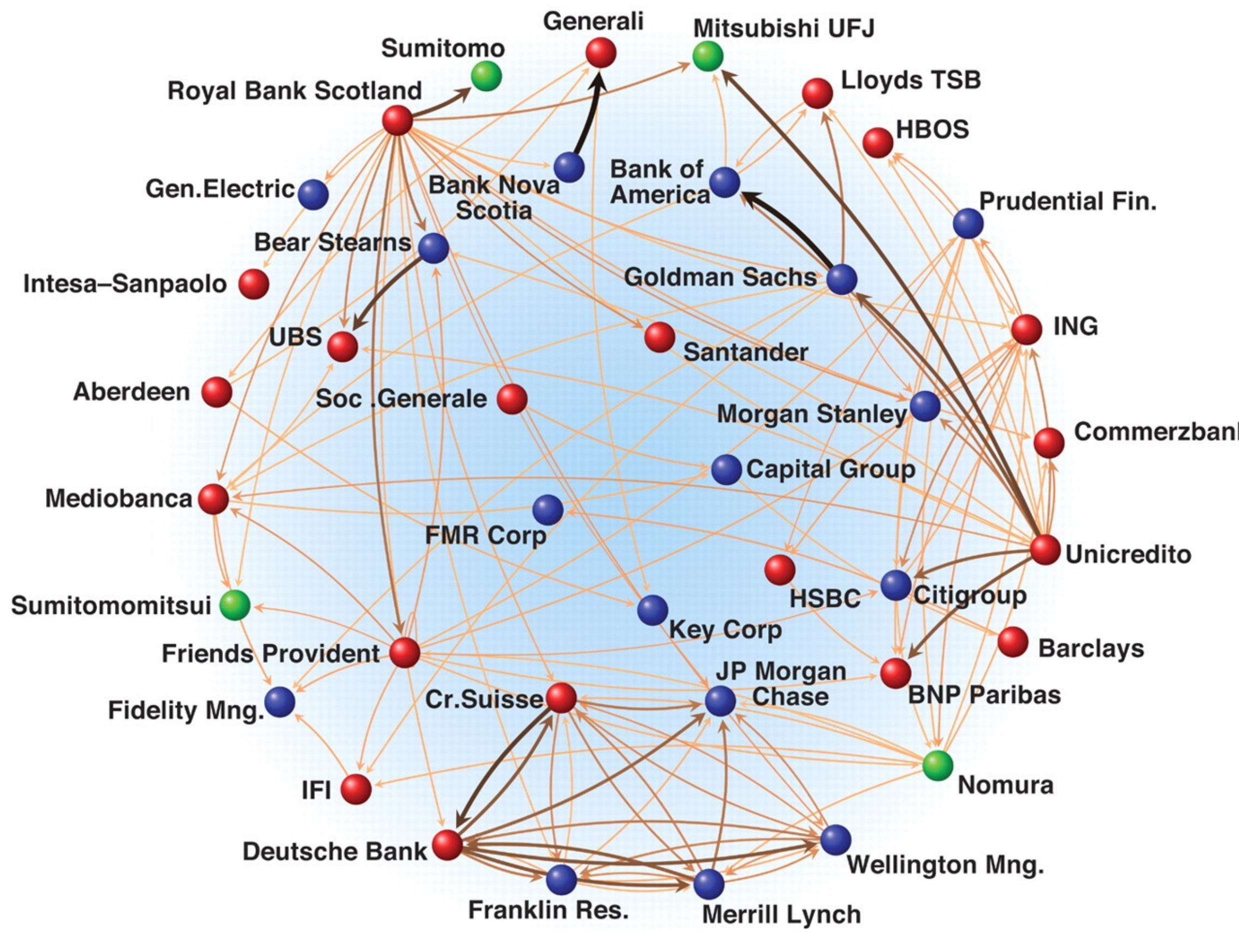
Interbank networks

$5 trillions

per day worldwide



Sample of the international financial network
Credits: ETH Zurich

This figure is taken from Staum, J., Feng, M., & Liu, M. (2016). IIE Transactions, 48(6), 501â€“510.

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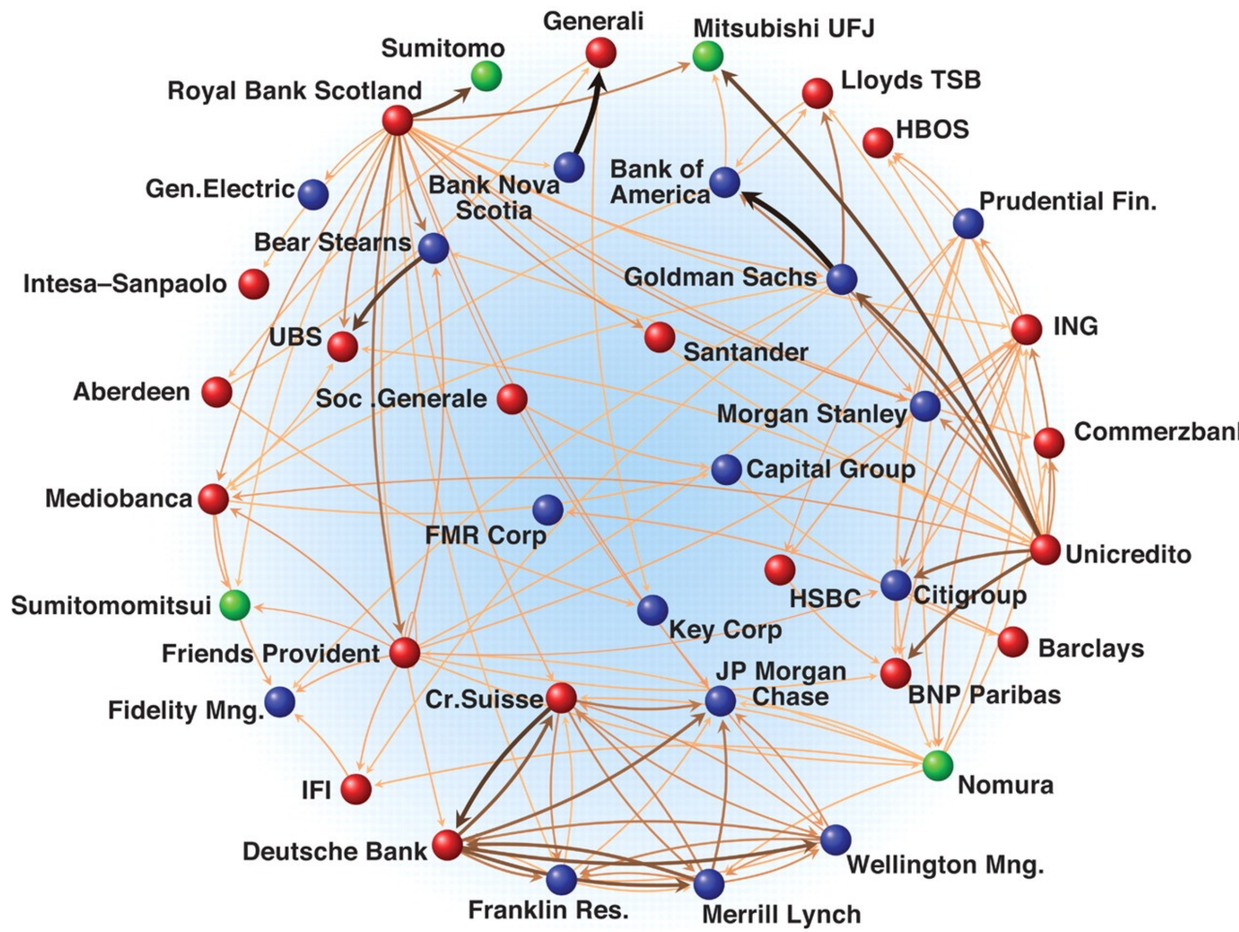

Sample of the international financial network
Credits: ETH Zurich

Interbank networks

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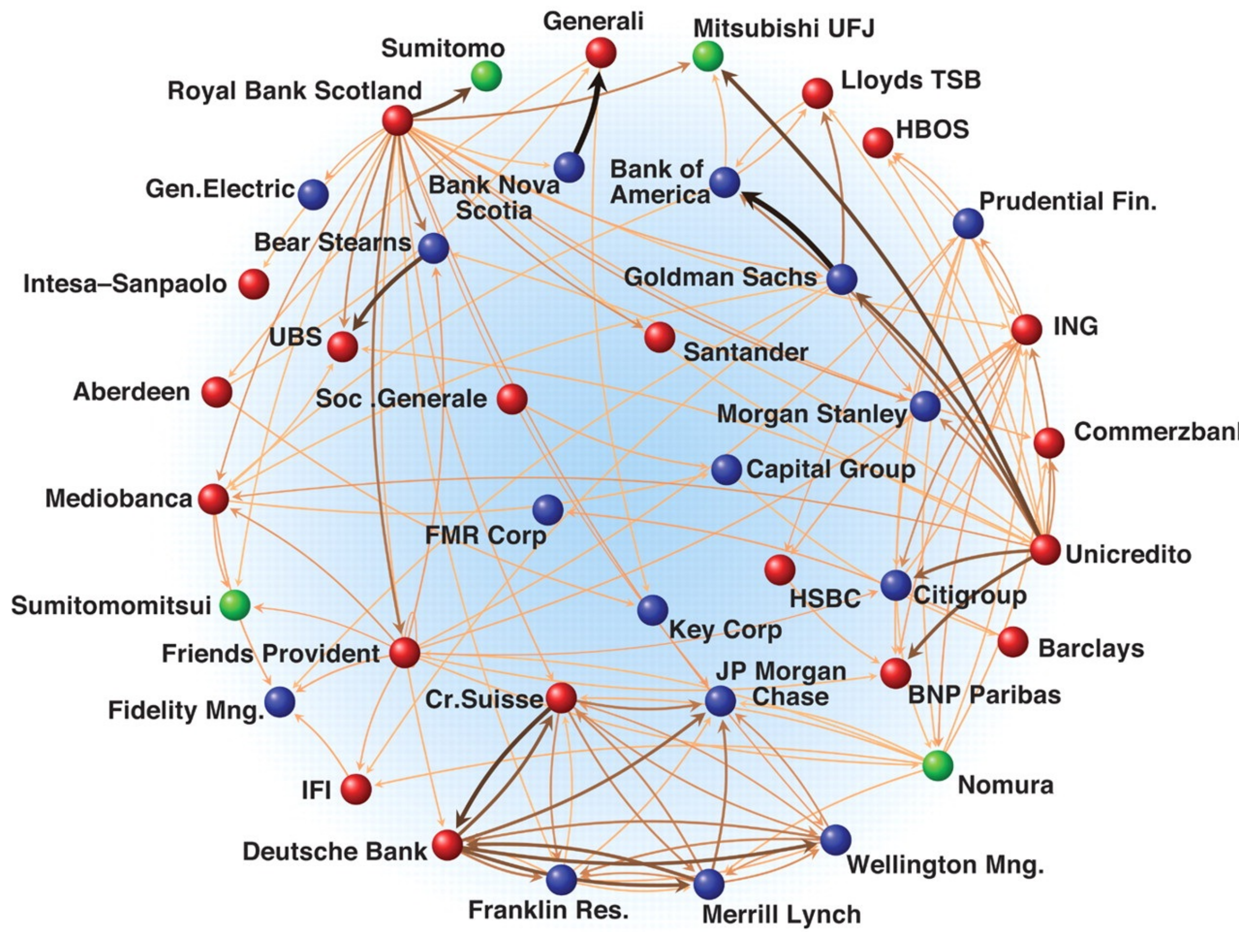
per day worldwide

2 million houses

in Manhattan

1.5 year

of the U.S. budget



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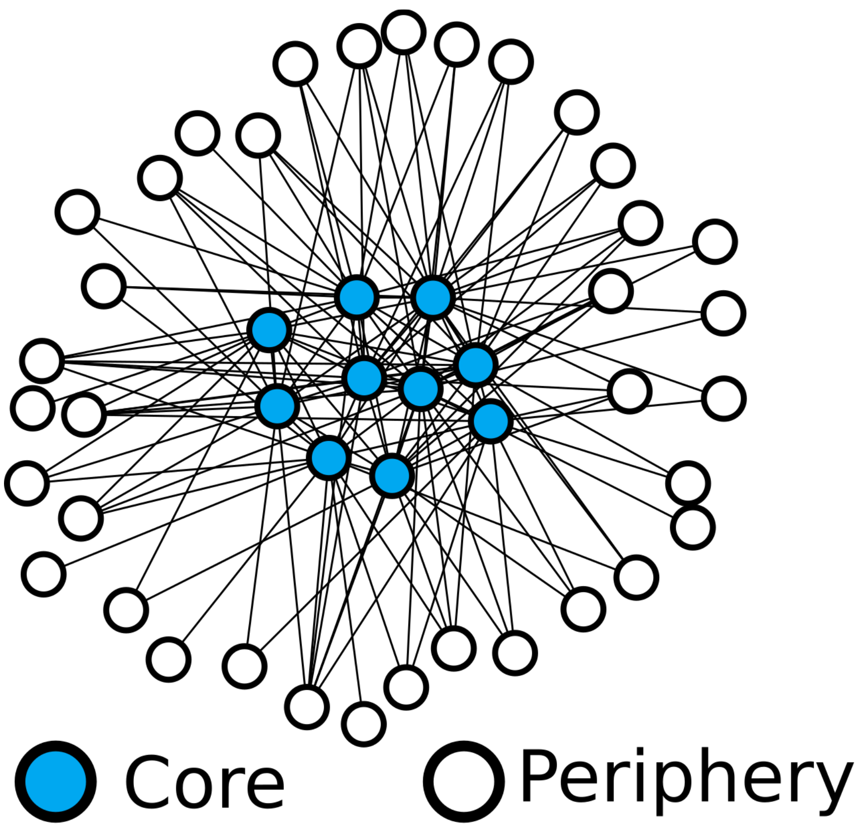
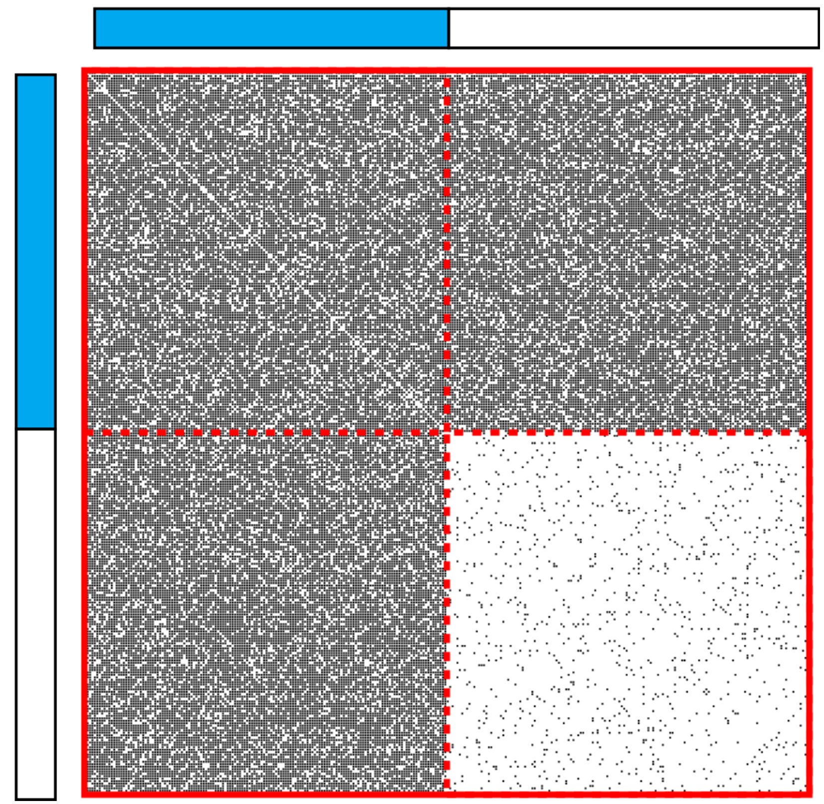
Core-periphery (CP) structure





$$\rho_{\text{core-core}} \geq \rho_{\text{core-periphery}} > \rho_{\text{periphery-periphery}}$$

$\rho_{x,y}$: Fraction of edges between nodes of types x and y.

Is CP structure "a stylized fact"?

Fricke and Lux, 2014

> ... a core-periphery structure could be seen as a new "stylized fact" of modern banking systems.

Manpy supportive studies

Soramaki et al. 2007, Iori et al 2008, Bech andAtalay 2010, Craig and Von Peter 2014, in'tVeld and van Lelyveld 2014, Langfield et al. 2014, Martinez-Jaramillo et al. 2014, Silva et al 2016

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Barucca and Lillo, 2016

> Specifically we find that, taking into account the degree, this interbank network is better described by a bipartite structure, ...

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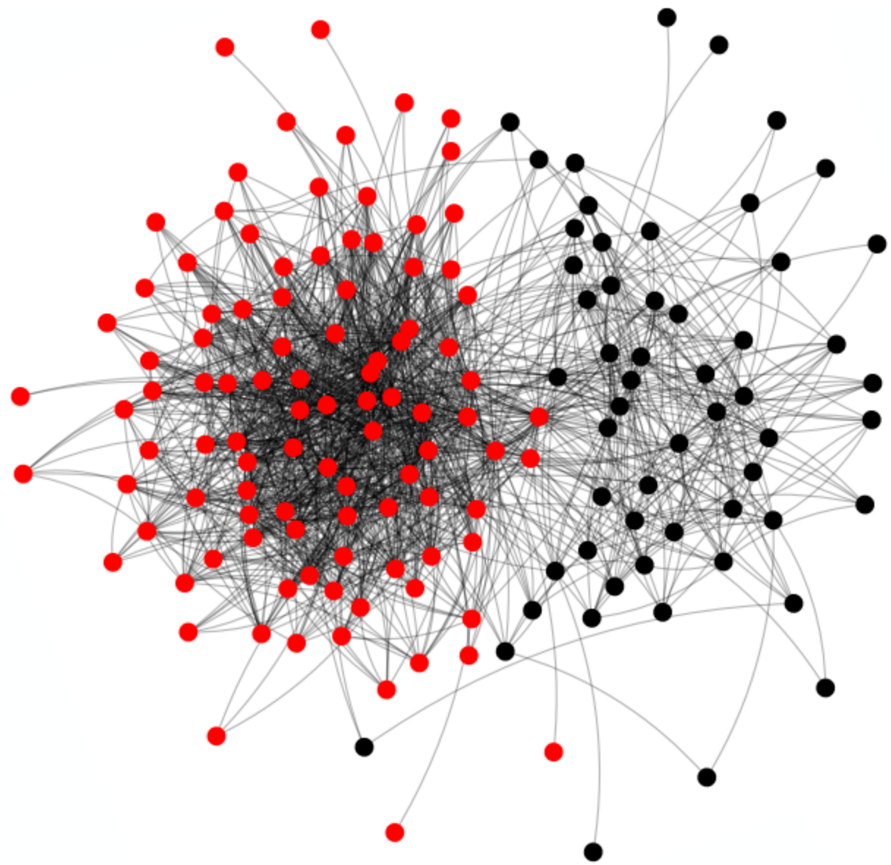
Calling a need for re-checking whether interbank networks are well characterized by CP structure

What we do



June 12, 2007—June 25, 2007

Interbank networks may be better characterized by multiple CP pairs

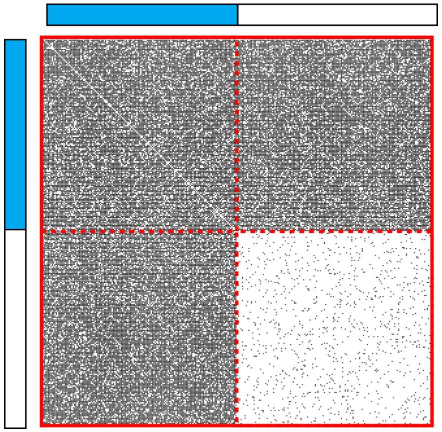
The figure is taken from Caccioli, F., Barucca, P., & Kobayashi, T. (2018), J. Comp. Soc. Sci., 1(1), 81-114.

Two algorithms for CP detection

MINRES algorithm

(Boyd et al., Soc. Netw., 32(2), 125-137, 2010)

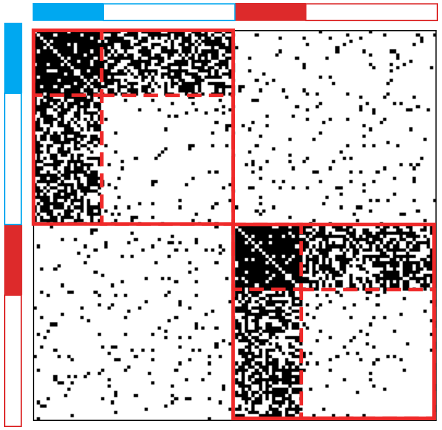
- Find a single CP structure
- Used in previous studies on interbank networks



Kojaku-Masuda algorithm

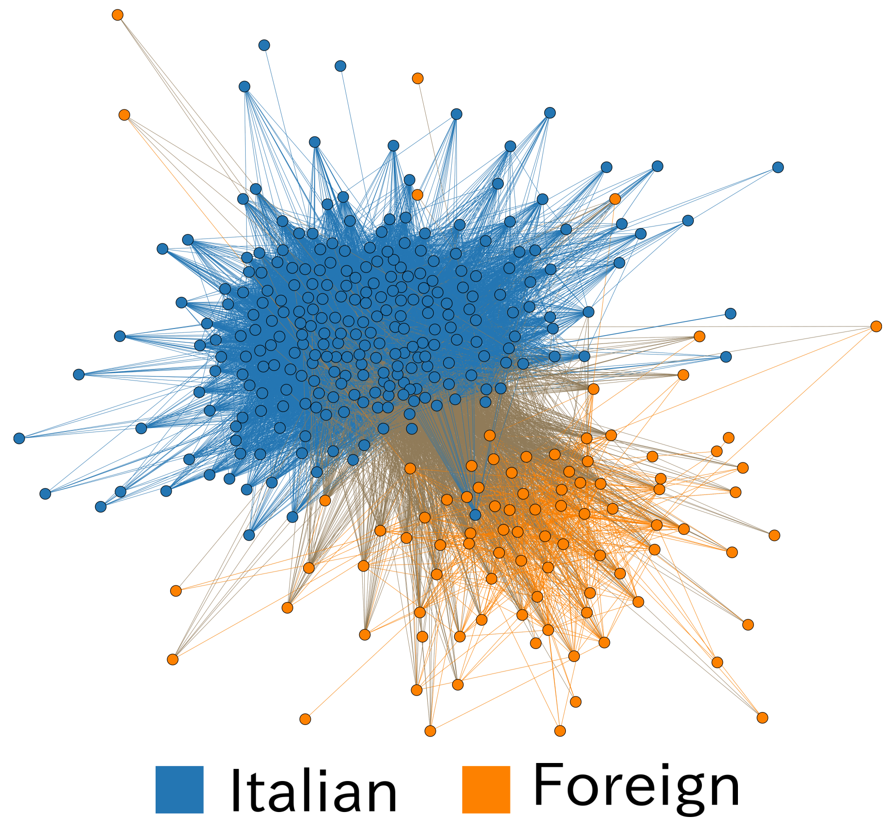
(Kojaku and Masuda, Phys. Rev. E 2017)

- Find multiple CP pairs
- Automatically determine # of CP pairs
- Buit-in significance test



Data: e-MID

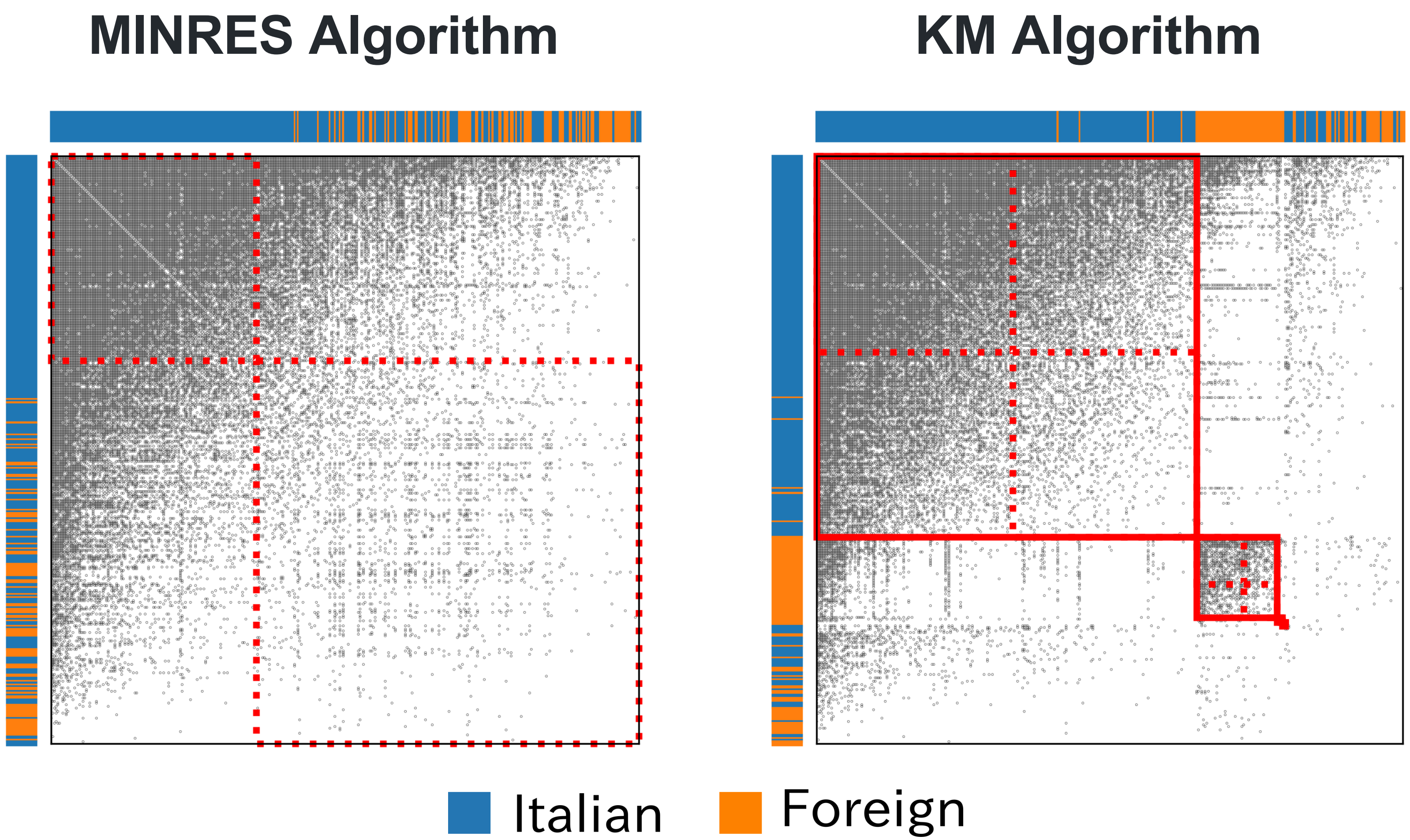
- Covers the Italian market and a large share of the entire market in the Euro area
- Contains all transaction records made in eMID.
- 350 banks in total



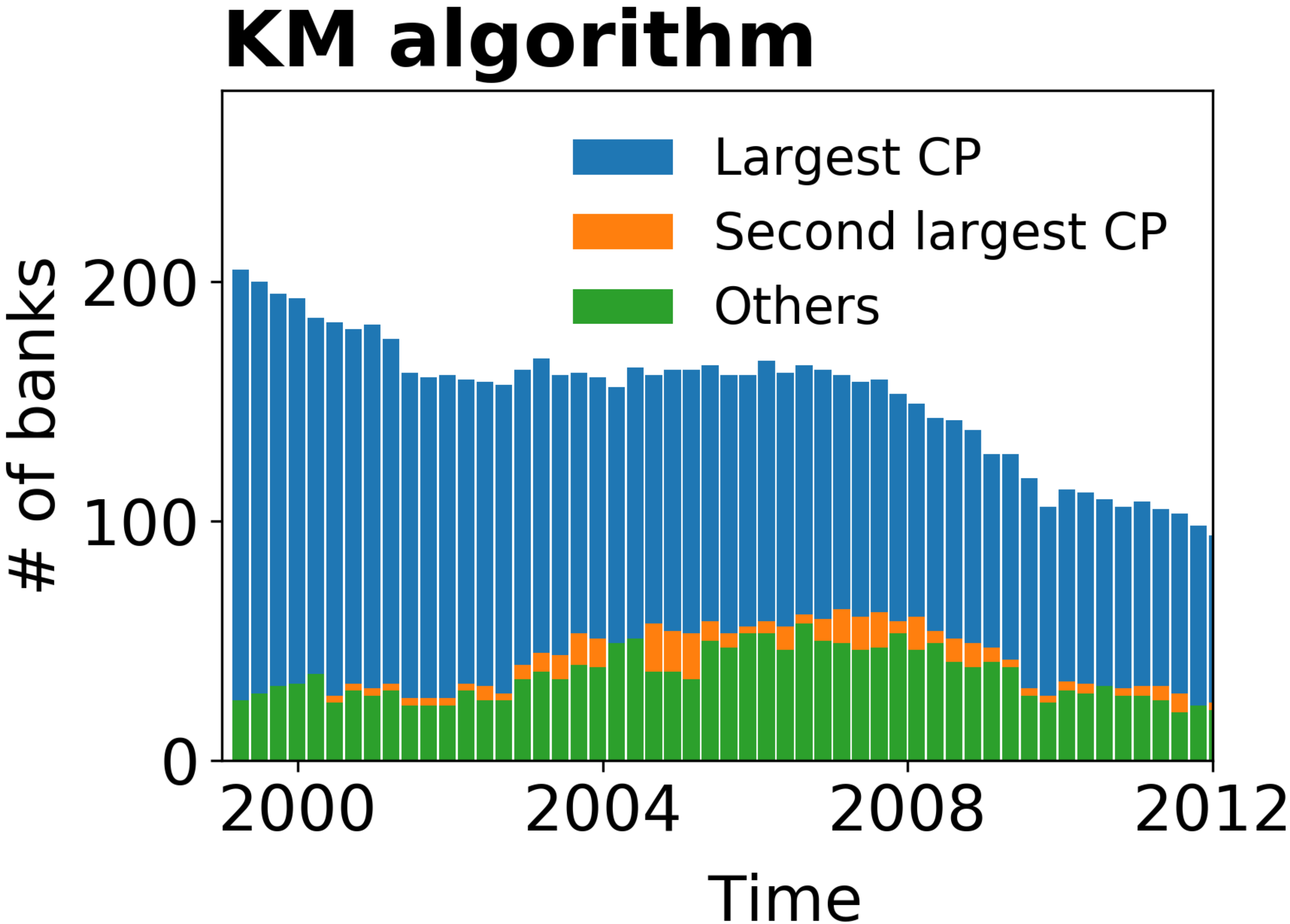
We analyse unweighted and undirected version of the e-MID network.

Results

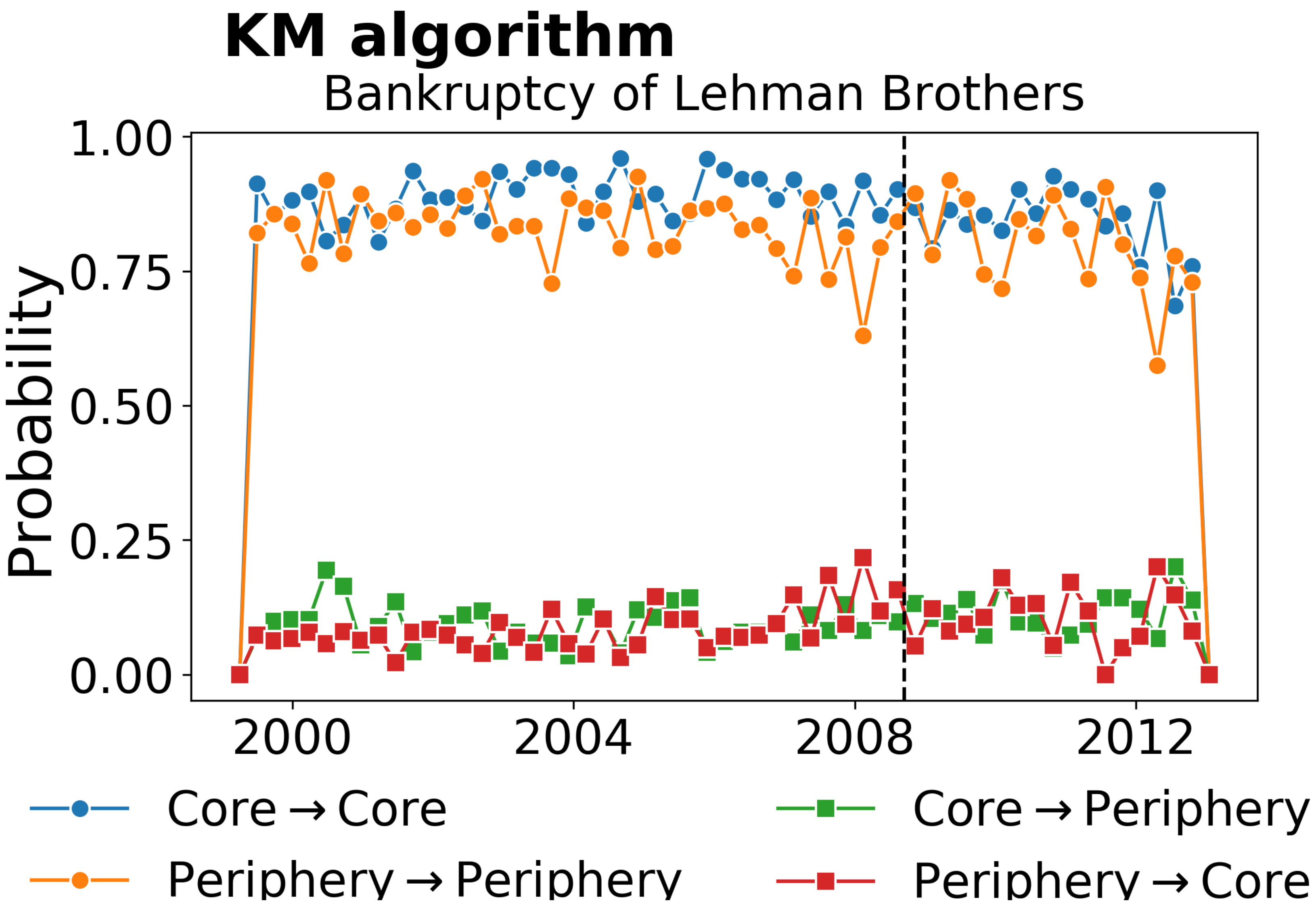
Static networks



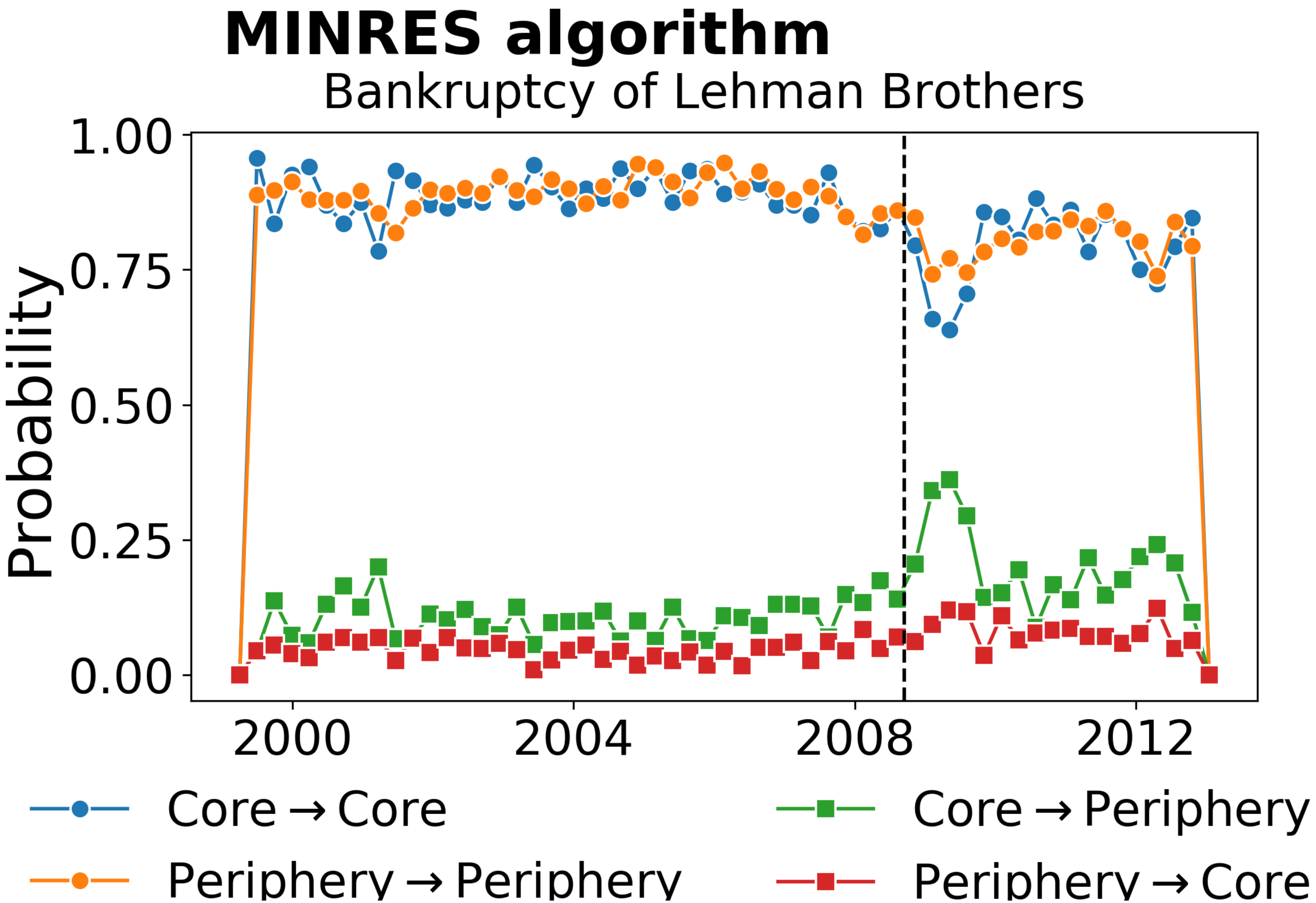
Size of CP pairs



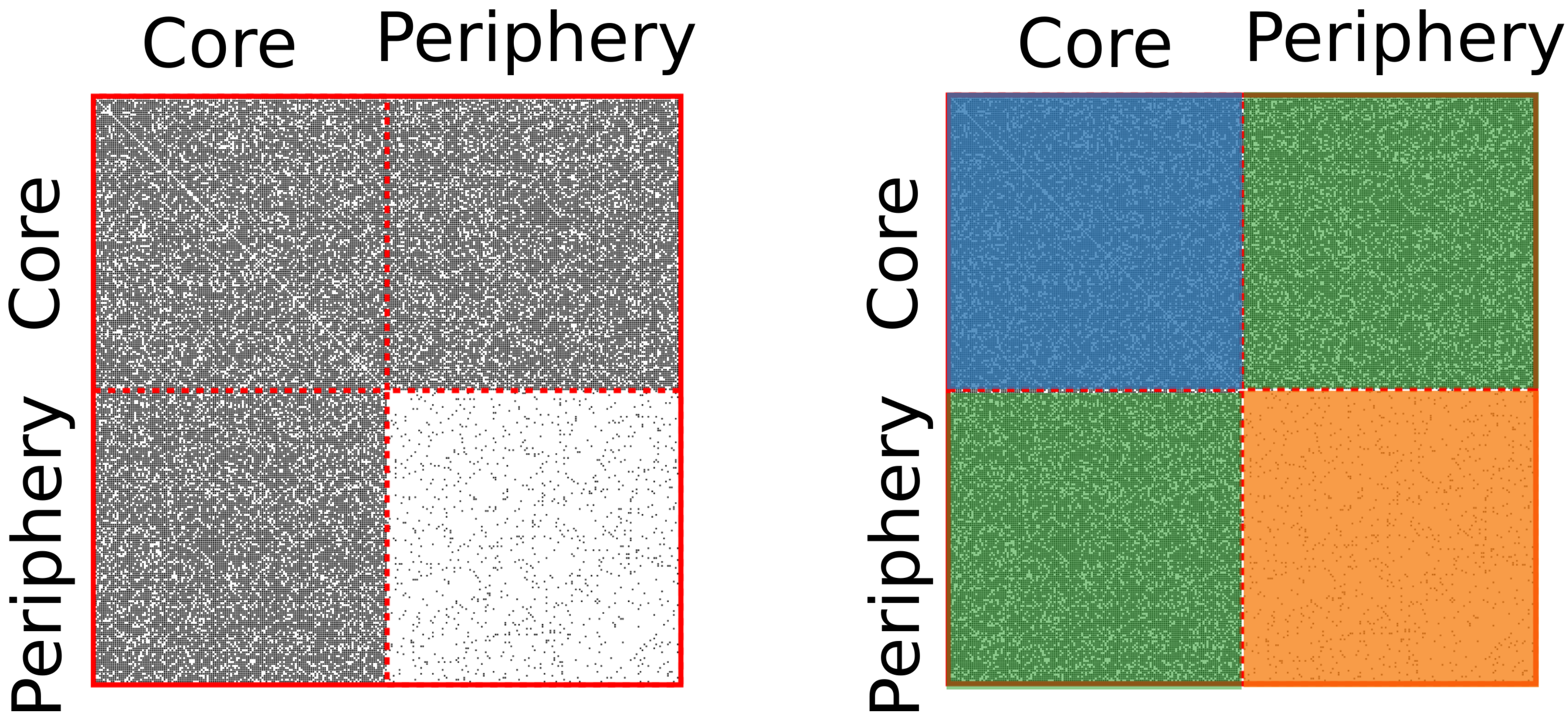
Transition of bank's roles (1)



Transition of bank's roles (2)

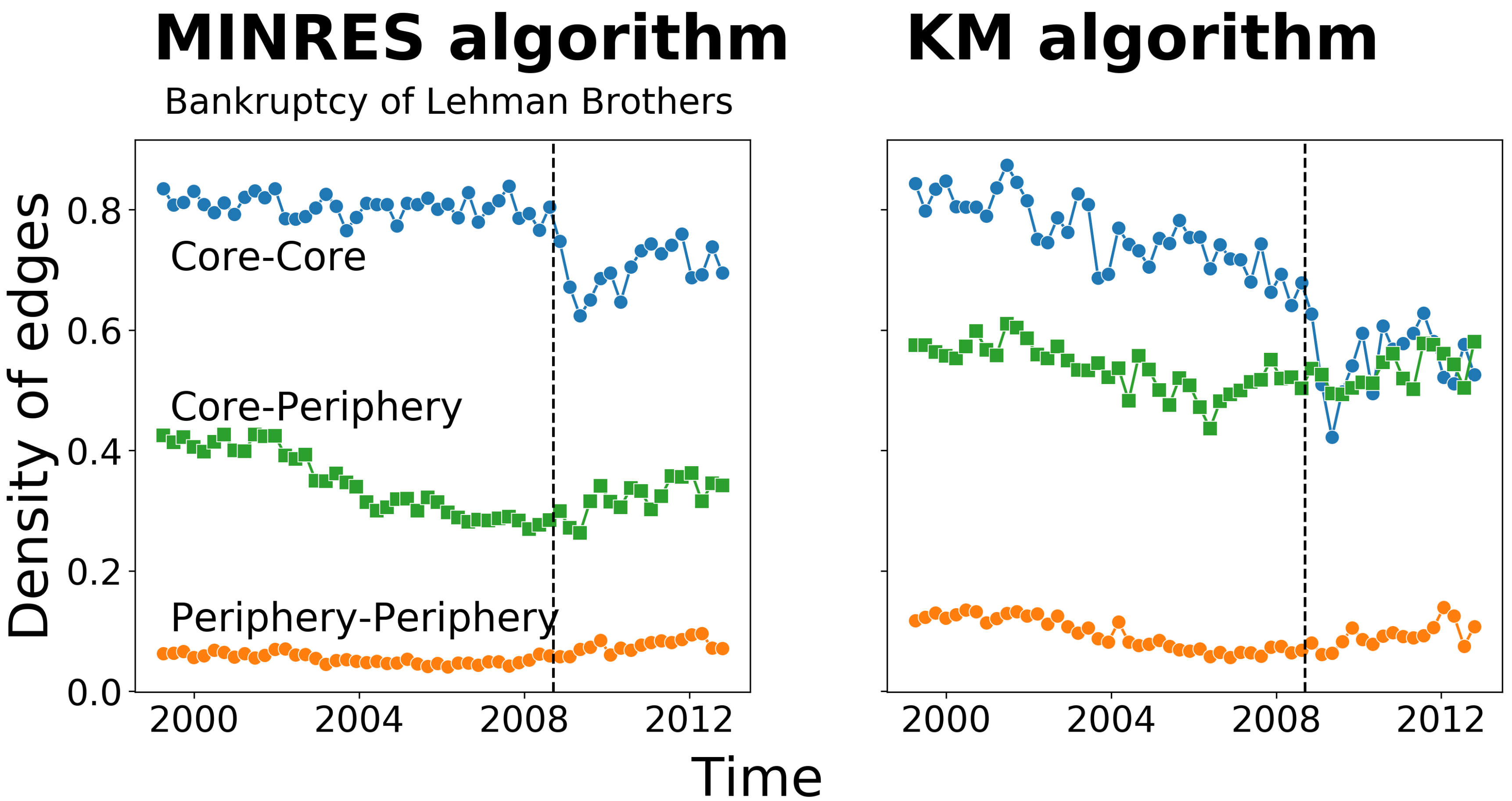


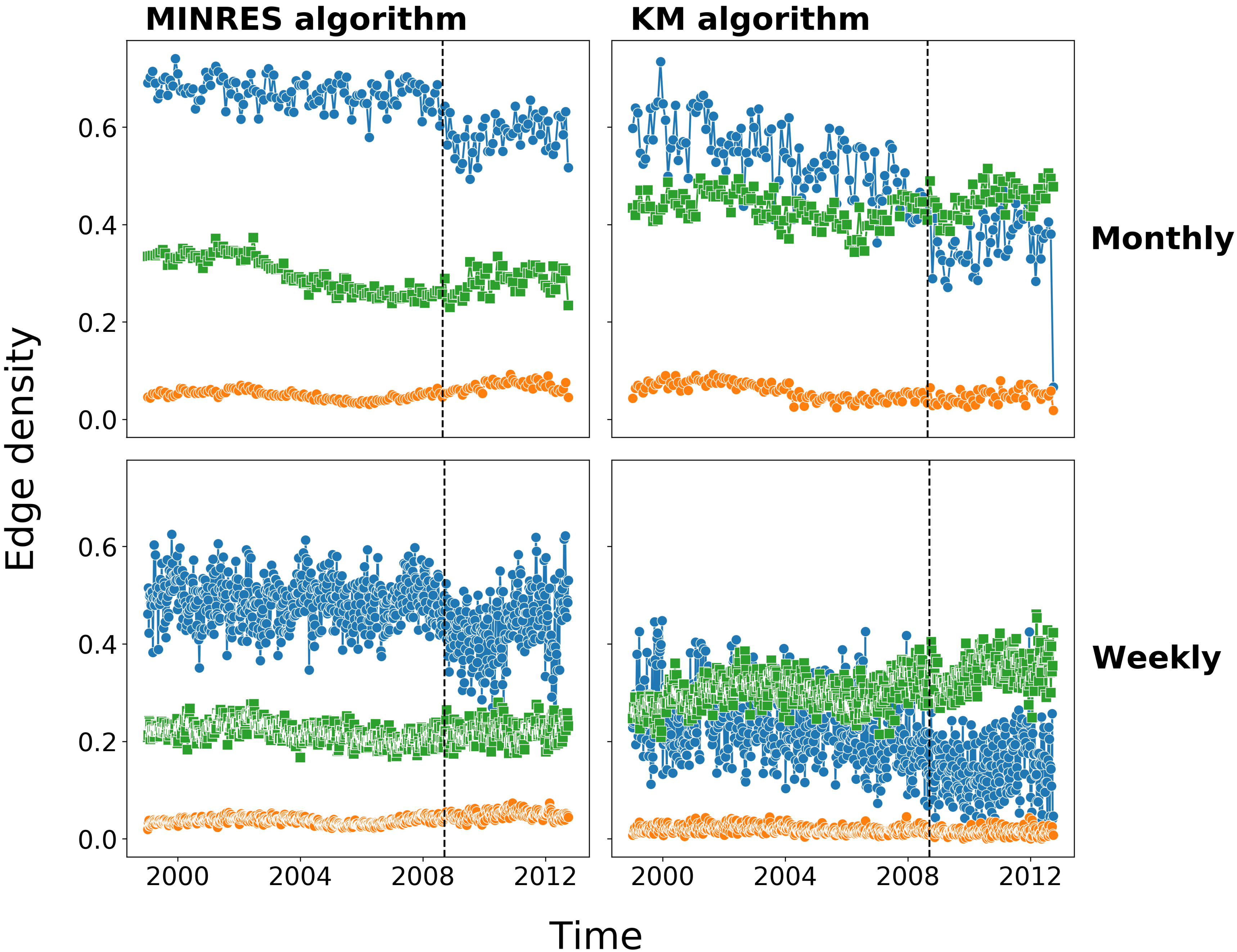
Internal structure of the largest CP (1)



$$\text{Density of edges} = \frac{\text{Actual number of edges}}{\text{Maximum number of edges}}$$

Internal structure of the largest CP (2)





Could not find CP after the global financial crisis

Summary

Analyses of single and multiple CPs in eMID led us to different conclusions:

- **Analysis of single CP**: Stable CP structure
- **Analysis of multiple CPs**: Collapse of CP structure

Restricting ourselves into single CP analysis may cause a distortion of our view

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Code: https://skojaku.github.io

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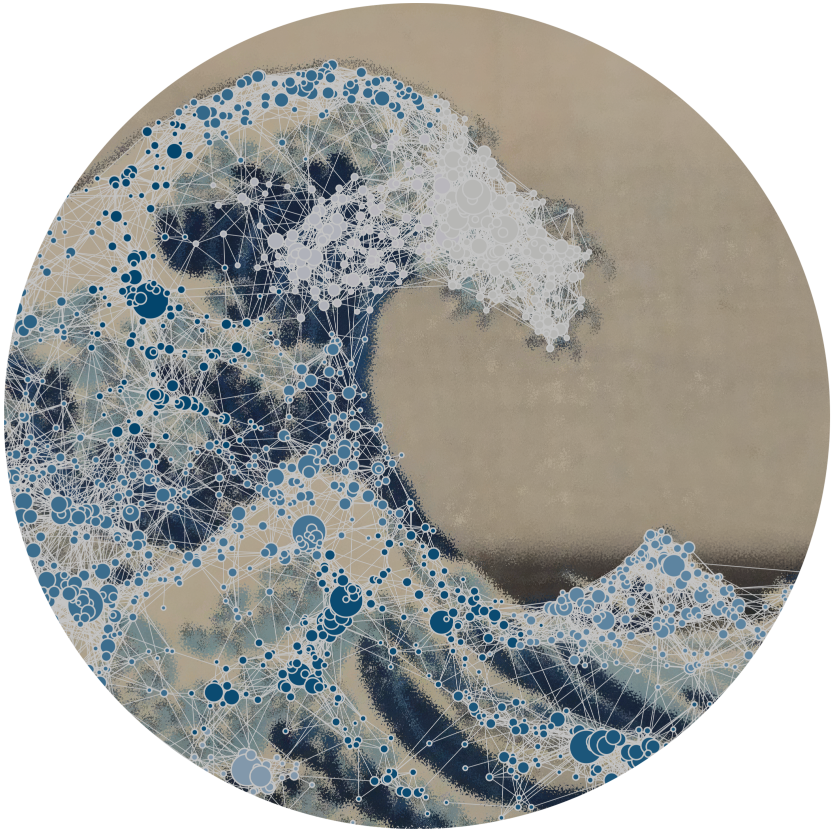
Netsci-X 2020 Tokyo



Deadline for submission: September 30

MINRES Algorithm

Find a single core and a single periphery in networks
(Boyd et al., Soc. Netw., 32(2), 125-137, 2010)

How it works

Define an idealised CP structure by

$$B_{ij}^{\mathrm{MINRES}} = \begin{cases} 1 & \text{(nodes } i, j \text{ are core)}, \\ 0 & (i, j \text{ are periphery}), \\ * & \text{(otherwise)}. \end{cases}$$

1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	0	0	0	0	0
1	1	1	1	1	0	0	0	0	0
1	1	1	1	1	0	0	0	0	0
1	1	1	1	1	0	0	0	0	0
1	1	1	1	1	0	0	0	0	0

Find a bipartition into a core and a periphery by solving

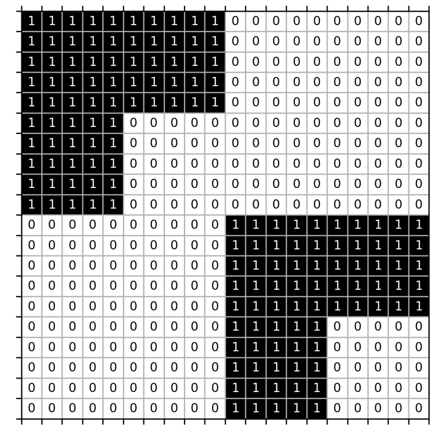
$$\min_{B^{\mathrm{MINRES}}} \sum_{i=1}^{N} \sum_{j=1}^{i} \left(A_{ij} - B_{ij}^{\mathrm{MINRES}} \right)^2 ,$$

where A is the given adjacency matrix.

Kojaku-Masdua (KM) algorithm

Find **multiple** core-periphery pairs in networks
(Kojaku and Masuda, Phys. Rev., 2017)

How it works



Define an idealised **multiple** CP pairs by

$$B_{ij}^{\mathrm{KM}} = \begin{cases} \delta(c_i, c_j) & \text{(nodes } i, j \text{ are core)}, \\ 0 & (i, j \text{ are periphery}), \\ \delta(c_i, c_j) & \text{(otherwise)}. \end{cases}$$

Find B^{KM} by maximising a modularity-like function

$$Q^{\mathrm{cp}} = \frac{1}{2M} \sum_{i=1}^{N} \sum_{j=1}^{N} \left(A_{ij} - \mathbb{E}[A_{ij}^{\mathrm{rand}}]\right) B_{ij}^{\mathrm{KM}}.$$

Kojaku and Masuda, Phys. Rev., 2017

Borgatti-Everett algorithm

Find a single core and a single periphery in networks

How it works

Define an idealised CP structure by

$$B_{ij}^{\mathrm{BE}} = \begin{cases} 1 & (i \text{ and } j \text{ are core}), \\ 0 & (i \text{ and } j \text{ are periphery}) \\ 1 & (\text{otherwise}) \end{cases}$$

1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	0	0	0	0	0
1	1	1	1	1	0	0	0	0	0
1	1	1	1	1	0	0	0	0	0
1	1	1	1	1	0	0	0	0	0
1	1	1	1	1	0	0	0	0	0

Find a bipartition into a core and a periphery by maximising

$$\max_{B^{\mathrm{BE}}} \rho(B^{\mathrm{BE}}, A),$$

where ρ is the Pearson correlation coefficient and A is the given adjacency matrix.

Borgatti and Everett, Soc. Netw., 2000