Multiplex financial networks: revealing the real level of interconnectedness in the financial system.

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BANCO DE MÉXICO

Outline[1]

Introduction

Data and notation

The Mexican multiplex network

Initial Results

Conclussions and further work

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[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.

Introduction

Most of the research on financial networks has focused on interbank networks and mostly in one type of market activity.

Clearly, these networks doesn't explain such high interconnectedness of the financial system. However, there are some important exceptions (I am sorry if I miss some):

- Montagna & Kok (2013)
- Bargigli et al. (2015)
- Molina-Borboa et al. (2015)
- **Poledna et al. (2015)**
- Aldasoro & Alves (2016)
- Bravo-Benitez et al. (2016)
- Musmeci et al. (2016)
- Bookstaber & Kenett (2016)

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 real interconnectedness and the complexity of the financial system

- 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 $a_{ij}^{[\alpha]} = 1$ otherwise.

If the links have weights, as it is the case in many financial networks, then the system can be described by the set of weighted matrices

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

Definitions

Then we have to move from the degree in one layer $k_i^{[\alpha]} = \sum_{i \neq j}^{N} a_{ij}^{[\alpha]}$ to the multiplex degree $\boldsymbol{k}_i = \{k_i^{[1]}, ..., k_i^{[M]}\}$

A node, i, is said to be active in a layer, α, if $k_i^{[\alpha]} > 0$. Let $b_i^{[\alpha]}$ denote the activity of a node in layer α, then $b_i^{[\alpha]} = 1$ if the node is active in layer α and 0 otherwise. The activity vector is defined as:

$$\boldsymbol{b}_i = \{b_i^{[1]}, ..., b_i^{[M]}\}$$

The total activity $B_i = \sum_{\alpha=1}^{M} b_i^{[\alpha]}$ represents the number of layers in which the node i is active.

Two empirical facts about multiplex networks is that not all nodes have connections in all layers and the node activity is heterogeneously distributed.

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.

Such models cluster the participants into blocks sharing similar connection properties.

In the multplex network context, this characterization take into account more than one kind of relationship.

The formal definition of the multiplex version of SBM is:

Let Q be the number of blocks and $Z_i = q$ if the individual i belongs to block q and let n be the number of nodes. Then,

$\forall (i,j) \in \{1,..,n\}^2, i \neq j, \forall w \in \{0,1\}^K, \forall (q,l) \in \{1,..,Q\}^2,$

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

$$P(Z_i = q) = \alpha_q$$

Definitions

This kind of model requires to estimate $(2^K - 1)Q^2 + (Q - 1)$ parameters:

$$\boldsymbol{\alpha} = (\alpha_1, .., \alpha_Q)$$

$$\boldsymbol{\pi} = (\pi_{ql}^{(w)})_{w \in \{0,1\}^K, (q,l) \in \{1,...,Q\}^2}$$

$$\theta = (\boldsymbol{\alpha}, \boldsymbol{\pi})$$

This parameters are estimated using a variational EM algorithm, which is a robust and flexible tool that theoretically converges towards the maximum likelihood estimates.

Outline

Unsecured Interbank and repo markets

(a) Unsecured interbank network   (b) Interbank Repo network
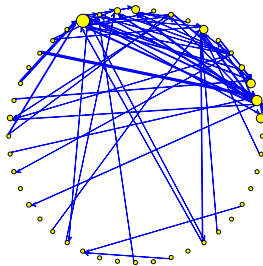
Unsecured Interbank and repo markets
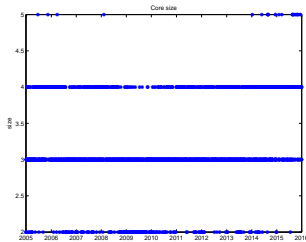
(c) Core size
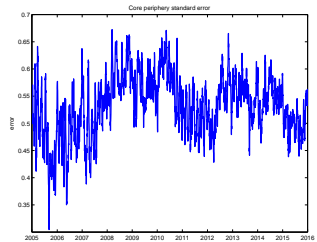
(d) Core periphery error

Payment system and total exposures network
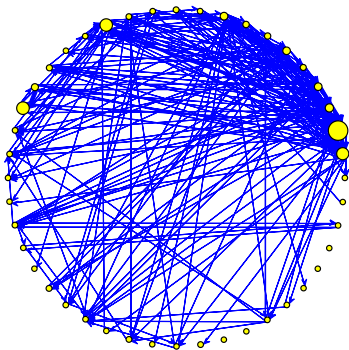
(e) Payment flows network
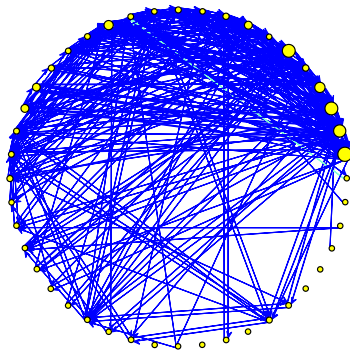
(f) Total exposures interbank network

The interbank repo market average HHI

Lending HHI
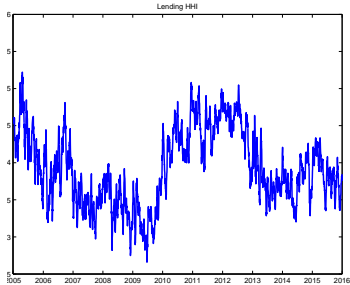
The Completness Index (CI) for the repo network

Completness index
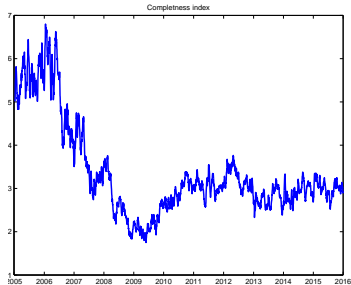
Average Clustering coefficient of the repo network

Clustering Coefficient
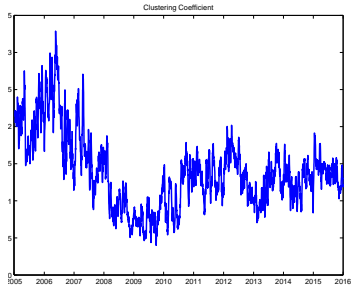
Extended repo Network
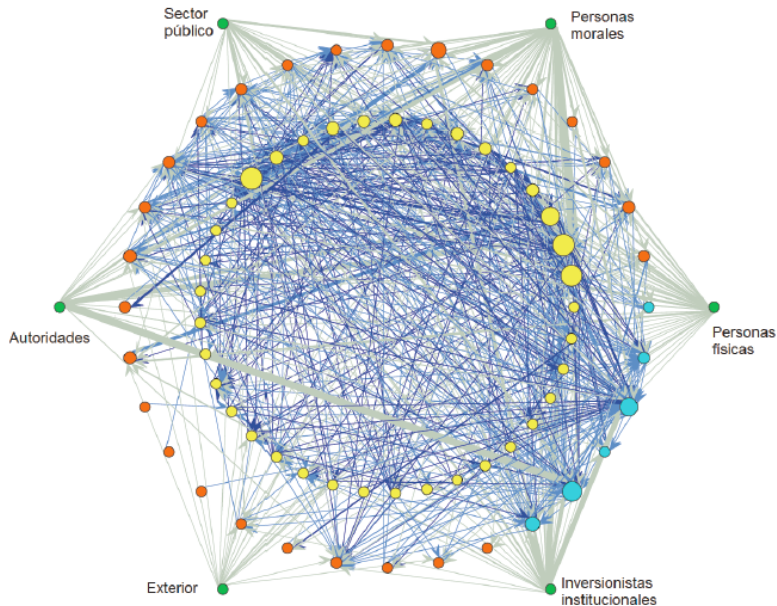
Securities cash market
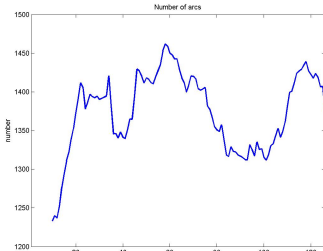
(g) Bond Market number of arcs
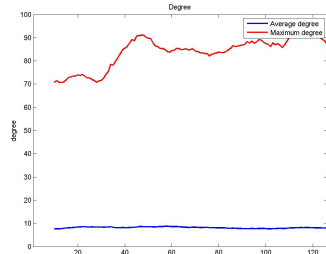
(h) Bond Market degree

Securities cash market
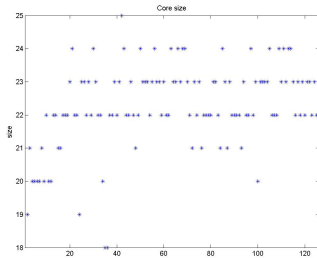
(i) Bond Market size of the core
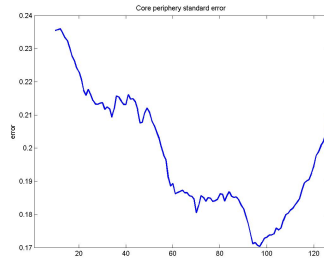
(j) Bond Market error for the core-periphery model

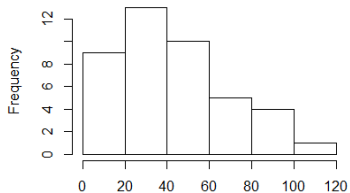# Surprise Network
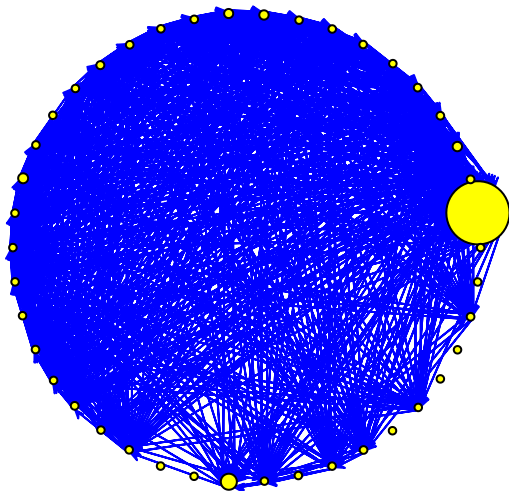
The securities holdings of banks

Outline

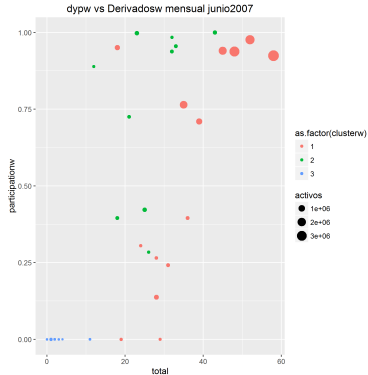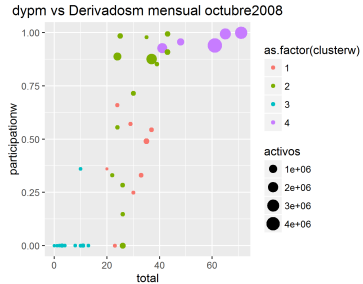# Empirical distributions

(k) Total Overlapping Degree
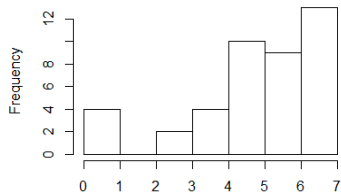
(l) Total Activity

SBM in the Mexican multiplex I
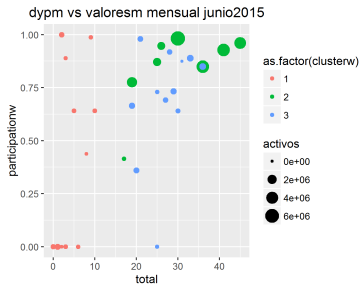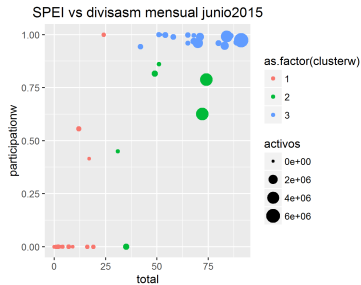

(m) June 2007
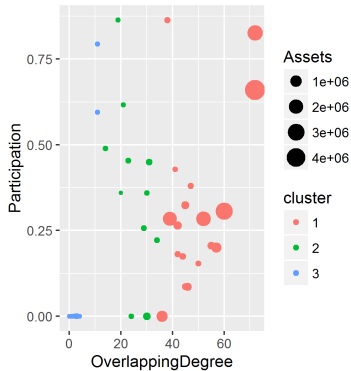
(n) October 2008

SBM in the Mexican multiplex II

(o) June 2015

(p) June 2015

SBM in the Mexican multiplex III

(q) October 2015

(r) June 2010

SBM in the Mexican multiplex IV

	Marginal Derivatives			
Cluster	1	2	3	4
1	0,911352	0,107149	0,001714	0,881911
2	0,154286	0,10882	0,000569	0,28902
3	0,001781	0,000611	3,02E-05	0,013551
4	0,882816	0,439329	0,025345	0,970987

	Derivatives given Dyp			
Cluster	1	2	3	4
1	0,991585	0,01614	0,339541	0,992222
2	0,315733	0,10898	0,002419	0,322823
3	0,08663	0,001624	0,00012	0,00534
4	0,991735	0,771587	0,034975	0,994253

Systemic risk in a multilayer context
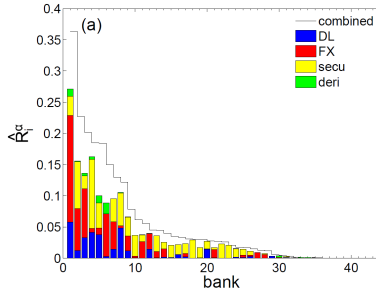
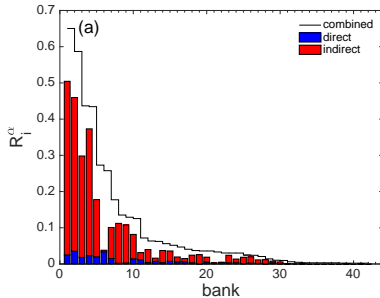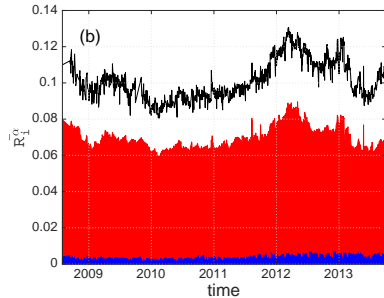(s) Systemic Risk Profile
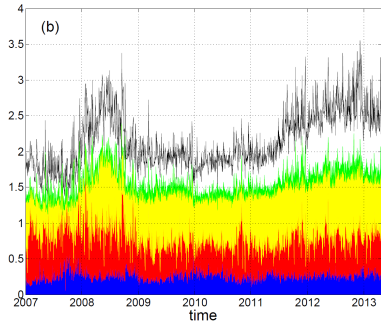
(t) Debt rank series

Overlapping portfolios and systemic risk

(u) Systemic Risk Profile

(v) Debt rank series

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
- Explore the time dimension
- 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.

References

- Poledna, S., S. Martinez-Jaramillo, F. Caccioli & Stefan Thurner (2016) Quantification of systemic risk from overlapping portfolios

- Battiston, F., V. Nicosia & V. Latora (2016) The new challenges of multiplex networks: measures and models

- Bookstaber, R. & D. Kennet (2016) Looking deeper, Seeing more: A Multilayer Map of the financial System

- Barbillon, P., S. Donnet, E. Lazega & A. Bar-Hen (2015) Stochastic Block Models for Multiplex Networks: an application to the network of researchers

- Halu A., R. Mondragon, P. Panzarasa & G. Bianconi (2013) Multiplex PageRank

Thank you

- Aseguradoras
- Banca de Desarrollo
- Banca Múltiple
- Casas de Bolsa
- Fondos de Inversión
- Gobiernos Centrales Extranjeros
- Otras Inst. Fin. Extranjeras
- Otras Inst. Fin. Mexicanas
- SIEFOREs