Credit risk and its effects on the interbank market

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Motivation

- Increasingly complex and interrelated networks as one of the main source of risk, amplification and propagation of shocks.
- Extensive literature on the structure of these networks and the effects of these structures on the propagation of both microeconomics and macroeconomic shocks.
- Contagion through commercial indebtedness among firms or economic sectors has deserved less attention (Acemoglu et al., 2005)

Objective

This work aims to contribute in filling that gap by building a commercial and financial debt network for Uruguay.

- Uruguay has a small interbank market:
  - In a stress scenario, contagion through the interbank market is low.
- There is some evidence about the effect that default by firms may have on banks:
  - Directly, through financial credit it is quite well undertood.
  - Indireclty, through commercial credit linkages there is less empirical evidence.
- We want to provide an empirical quantification on the latter type of effects.

Contribution

- Conduct a survey on commercial debt to a sample of firms:
  - Representative of the universe of firms with more than 50 employees
  - Does not include firms belonging to the primary activity sector, financial intermediation, public sector or real state activities.
  - For these sectors connections are inferred.
- Combine this information with balance sheet and credit registry data to build a commercial and financial debt network.
- Provide a series of measures of interconnectedness and topology of the networks.
- Identify the most central firms in terms of commercial debt, and the most central banks in the network.
- Quantify the exposition of banks to credit risk originated in firms
- Final goal: Perform a stress test exercise consisting in the propagation of a default shock in order to analyze the vulnerability of the network.

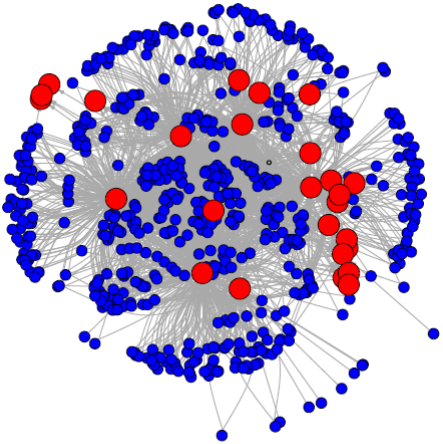
Data sources

- Firm level survey conducted to 240 firms by the Central Bank of Uruguay in October 2018 with information about:
  - The amount of commercial debts and sales credit.
  - The three main debtors and creditors for each firm.
  - Sectorial information of firms, debtors and creditors.
- Balance sheet data from the Central Bank economic activity survey.
- Central Bank Credit Register database containing all the loans given to firms by banks.

Network

- **Firm-Bank network**: We build a network considering a total of 240 firms and we add banks and other financial institutions (26 institutions in total - 11 banks)
  - Links between nodes represent financial credit
- **Bank-Bank network**: We also build a network for interbank loans
- **Firm-Firm network**: Two different approaches
  - **Inferred**: Considering the three main debtors and creditors for the 240 firms in the survey
  - **Imputed**: Only with data of the 240 firms we use some imputation methods to complete the relationship between these firms.

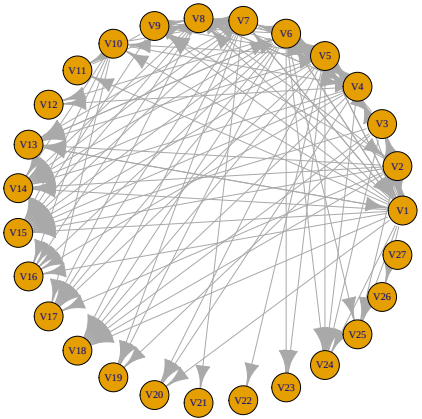
Firms-Banks network



Firms-Banks network

Descriptive Numbers	
Survey firms	240
Survey firms + main debtors and creditors	1073
Total firms with financial credit	613
Proportion of firms with FC	0.57

Bank-Bank network



Network measures

- In order to characterize the network and identify the nodes (banks) that are more central we use conventional measures of centrality
- As our interest is in the bank credit risk exposition we also compare the differences in this measures when considering the Bank to Bank network and the Firm and Bank network (inferred)

Network measures: Centrality I

- **Objective:** Identify the most important or central node in the network. The measures differ in the concept of what we mean by important or central.
- **Degree centrality** of a node defined as the number of edges attached to it. In the Firm-Bank network it's equivalent to the In-degree centrality
- **In-degree centrality** only considers the edges that go to node i
- **Out-degree centrality** only considers the edges that originate in the node i

Network measures: Firms to bank and Bank to Bank

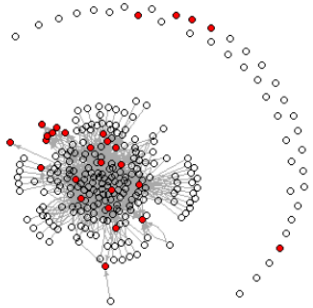
Credit to firms	links	%	Bank to bank	links in		links out
B6	461	75%	**B1**	25	**B1**	19
B4	420	69%	**B6**	23	**B6**	18
B7	324	53%	**B5**	20	**B5**	13
B5	273	45%	**B7**	14	**B7**	10
B1	248	40%	**B8**	13	**B2**	9
B8	180	29%	**B4**	12	**B3**	7
B9	88	14%	**B2**	11	**B4**	7
B10	66	11%	**B3**	10	**B8**	7
B13	28	5%	**B15**	10	**B10**	6
B3	26	4%	**B9**	8	**B9**	5

Bank centrality

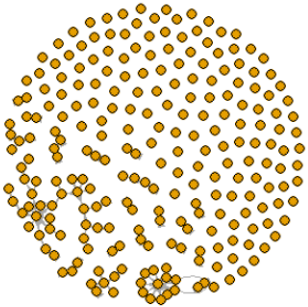
- Banks ranking differs if we consider the interbank market or the financial credit between firms and banks.
- Our main interest is to add the layer firm to firm commercial debt to the network.
- We have as starting point the 240 firms from the survey and the commercial debts between them if they are classified for the others as main debtor or creditor
- We also have the financial debt of this 240 firms.

Firms-Firms network imputed : starting point

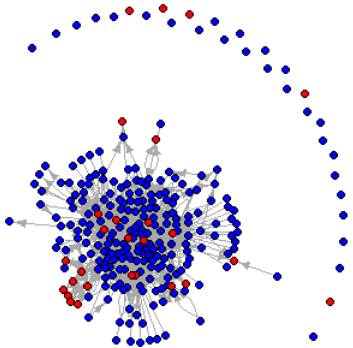
240 Firm - Bank



240 Firm - Firm network starting point

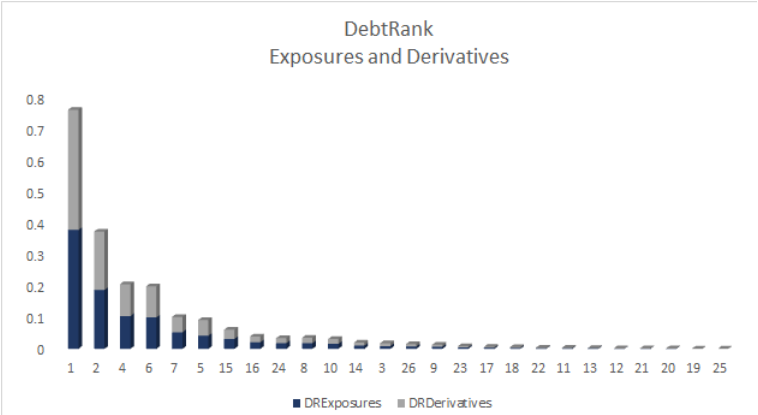


Firms-Firms-Banks network imputed : starting point

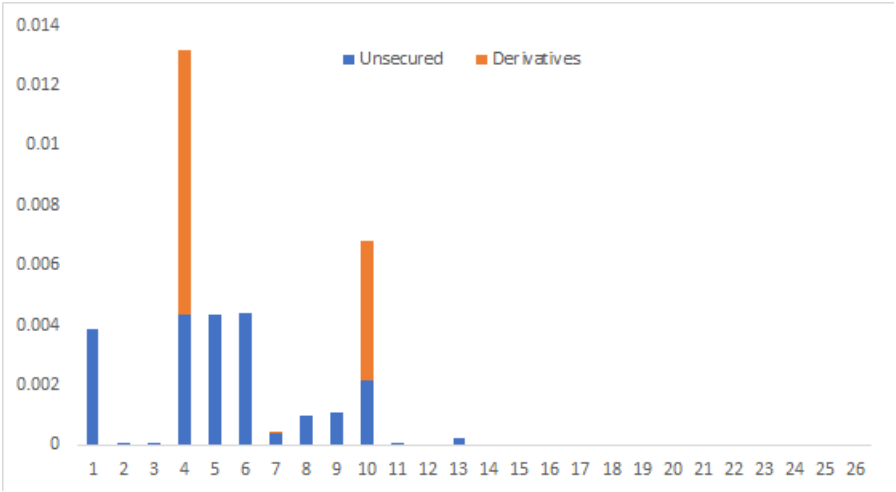


Debt rank

Debt Rank of node i, is a number measuring the fraction of the total economic value in the network (equity) that is potentially affected by the distress or the default of node i. We obtain debt rank for financial institutions considering the inter-bank credit exposures and derivatives.



Debt rank without initial shock



Network reconstruction methods

- **Maximum entropy (ME)** tends to create complete networks. Initial guess network: firm i's exposure to firm j is the product of i's aggregate credit position and firm j aggregate debt position. Then the network is re-escale by the aggregate position constrains. Upper bound of connections (Upper y Worms, 2004).
- **Minimum density (MD)** Minimises the number of links necessary for distributing a given volume of loans. Lower bound of connections (Anand et al., 2014)
- **Fitness model** An adjacent matrix is constructed considering the constrains about the total of creditors and debtors and then weights are assigned using the RAS algorithm. Intermediate network.
- There are other methods well documented in Anand et al. (2017)

Firm to firm fitness model network reconstruction

- We have a system of N firms
- For each firm i we know the total amount a_i of loans to other firms, the total amount l_i of money borrowed from other firms
- The number of creditors k_i^{out} and the number of debtors k_i^{in}
- We also know the identity of a subset of creditors and debtors (v_i^{out} and v_i^{in})

Problem definition

Given the information specified above, we have an incomplete matrix of interfirm exposures, which we need to fill by satisfying the constraint on the total in and out degree and in and out strength of each node.

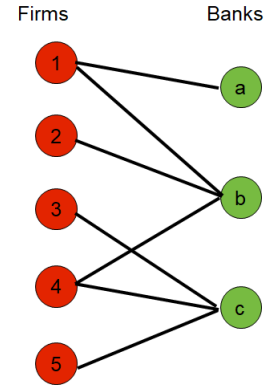
Firm-Firm network using fitness model

- Reconstruction of firm-firm network
  - Step 1: First we reconstruct a binary adjacency matrix that satisfies (on average) the constraint on in and out degree using a fitness model
  - Step 2: We assign weights to the links using the RAS method
- Building a network of effective exposure of banks towards firms
  - in the presence of credit relationships between firms, a bank can be exposed towards firms it did not directly lent to.
  - if bank a lends to firm i and not to firm j, but firm i lends to firm j, the inability of firm j to pay its debt towards bank i may affect a.

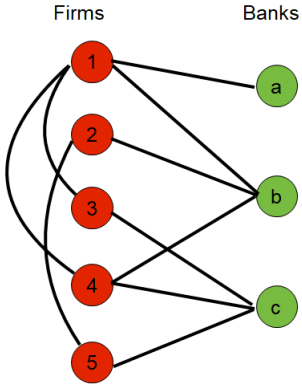
Network of effective exposure

- We have a bipartite network of relations between bank and firms
- Firms are however not independent, there are credit relations between them
- This means that banks could have "hidden" exposures towards firms they are not directly linked to
- **We want to quantify the importance of these hidden exposures**

A toy example



Nominal exposures:
Bank a is exposed to firm 1 only



Effective exposures:
Bank a is actually exposed to other firms (e.g. 3 and 4) through the firm-firm network

Quantifying effective exposures

- We propose a simple way to quantify effective exposures.
- The method is similar to the one proposed by Elliot, Golub and Jackson for stock ownerships.
- It is based on a self-consistent relation and is related to network centrality measures

Quantifying effective exposures II

- V_{ai} exposure of bank a to firm i
- W_{ij} Debt of firm i towards firm j, l_i total debt of firm i
- $\Pi_{ij} = \frac{W_{ij}}{l_i}$ fraction of firm i's debt own by firm j
- We estimate the effective exposure of bank a toward firm i as

$$\tilde{V}_{ai} = V_{ai} + \sum_j \Pi_{ij} V_{aj} + \sum_{jk} \Pi_{ik} \Pi_{kj} V_{aj} + \dots$$

Nominal exposure of a to i

Nominal exposure of a to j times fraction of i's debt owned by j

Nominal exposure of a to j times fraction of k's debt own by j times fraction of i's debt owned by k

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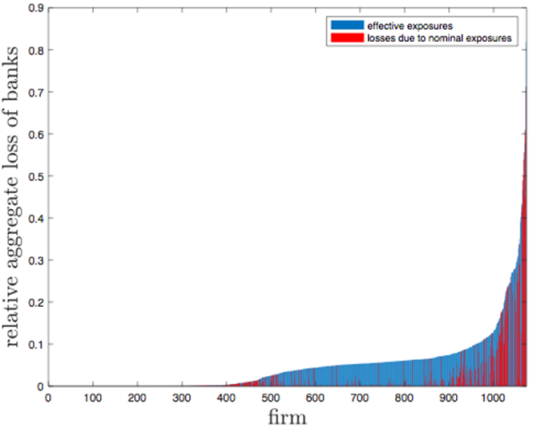
In more compact form

- Effective exposure of bank a to firm i: $\tilde{V}_{ai} = \sum \left[(1 - \Pi)^{-1}\right]_{ij} V_{aj}$
- The underlying assumption is that if a firm defaults, its creditors (linearly) propagate some loss to their creditors, and so on.
- In practice the propagation could stop if some creditors absorb the loss without passing it further on
- **This is an upper bound to effective exposures. Nominal exposures are a lower bound.**

A stress test experiment

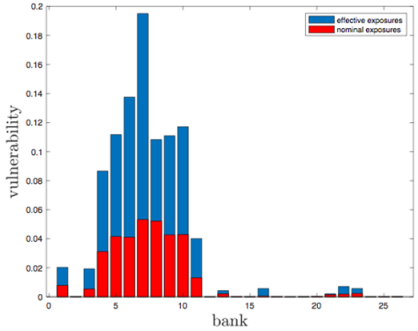
- We imagine a firm defaults
- We compute the portfolio losses experienced by banks in the system due to nominal vs. effective exposures.
- We compute the impact of a firm as the fraction of banks equity that would be impacted by the default of the firm
- **We compute the vulnerability of a bank as the fraction of equity lost averaged across all initial shocks**

Impact to firms



Some firms that appear to be unimportant by looking at nominal exposures are in fact very important because of their position in the firm-firm network

Vulnerability of banks



Neglecting effective exposures can significantly underestimate banks vulnerability

What's next?

- Expand the network, and obtain the full commercial debt network for firms with more than 50 employees (total of 1600 firms).
- Check over the assumptions that we made (consider collateral for firms and provisions that Banks have over credits)

What do we take from this course?

- Three networks and the analysis of their topology.
- Debt rank for financial institutions considering the inter-bank credit exposures and derivatives.
- The quantification of the bank exposition (Debt rank) to credit risk originated in firms (directly and indirectly).

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