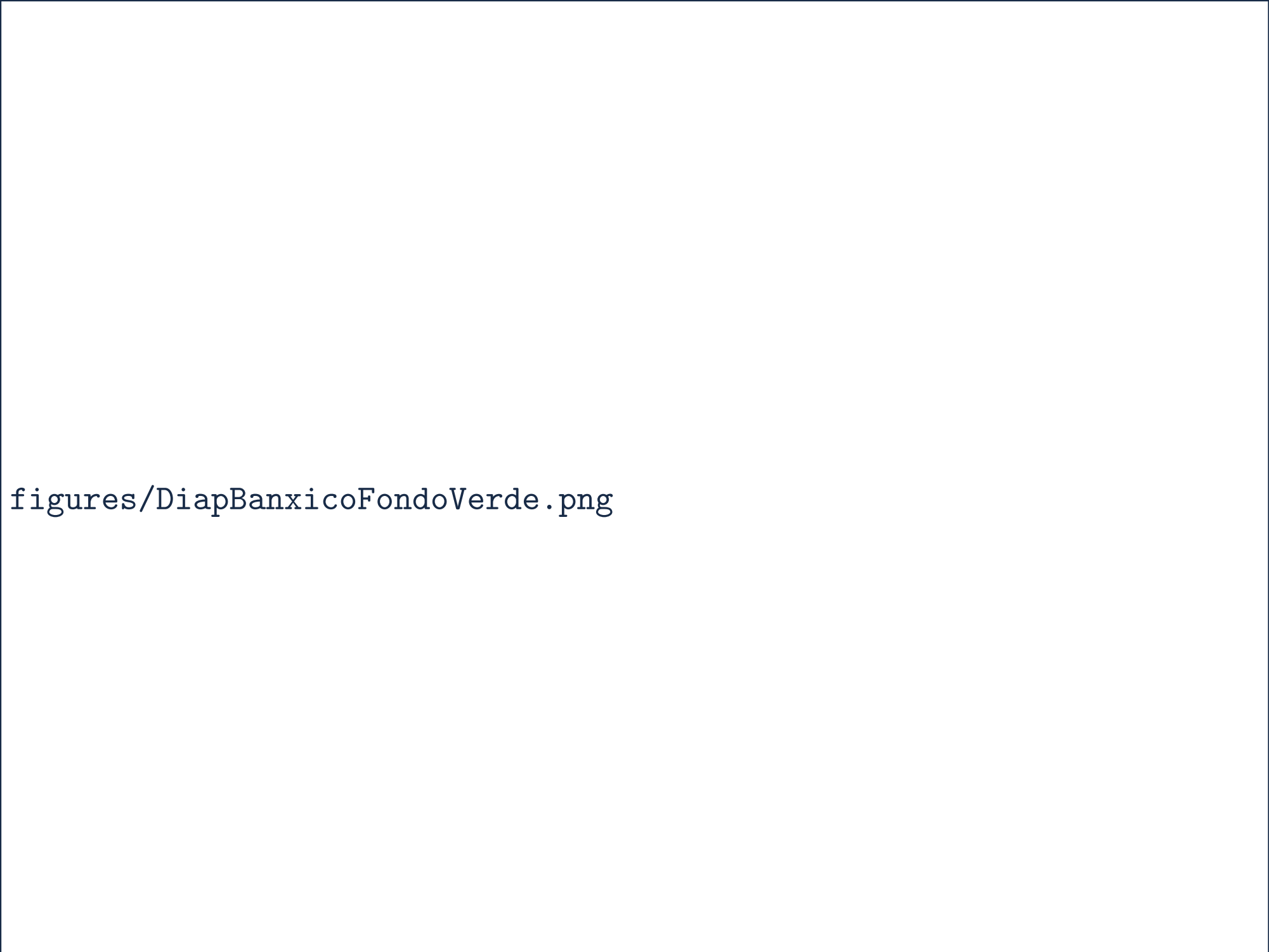

figures/DiapBanxicoFondoVerde.png

Outline[1]

[1] The opinions expressed here are those of the authors and do not reflect the point of view of Banco de Mexico.

Outline

Introduction

- There has been a lot of recent research on financial networks for the purposes of studying systemic risk, performing stress testing or determining the relevance of financial institutions.
- A commonly shared view is that the financial system is highly interconnected.
- However, most of the works use the interbank unsecured market as the only source to measure interconnectedness in the banking system.

Introduction

- Financial institutions interact in different markets, which can be thought of as different networks within a meta-structure which can be interpreted as a multilayered network or a multiplex network.
- The selection of either structure depends on the specific characteristics of the system and on the different aspects under study.
- This gives rise to a rich set of complex interactions among these layers, each with different topological properties.
- It is a possibility to simple aggregate all the layers in order to study the system of interest; nevertheless, insightful information regarding interactions is lost when the multiplex structure is neglected.

Objectives

This work has a main goal

- Characterize the multiplex network of the Mexican financial system.

Related objectives

- Propose new metrics and methods in order to characterize and understand the multiplex network of the Mexican financial system, which can be used in other jurisdictions.
- Identify important players in the multiplex structure rather than only on single layers.
- Reveal the interconnectedness and the complexity of the financial system by analyzing how banks interact with each other and how these interactions change through time.
- These should help in order to derive better systemic risk models and to improve stress testing.

Outline

Data

A complete picture of the real degree of interconnectedness in the financial system is missing mainly driven by important data gaps.

- The Mexican government tightened banking regulation after the Tequilla crisis in 1994
- The Mexican Central Bank, Banco de México, set up a data warehouse to which all banks are obliged to report data since 2005 **daily data on transactions** on **unsecured interbank loans, repo transactions, securities holdings and derivative positions**.

In this project we consider

- Daily data on many different market activities in the Mexican banking system on unsecured and secured (repo) interbank loan transactions, derivatives exposures, payment system flows and securities holding between commercial banks in Mexico, from 2005 onwards

Definitions

The multiplex network referred in most of this presentation is the multiplex banking system.

The multiplex network $\mathcal{M}$ consists of N nodes and M layers

The whole structure can be described by the set of adjacency matrices

$$\mathcal{M} \equiv A = \{A^{[1]}, ..., A^{[M]}\}$$

where $A^{[\alpha]} = \{a_{ij}^{[\alpha]}\}$, with $a_{ij}^{[\alpha]} = 1$ if i and j performed a financial transaction in market α and $a_{ij}^{[\alpha]} = 0$ otherwise.

Definitions

One important concept is that of the overlapping degree, computed as:

$$o_i = \sum_{\alpha=1}^{M} k_i^{[\alpha]}$$

Another important concept is that of the multiplex participation coefficient:

$$P_i = \frac{M}{M-1}\left[1 - \sum_{\alpha=1}^{M}\left(\frac{k_i^{[\alpha]}}{o_i}\right)^2\right]$$

If $P_i = 1$ then all the links incidents in node i are equally distributed across layers whereas $P_i = 0$ if node i is only active in one layer.

P_i and o_i are useful to classify the nodes in multiplex hubs (high P_i and o_i); focused hubs (high o_i and low P_i); multiplex leaves (low o_i and high P_i) and focused leaves (low o_i and low P_i)

Definitions

- Stochastic Block Models have proved to be a useful tool to uncover the latent structure in complex networks.
- The main hypothesis of these models is that the attributes of agents affect the way they interact with each other.
- Agents with similar attributes are classified in the same cluster and the relation between agents is conditioned according to the cluster they belong.
- In the multiplex network context, this characterization take into account the way they connect with others in the different layers.

Definitions

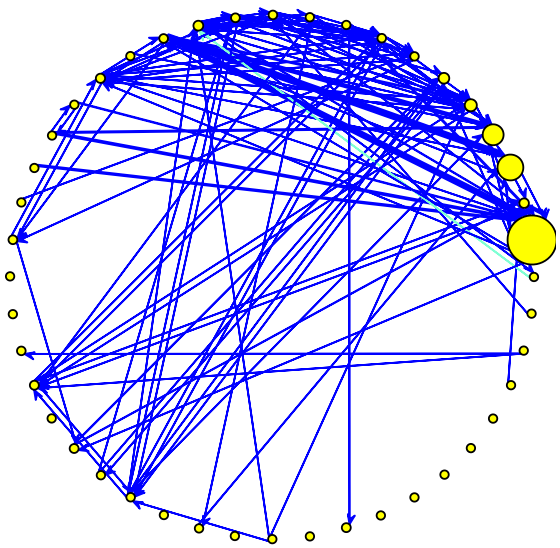
Let Q be the number of blocks or clusters in a financial system and $Z_i = q$ f the individual i belongs to block q and let n be the number of nodes.
Then, $\forall (i,j) \in \{1,..,n\}^2, i \neq j, \forall w \in \{0,1\}^K, \forall (q,l) \in \{1,..,Q\}^2,$

$$P(X_{ij}^{1:K} = w | Z_i = q, Z_j = l) = \pi_{ql}^{(w)}$$

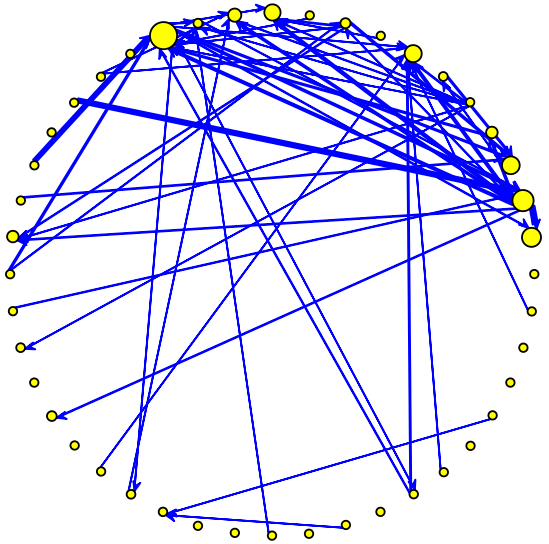
In other words, the probability that 2 banks are connected in any layer depends on the cluster they belong.

Outline

Unsecured Interbank and repo markets

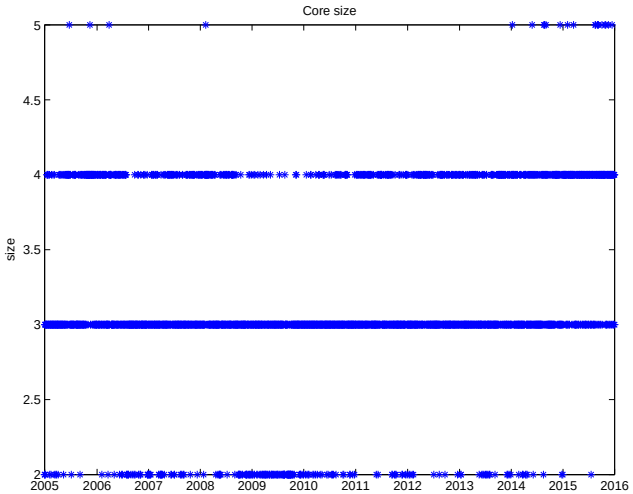


(a) Unsecured interbank network

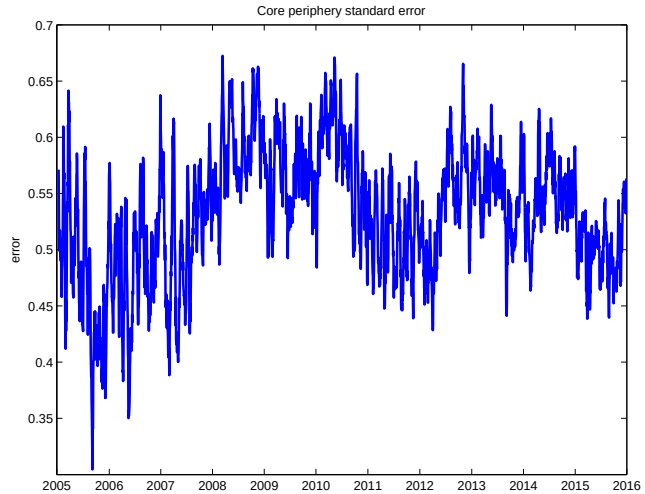


(b) Interbank Repo network

Unsecured Interbank and repo markets

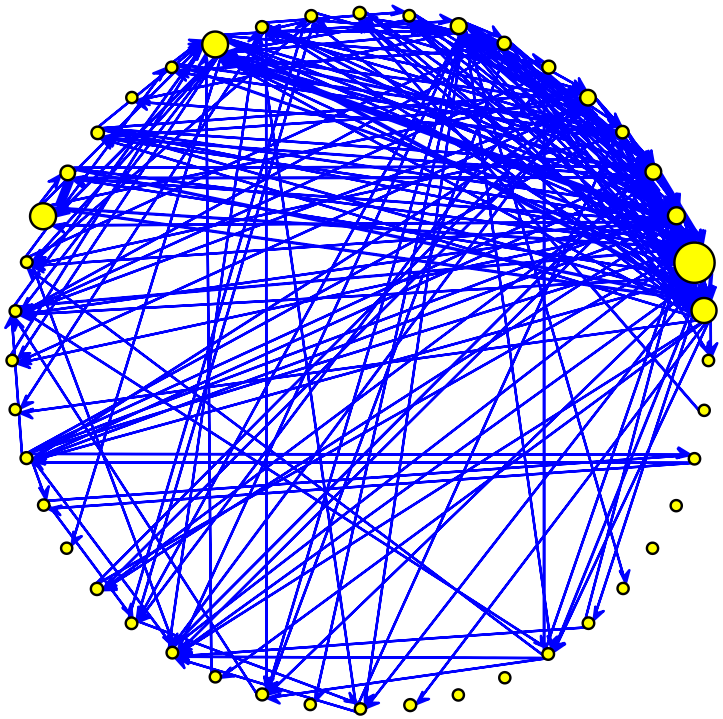


(c) Core size

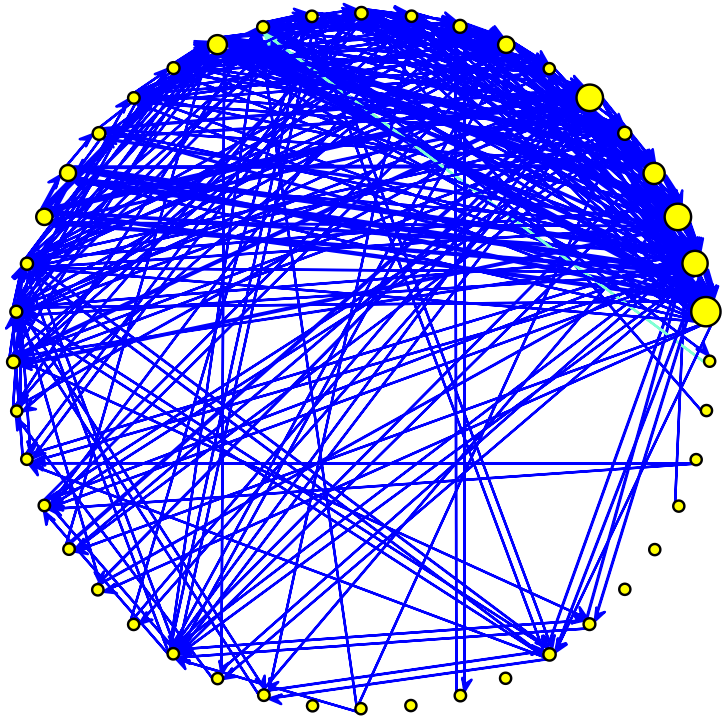


(d) Core periphery error

Payment system and total exposures network

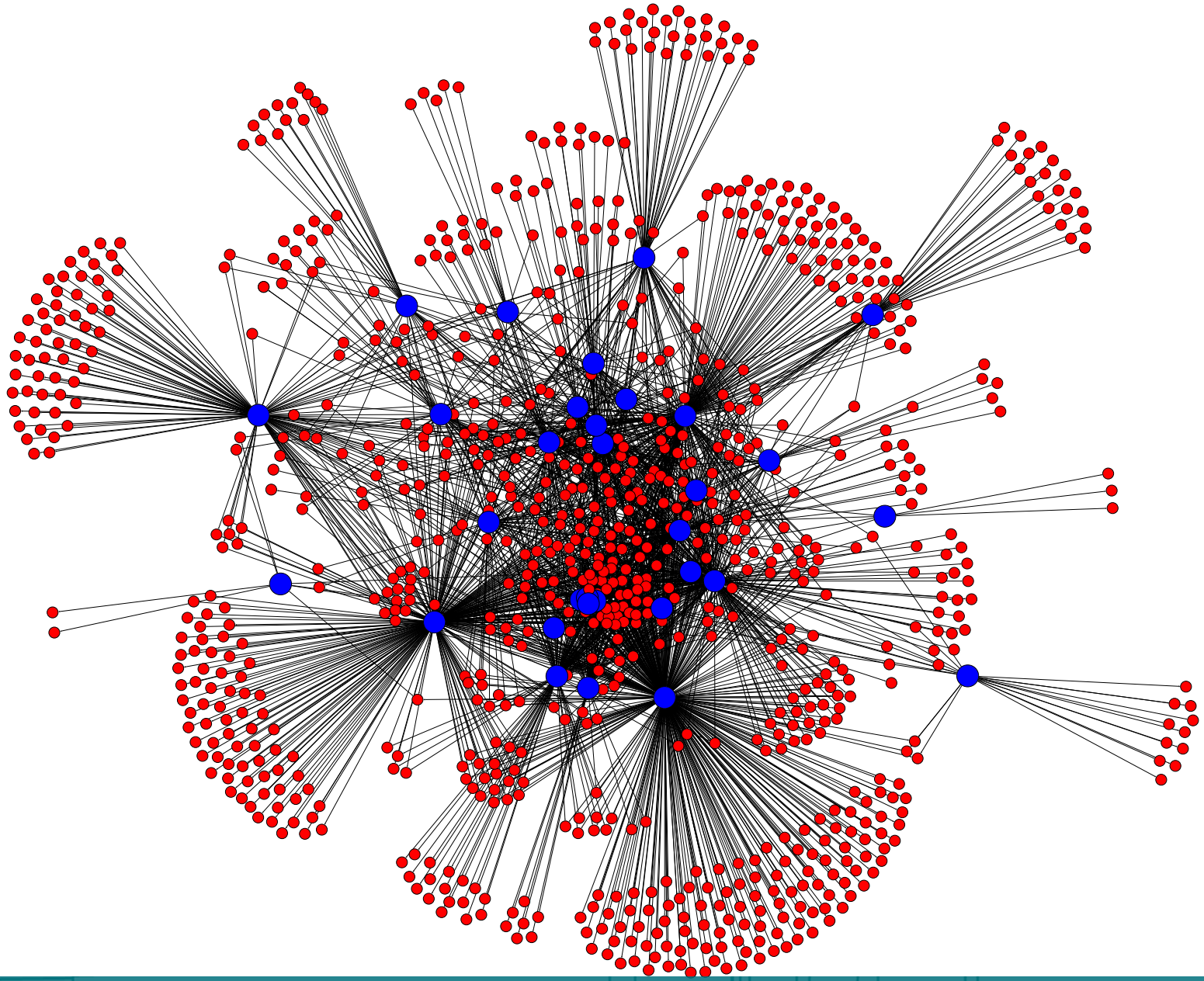


(e) Payment flows network



(f) Total exposures interbank network

The securities holdings of banks



Outline

Initial Results

In this work we study 6 different layers or types of interactions among banks:

- Transactions on the securities market (CVT layer)
- Payment system flows (SPEI layer)
- Exposures arising from interbank deposits and loans, cross holding of securities,derivatives transactions and foreign exchange transactions. All these networks were aggregated in a single network. (Total layer)

Importance of a layer

It is desirable to determine the relevance of each layer of the multiplex system. This question has been answered in Zhu et al 2014 by using correlations among simplex networks. The authors define the inter-simplex correlations for each node as:

$$C_{isr} = \frac{\sum_j a_{ij}^s a_{ij}^r}{\sum_j a_{ij}^s + \sum_j a_{ij}^r - \sum_j a_{ij}^s a_{ij}^r}$$

where a_{ij}^s is the interaction of banks i and j in layer s. This coefficient takes values in $[0, 1]$. The authors define the correlation among layers as:

$$C_{sr} = \frac{1}{n} \sum_i C_{isr}$$

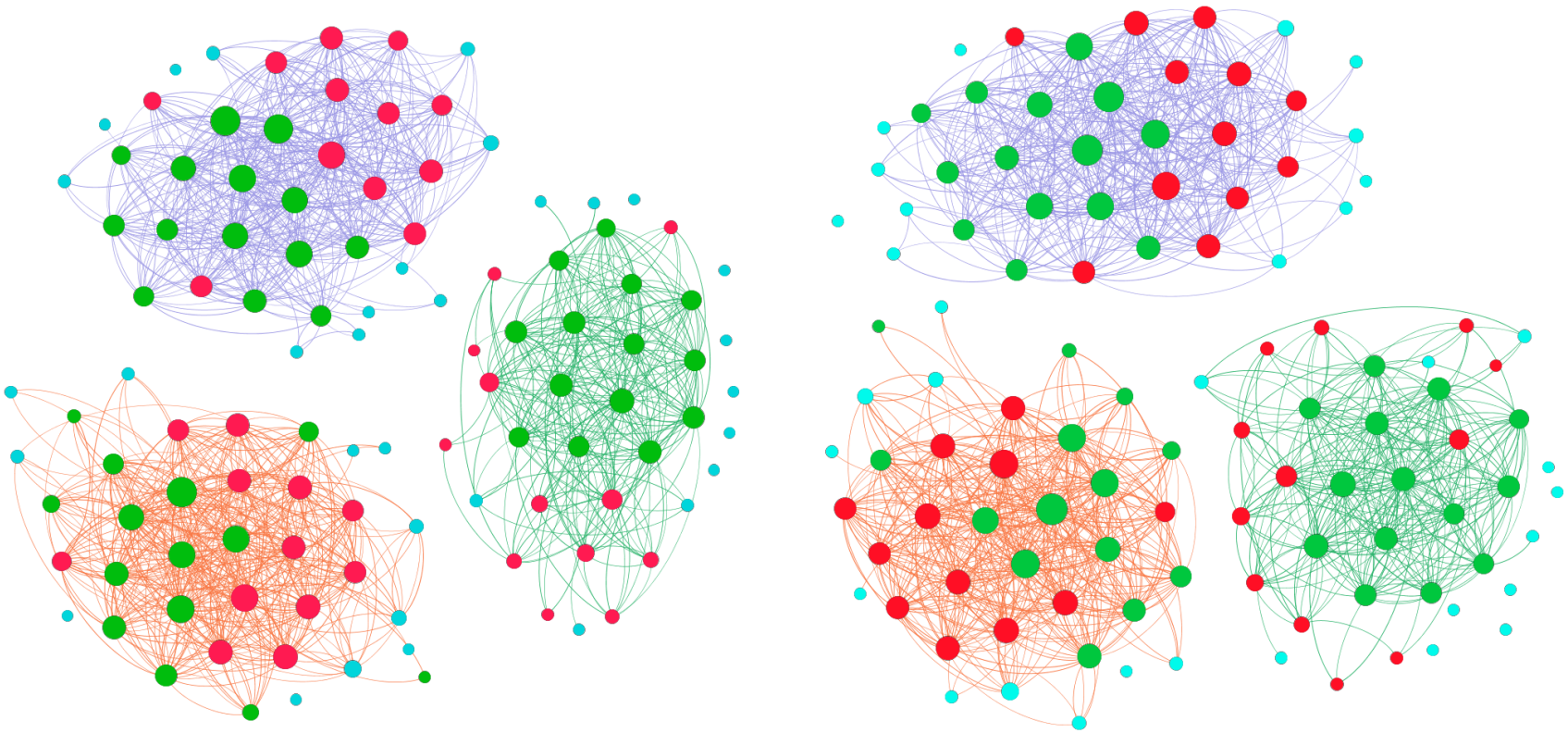
where n is the number of nodes in the multiplex, C_{sr} takes values in $[0, 1]$.

Importance of a layer

After computing correlations among all layers, the authors define the importance of a layer as:

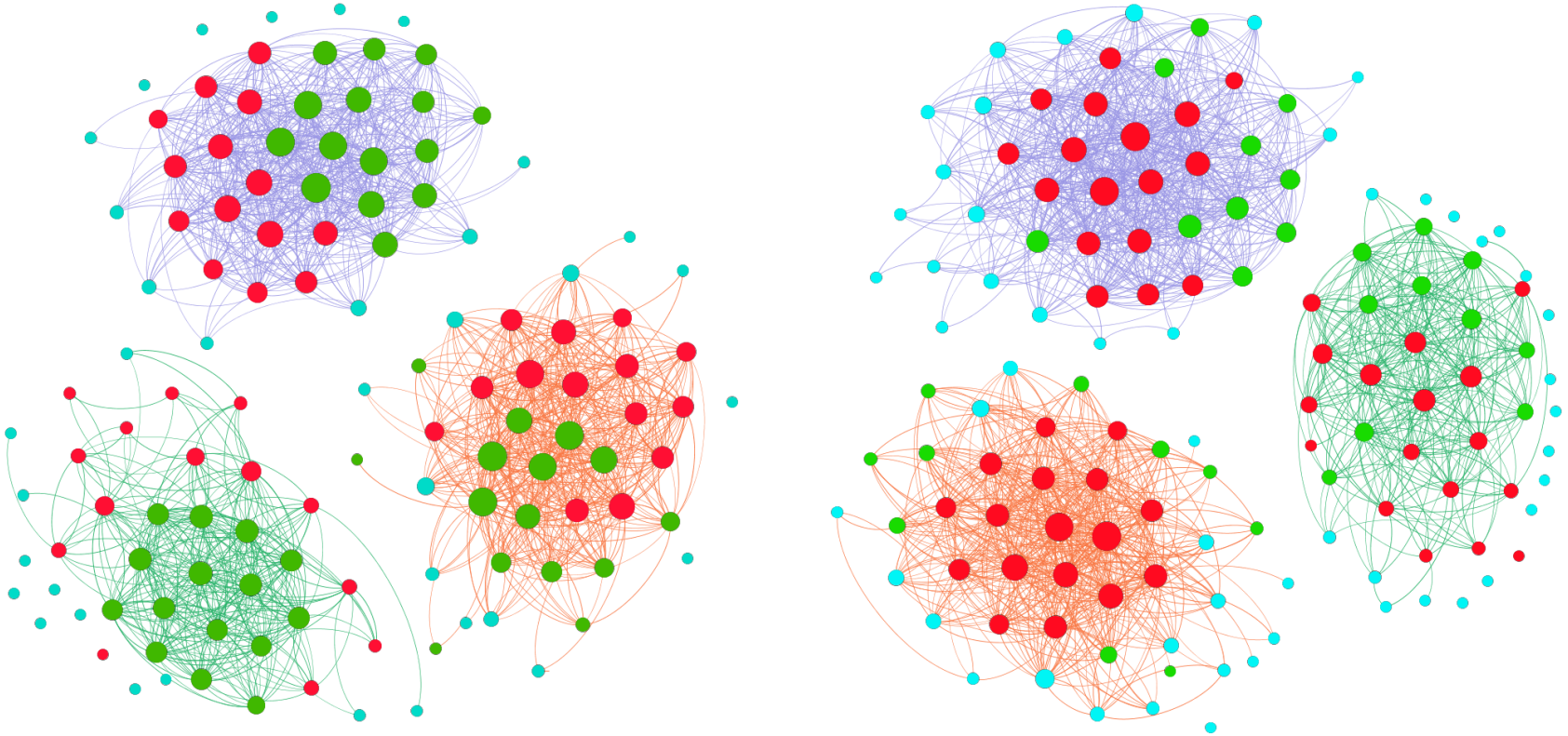
$$I_s = \frac{\sum_r C_{rs}}{\sum_s \sum_r C_{rs}}$$

Network	June 2007	October 2008	June 2010	June 2015
CVT	0.572	0.422	0.455	0.469
SPEI	0.648	0.572	0.555	0.530
Total	0.780	0.645	0.678	0.640



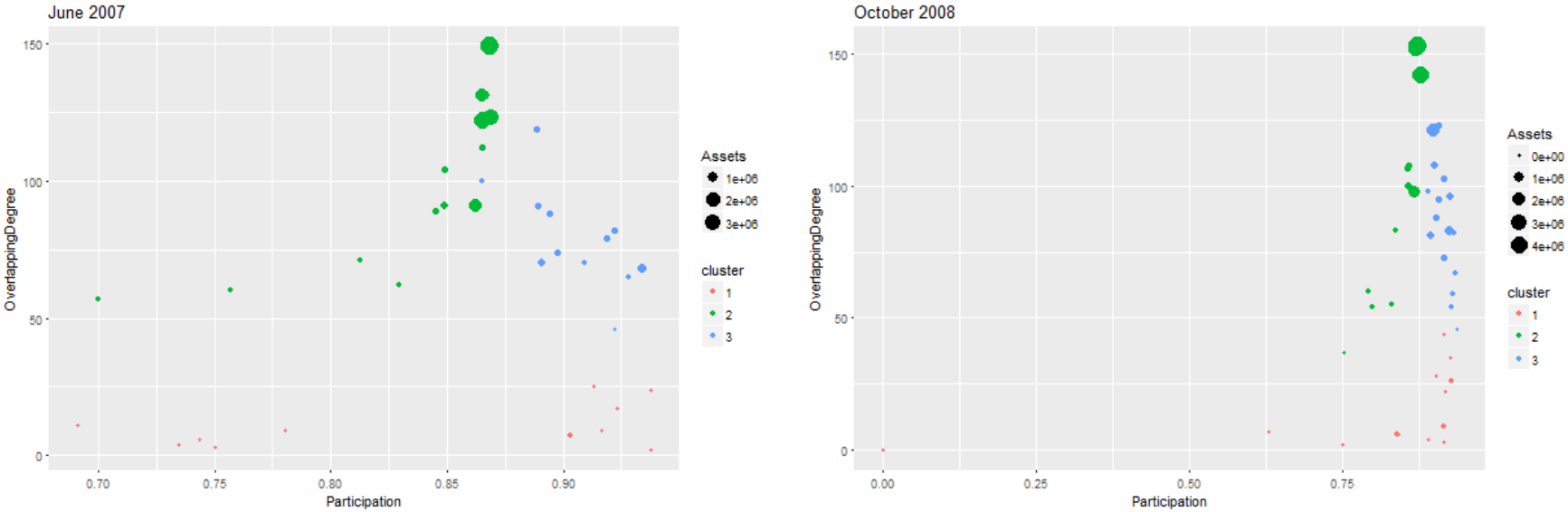
(g) June 2007 (h) October 2008

Figure: Clusters found using Bernoulli Multiplex SBM



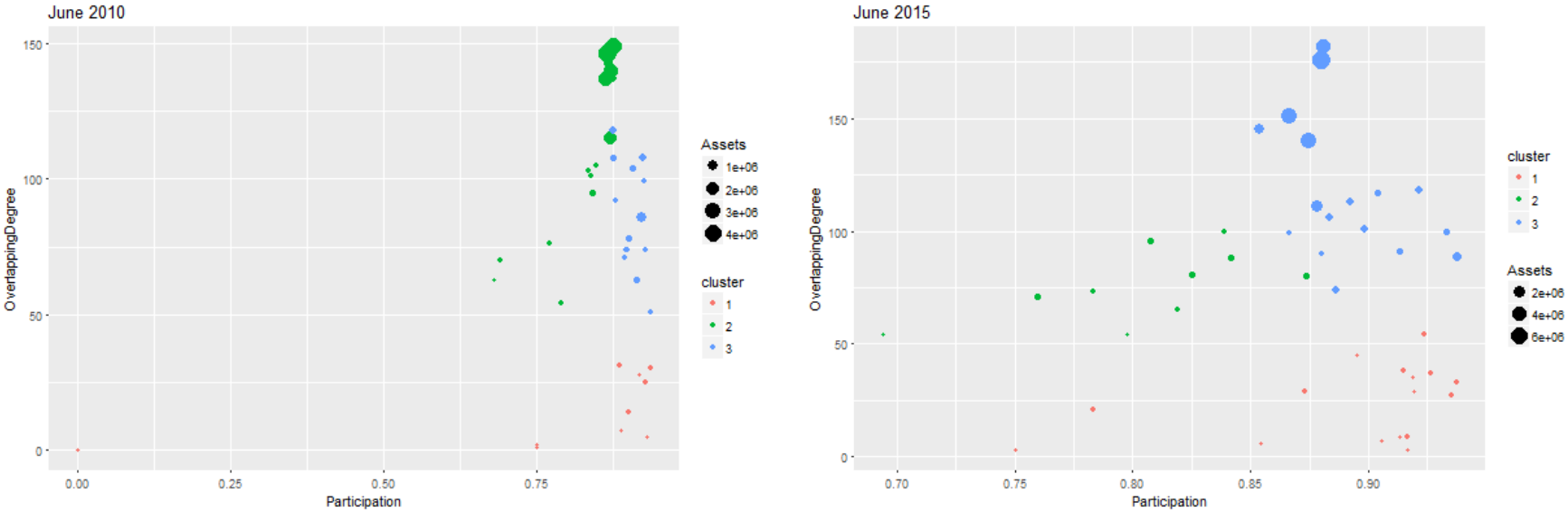
(a) June 2010 (b) June 2015

Figure: Clusters found using Bernoulli Multiplex SBM



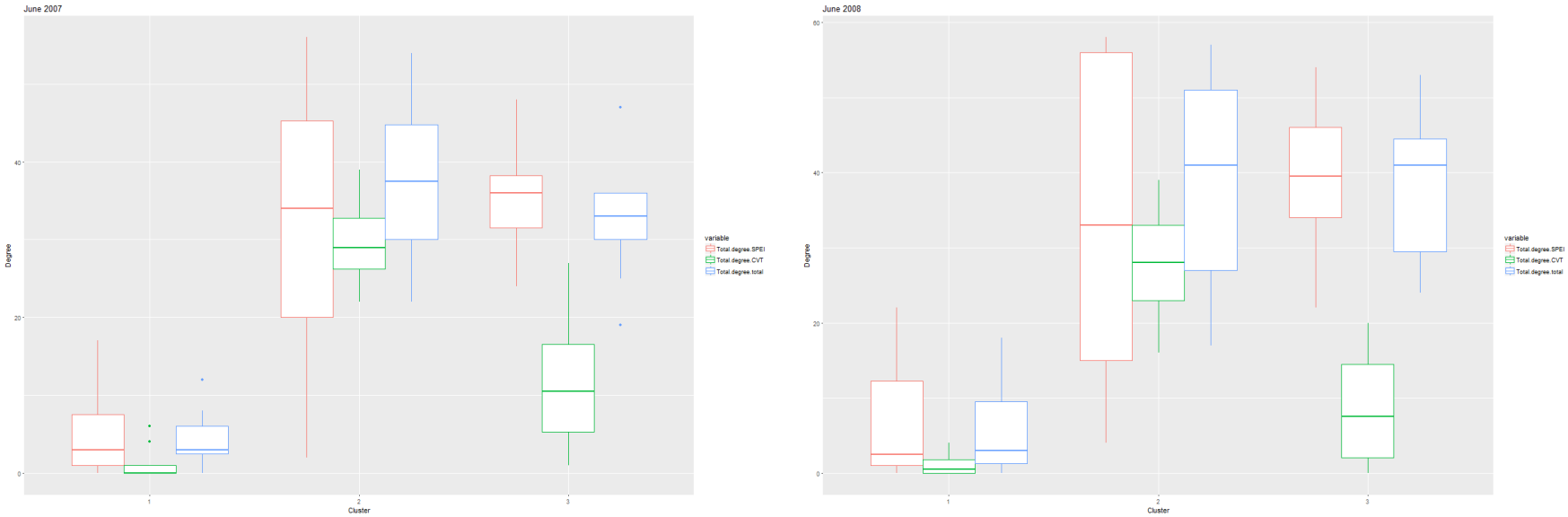
(a) June 2007 (b) October 2008

Figure: Clusters found using Bernoulli Multiplex SBM



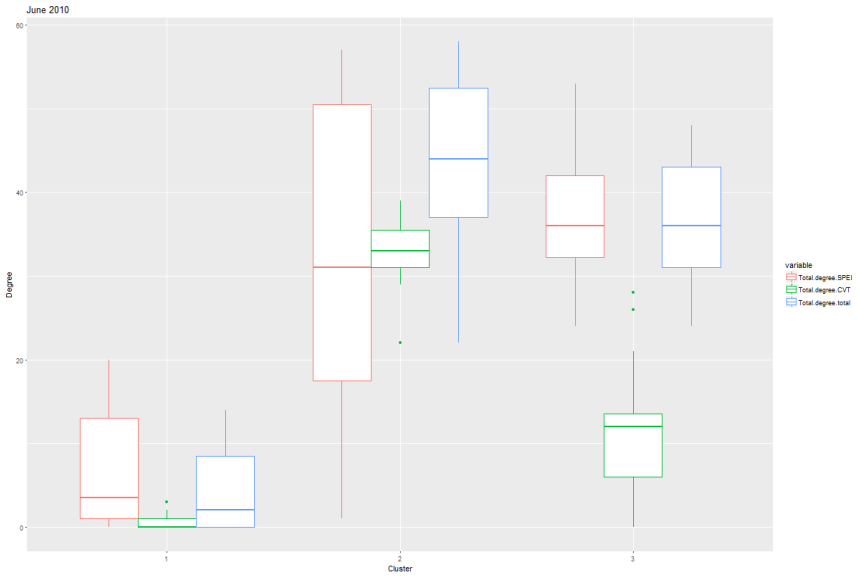
(a) June 2010 (b) June 2015

Figure: Clusters found using Bernoulli Multiplex SBM

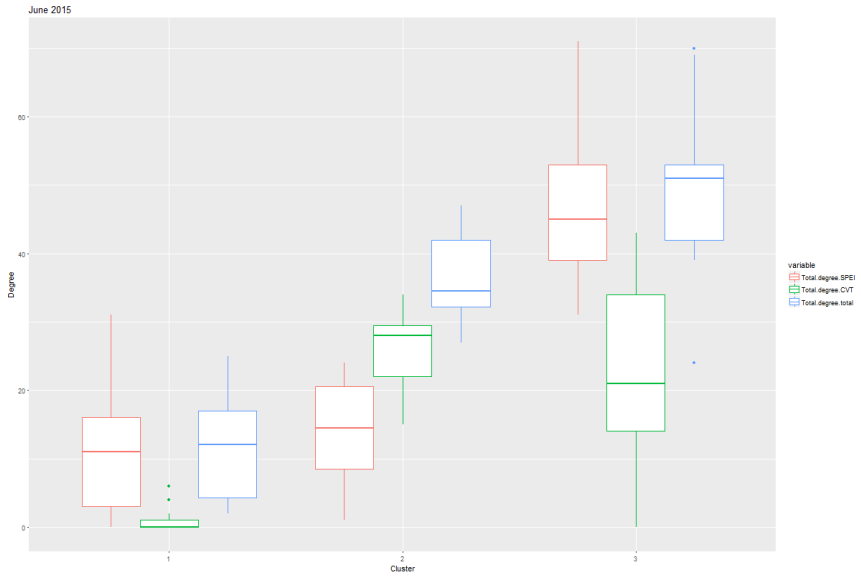


(a) June 2007 (b) October 2008

Figure: Clusters found using Bernoulli Multiplex SBM

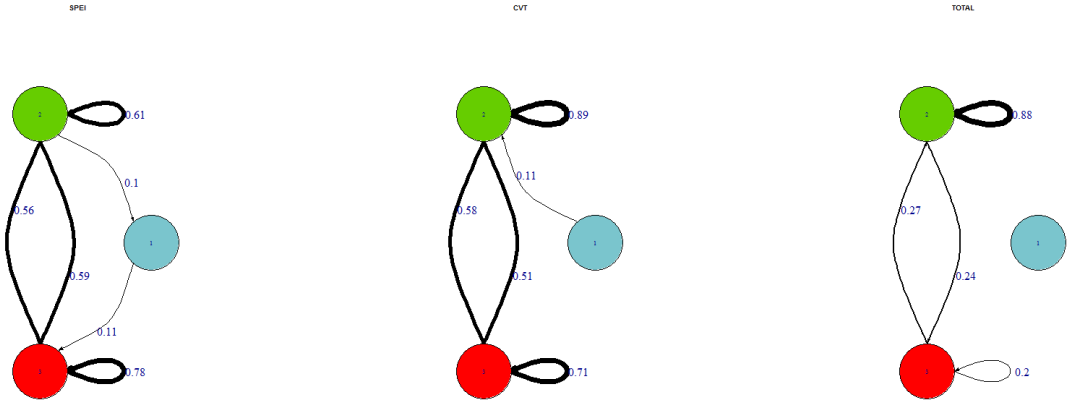


(a) June 2010

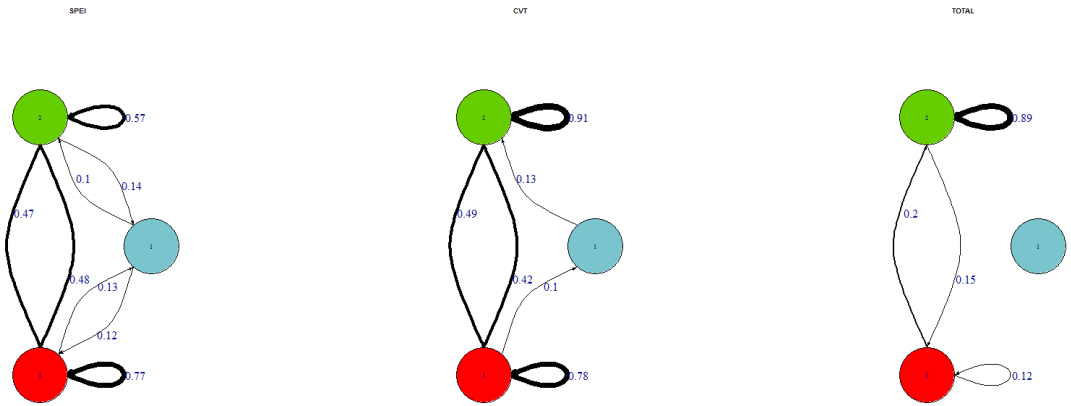


(b) June 2015

Figure: Clusters found using Bernoulli Multiplex SBM

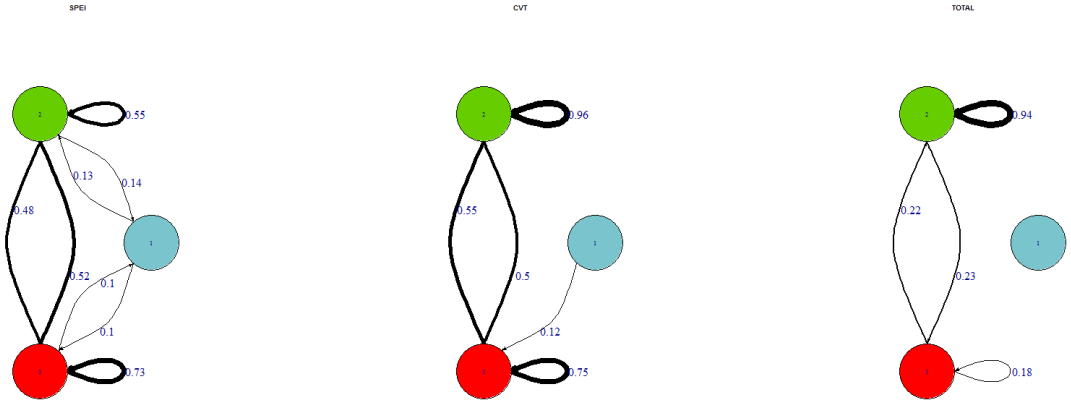


(a) June 2007

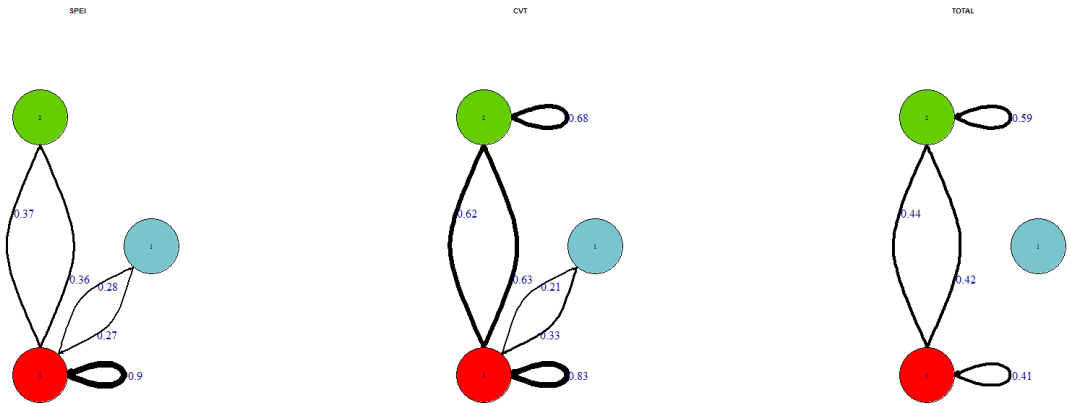


(b) October 2008

Figure: Marginal Distributions

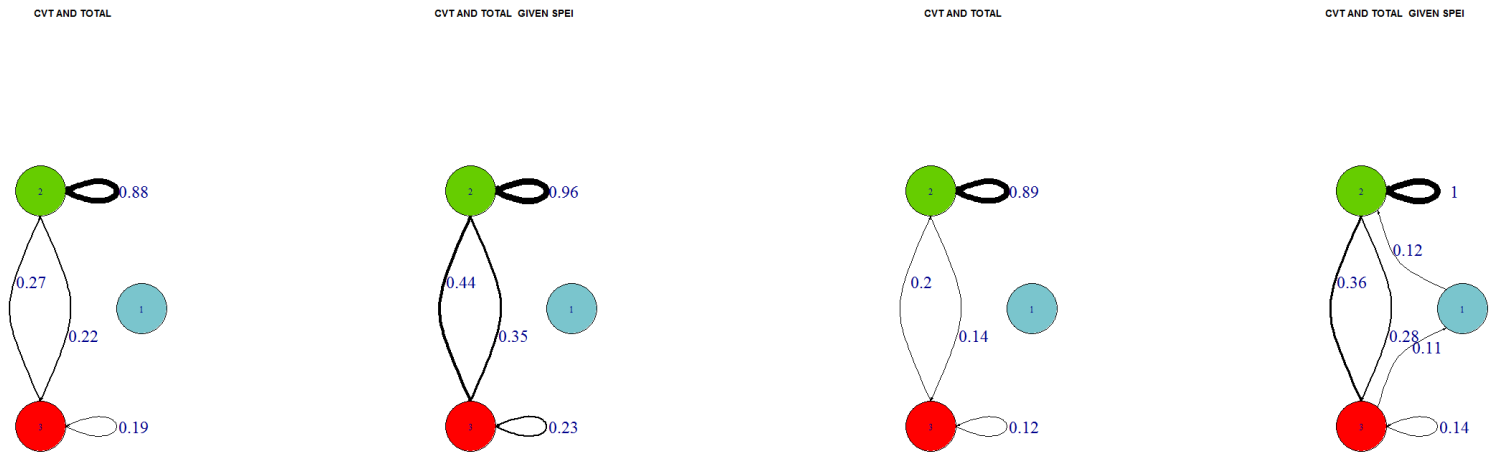


(a) June 2010



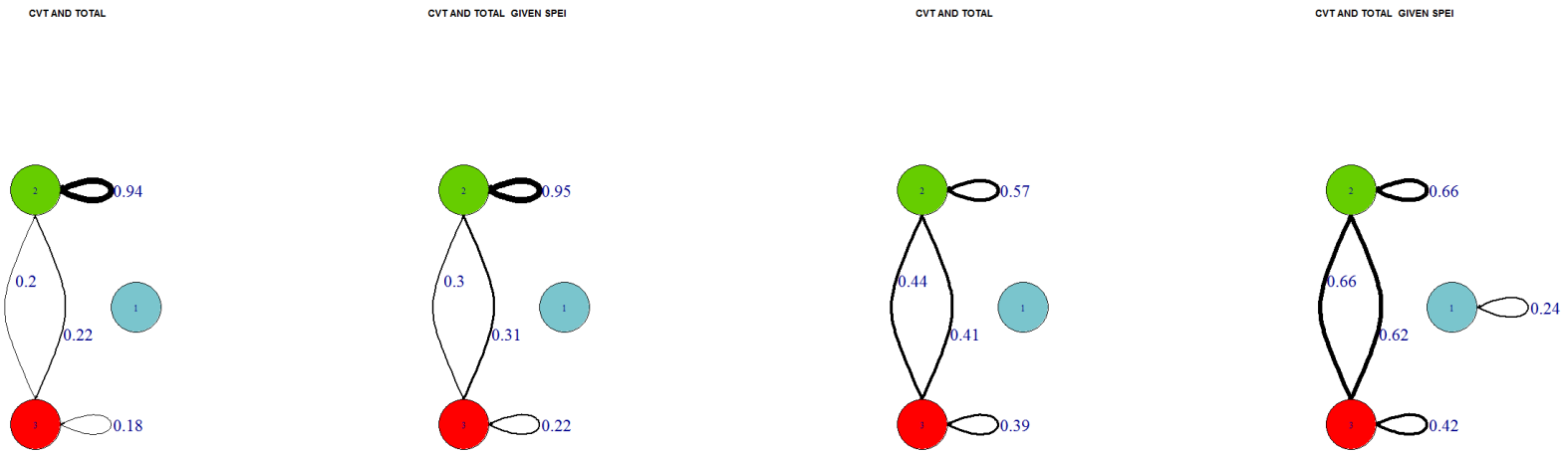
(b) June 2015

Figure: Marginal Distributions



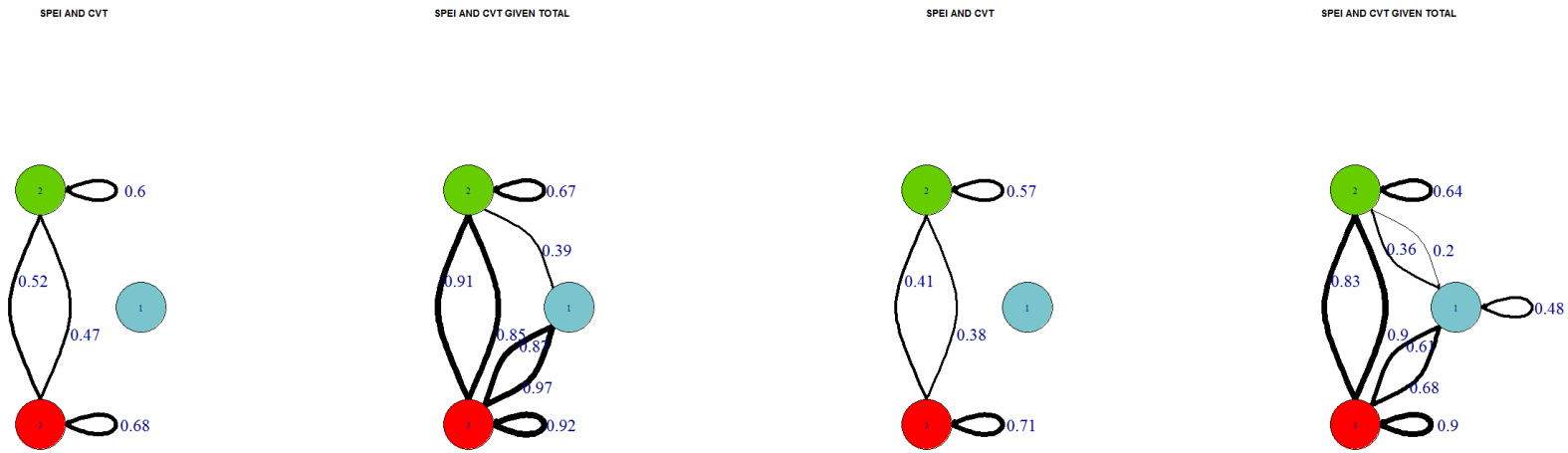
(a) June 2007 (b) October 2008

Figure: Joint Distributions of CVT and TOTAL networks



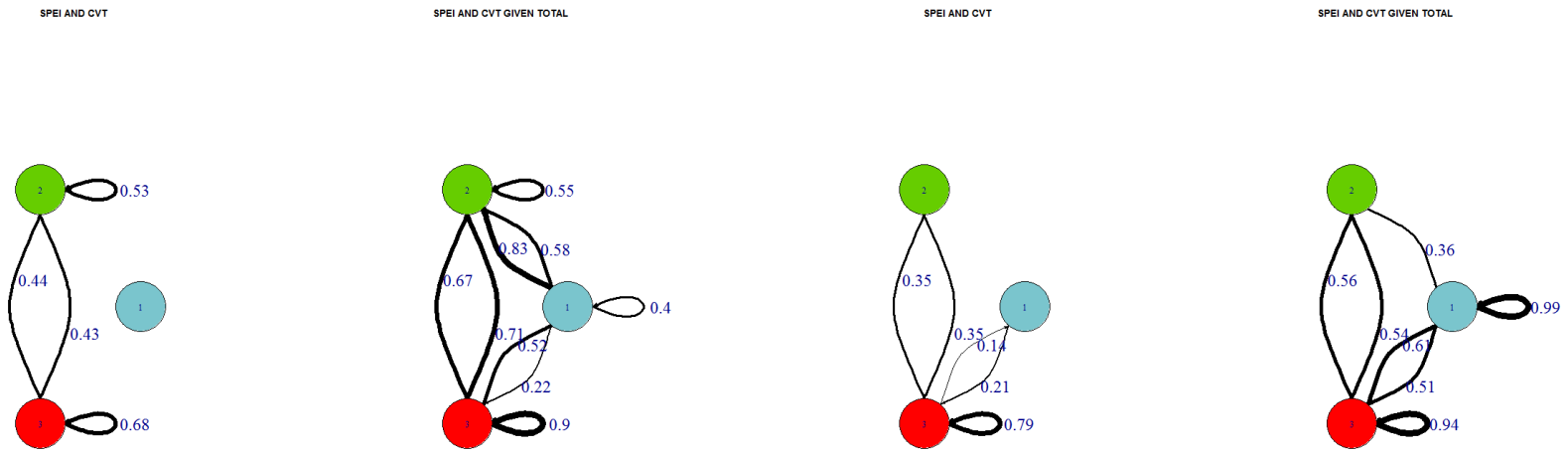
(a) June 2010 (b) June 2015

Figure: Joint Distributions of CVT and TOTAL networks



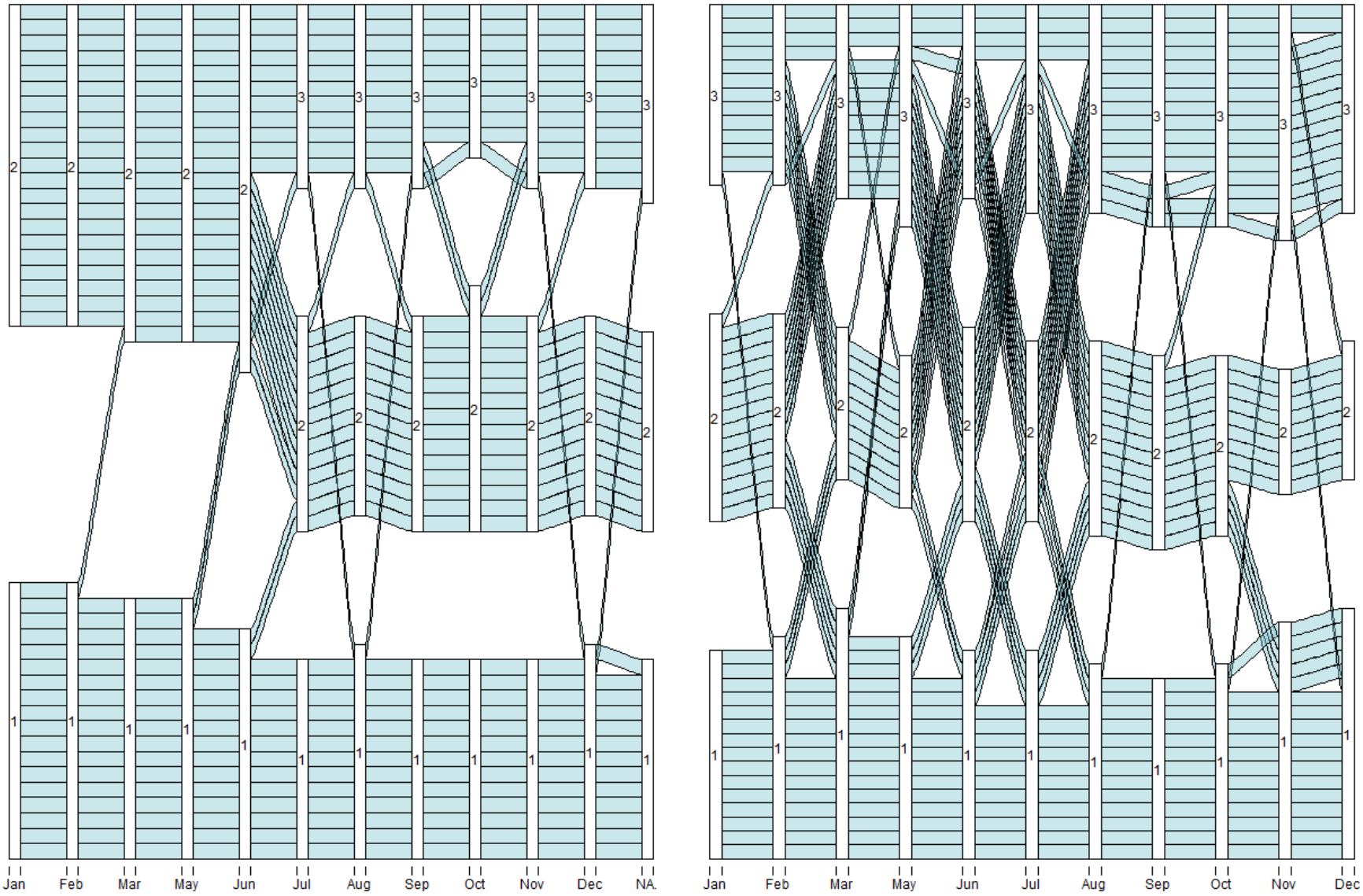
(a) June 2007 (b) October 2008

Figure: Joint Distributions of CVT and SPEI networks



(a) June 2010 (b) June 2015

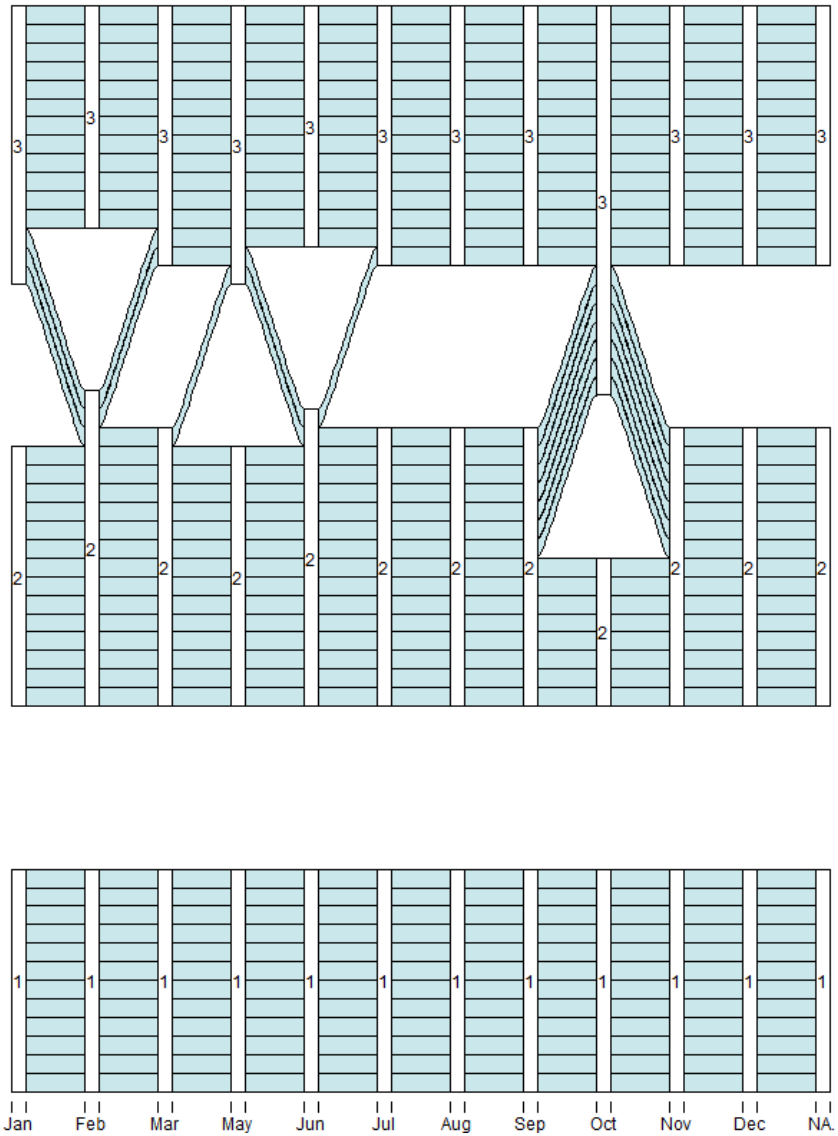
Figure: Joint Distributions of CVT and SPEI networks



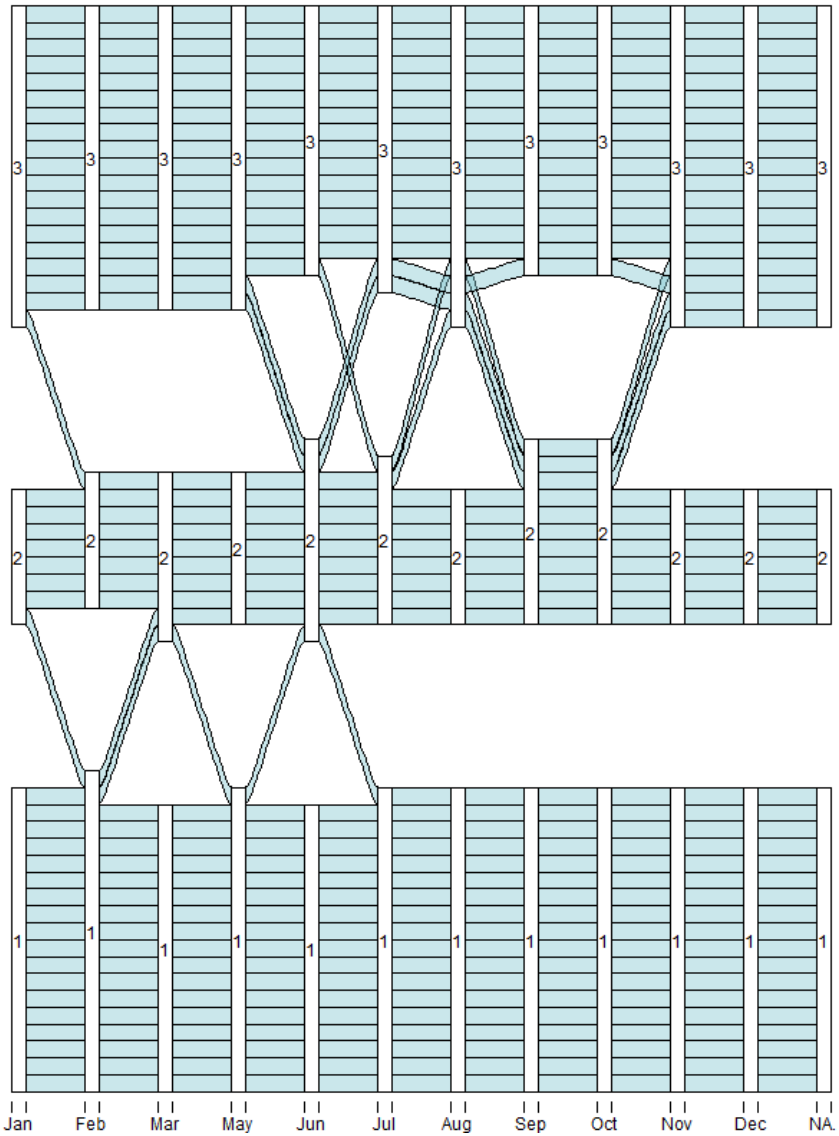
(a) 2007

(b) 2008

Figure: Evolution of clusters



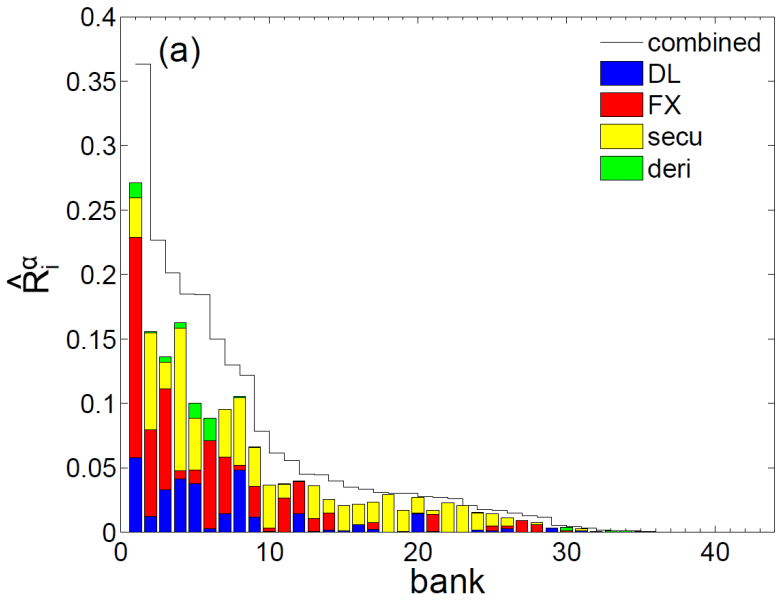
(a) 2010



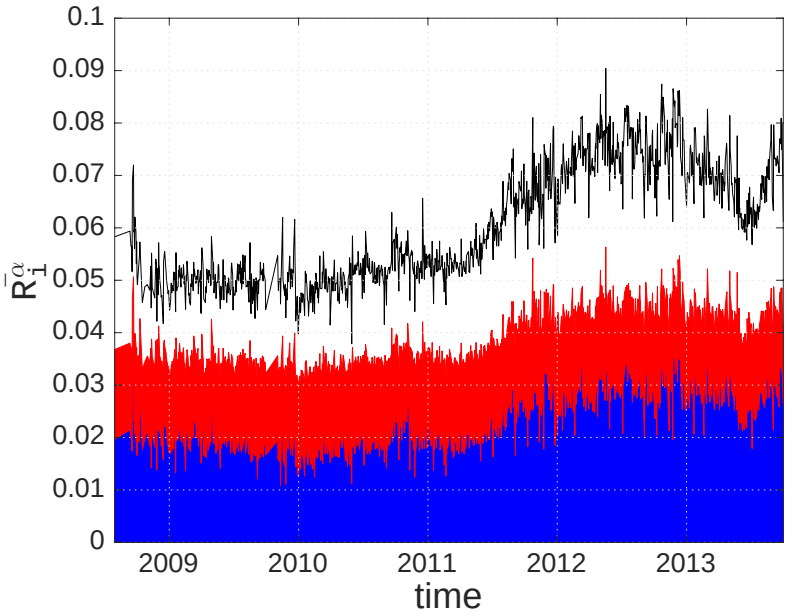
(b) 2015

Figure: Evolution of clusters

Systemic risk in a multilayer context

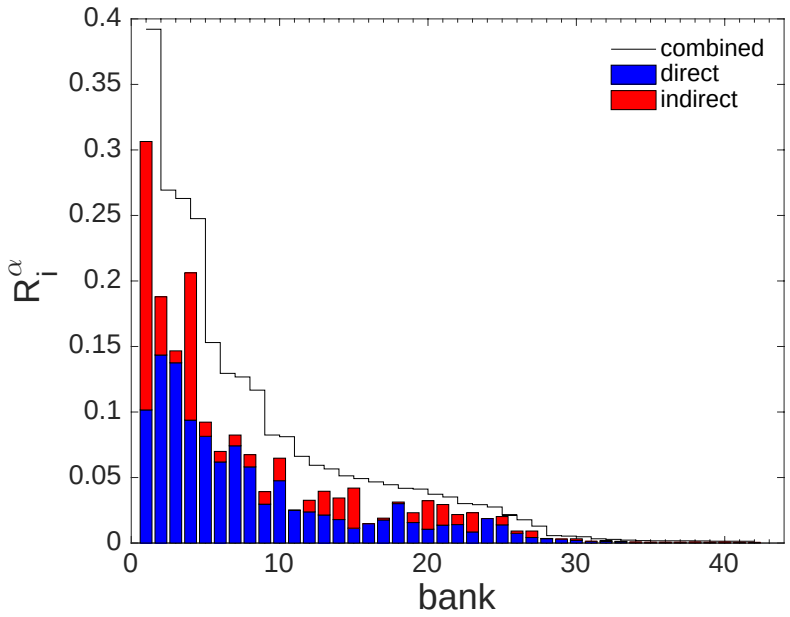


(a) Systemic Risk Profile

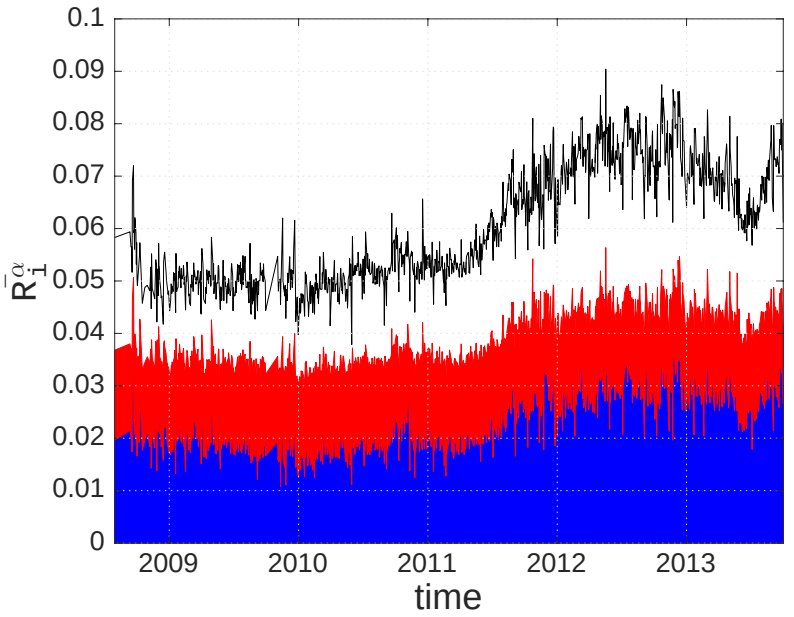


(b) Debt rank series

Overlapping portfolios and systemic risk

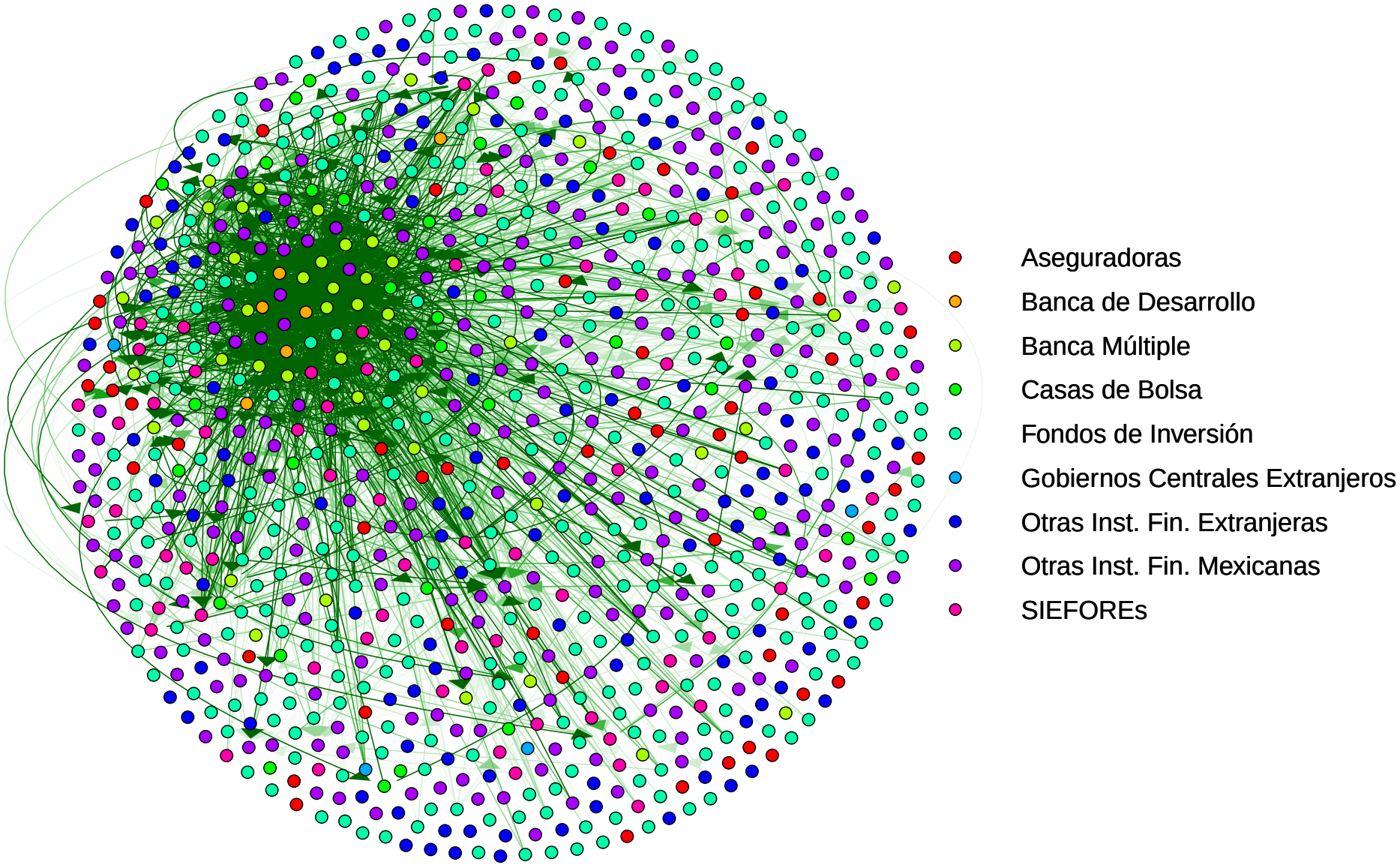


(c) Systemic Risk Profile



(d) Debt rank series

What about the financial system?



Outline

Conclusions and further work

- We have started to study the multiplex of the Mexican financial system
- It is possible to include more layers related to different market activities than in previous exercises
- First results: the multiplex approach deliver important information not available on a individual layer view
- This has important implications from the systemic risk point of view

Further work

Future work

- Extend the multiplex analysis to more financial intermediaries.
- Include some more sophisticated metrics into the multiplex context.
- Study more in depth stochastic block models and centrality into the multiplex context.
- Study how to compress some layers without lossing information.
- Apply all these for weighted multiplex networks.

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Thank you