Commercial and financial debt network in Uruguay

Andrea Barón  Victoria Landaberry  Rodrigo Lluberas  Jorge Ponce

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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 industries or economic sectors has deserved less attention (Acemoglu et al., 2005)
Objective

This paper 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 understood.
  - Indirectly, through commercial credit linkages there is less empirical evidence.
- We 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 corporates 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 network.

- Identify the most central sectors in terms of commercial debt, and the most central banks in the network.

- 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.
We build a network considering a total of twelve sectors in the economy.

**Cuadro: Total sales credit and commercial debt (Uruguayan pesos)**

<table>
<thead>
<tr>
<th>Sector</th>
<th>Firms</th>
<th>Sales credit</th>
<th>Commercial debt</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary Activities</td>
<td>0</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Manufacturing industry</td>
<td>101</td>
<td>65.494.037.217</td>
<td>30.165.504.698</td>
</tr>
<tr>
<td>Electricity, gas and water</td>
<td>1</td>
<td>29.244.106</td>
<td>18.172.739</td>
</tr>
<tr>
<td>Building trade</td>
<td>2</td>
<td>1.269.045.595</td>
<td>494.193.982</td>
</tr>
<tr>
<td>Commerce</td>
<td>43</td>
<td>24.454.984.231</td>
<td>21.451.037.893</td>
</tr>
<tr>
<td>Hotels and restaurants</td>
<td>8</td>
<td>441.909.218</td>
<td>365.789.382</td>
</tr>
<tr>
<td>Transportation, storage and communications</td>
<td>38</td>
<td>10.579.487.571</td>
<td>9.353.670.484</td>
</tr>
<tr>
<td>Financial intermediation</td>
<td>0</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Real State</td>
<td>0</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Public sector</td>
<td>0</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Teaching</td>
<td>9</td>
<td>2.330.114.133</td>
<td>246.611.246</td>
</tr>
<tr>
<td>Others</td>
<td>38</td>
<td>16.076.815.742</td>
<td>7.047.796.714</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>240</strong></td>
<td><strong>120.675.637.813</strong></td>
<td><strong>69.142.777.138</strong></td>
</tr>
</tbody>
</table>

Source: Survey of economics expectation, October 2018
Network measures

- The network structure is defined by the nodes and edges that compose it. In the debt commercial network our nodes are the economic sectors and the edges are the linkage between two nodes. In this case, edges represent whether one sector owes to another one.

- In order to characterize the network and identify the nodes that are more central we use conventional measures about the topology of the network. In particular, we obtain different centrality measures, size, density, transitivity and reciprocity of the network.
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.

\[ DG_i = \sum_{j=1}^{n} (A_{ij} + A_{ji}). \tag{1} \]

In-degree centrality only considers the edges that go to node \( i \) (all the sectors that owes debt to node \( i \))

\[ In - DG_i = \sum_{j=1}^{n} (A_{ji}). \tag{2} \]
Network measures: Centrality II

- **Out-degree centrality** only considers the edges that originate in the node $i$, (all the sectors that $i$ owes to):

$$Out-DG_i = \sum_{j=1}^{n} (A_{ij}).$$  \hspace{1cm} (3)

- **Centrality closeness** takes into account, not only the number of linkage or nodes related to define the centrality of the node, but also the distance between the different nodes. Following this measure, a node is more central when the distance between this nodes and all the other nodes in the network is the lowest. Centrality closeness is the inverse of the sum of the distances of the geodesic path (shortest path $d$) between the node $i$ and all the other nodes in the network (Freeman, 1978).

$$CC_i = \frac{1}{\sum d(i,j)}.$$  \hspace{1cm} (4)
Network measures: Centrality III

- **Betweeness centrality** is defined as the proportion of times that node $i$ is necessary to node $k$ to reach node $j$ following the geodesic path between nodes $k$ and $j$.

  \[ BC_i = \sum_k \sum_j \frac{g_{kij}}{g_{kj}} \] (5)

- **Eigenvector centrality**: considers the influence of a node. It assigns a score to each node in the network considering that having connections with nodes that also have high level of connections makes that node more central (Solá et al., 2013).

  \[ EC_i = \sum_k \sum_j \frac{g_{kij}}{g_{kj}} \] (6)
In this paper we use all the measures as they provide different information about the importance of a particular node.

Following Valenti et al. (2008) in general these measures are positive correlated but the magnitude of the correlation is not high enough to assume that they are redundant.
Network measures: Size and density

- **Size measures** are used to compare two networks as a whole or to evaluate the evolution of the same network in two different time moments.
  - **Diameter** is the longest path in terms of number of edges between two nodes of the network.
  - **Mean distance** is the mean of the number of connections that exist between two nodes in the network.

- **Density** measures the interconnection level between all nodes. It is defined as the proportion of connections in the network over the maximum number of connections that could exist in it.
Network measures: Reciprocity and transitivity

- **Reciprocity** is the probability that two nodes in a network are mutually related.
- **Transitivity** is the probability that two nodes are connected.
The structure of the network has implications about the way that shock propagates.

A network with medium values of density, reciprocity and transitivity would be more susceptible to the widespread of shocks.

The structure may have different effects for different shocks size as pointed by (Acemoglu et al., 2015): A perfectly diversified network is optimal for moderate shocks while is the worst possible in the context of a large shock.
Commercial debt network in Uruguay

Note: Edges width represent the amount owed and the size of the nodes represent total commercial debt from the sector.
A medium connectivity network

- Twelve directed nodes
- Diameter=3
- Mean distance=1.52
- Density=0.51
- Reciprocity=0.77
- Transitivity=0.69

This medium connectivity in the network
  - Is better for large shocks according to Acemoglu et al. (2015).
  - But, the widespread of contagion of a particular sector default may be bigger than in other networks (Elliot et al., 2014).
The most central sectors in the network

- “Commerce”, “manufacturing” and “transportation, storage and communication” are the most central nodes.
- “Real estate” is the less central sector.
- “Transportation, storage and communication” sector is very central in terms of the connections with other economic sectors but its debt is more diversified and its indebtedness level in terms of its production (5%) is small than the observed for “commerce” and “manufacturing”.
- There is a high level of indebtedness from the “commerce” sector to the “manufacturing” sector.
<table>
<thead>
<tr>
<th>Sector</th>
<th>Centrality</th>
<th>In degree centrality</th>
<th>Out degree centrality</th>
<th>Closeness centrality</th>
<th>Betweeness centrality</th>
<th>Eigenvector centrality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manufactirung industry</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Commerce</td>
<td>3</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Transportation, S. and C.</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Others</td>
<td>4</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>4</td>
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<tr>
<td>Hotels and restaurants</td>
<td>5</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Buildings</td>
<td>6</td>
<td>4</td>
<td>5</td>
<td>5</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Electricity, G. and W.</td>
<td>7</td>
<td>5</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>Public Sector</td>
<td>7</td>
<td>6</td>
<td>4</td>
<td>4</td>
<td>8</td>
<td>7</td>
</tr>
<tr>
<td>Teaching</td>
<td>7</td>
<td>7</td>
<td>4</td>
<td>4</td>
<td>8</td>
<td>11</td>
</tr>
<tr>
<td>Primary Activity</td>
<td>7</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>Financial Intermediation</td>
<td>7</td>
<td>7</td>
<td>4</td>
<td>4</td>
<td>9</td>
<td>10</td>
</tr>
<tr>
<td>Real State</td>
<td>8</td>
<td>8</td>
<td>7</td>
<td>7</td>
<td>9</td>
<td>12</td>
</tr>
</tbody>
</table>
Financial debt network in Uruguay

- Most of the banking institutions are connected with all sectors, except for 4 banks.
- We obtain the centrality measure of the banks in the network, the interconnections are weighted by the participation of the credit to firms of each institution on the total credit to firms granted by the financial system.
- The most central banks identified with centrality measures coincide with those that have a higher capital requirement for systemic risk.
- Banks with higher capital requirements for systemic risk are also the most exposed to the economic activity sectors that were identified as the most centrals in terms of commercial indebtedness.
Financial indebtedness of the most central sectors

Note: Edges width represent the amount owed and the size of the nodes represent total financial debt from the sector.
### Financial and commercial debt network

<table>
<thead>
<tr>
<th>Sector</th>
<th>Financial debt (% GDP)</th>
<th>Commercial debt (% GDP)</th>
<th>Total debt (% GDP)</th>
<th>Participation of sectoral production in GDP (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary Activities</td>
<td>75.8%</td>
<td>NA</td>
<td>NA</td>
<td>5.6%</td>
</tr>
<tr>
<td>Manufacturing industry</td>
<td>32.6%</td>
<td>14.1%</td>
<td>46.6%</td>
<td>11.7%</td>
</tr>
<tr>
<td>Electricity, gas and water</td>
<td>32.5%</td>
<td>0.04%</td>
<td>32.5%</td>
<td>2.7%</td>
</tr>
<tr>
<td>Building trade</td>
<td>8.6%</td>
<td>0.3%</td>
<td>8.9%</td>
<td>9.4%</td>
</tr>
<tr>
<td>Commerce</td>
<td>38.2%</td>
<td>11.7%</td>
<td>49.9%</td>
<td>10.0%</td>
</tr>
<tr>
<td>Hotels and restaurants</td>
<td>5.6%</td>
<td>0.5%</td>
<td>6.1%</td>
<td>4.1%</td>
</tr>
<tr>
<td>Transportation, storage and</td>
<td>21.6%</td>
<td>9.4%</td>
<td>31.0%</td>
<td>5.4%</td>
</tr>
<tr>
<td>communications</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Financial intermedation</td>
<td>11.2%</td>
<td>NA</td>
<td>NA</td>
<td>4.7%</td>
</tr>
<tr>
<td>Real State</td>
<td>3.1%</td>
<td>NA</td>
<td>NA</td>
<td>11.6%</td>
</tr>
<tr>
<td>Public sector</td>
<td>12.7%</td>
<td>NA</td>
<td>NA</td>
<td>5.1%</td>
</tr>
<tr>
<td>Teaching</td>
<td>0.8%</td>
<td>0.3%</td>
<td>1.1%</td>
<td>4.7%</td>
</tr>
<tr>
<td>Others</td>
<td>9.5%</td>
<td>2.7%</td>
<td>12.2%</td>
<td>14.1%</td>
</tr>
</tbody>
</table>
Stress test framework

- We perform a default contagion exercise among the economic sectors in a context of financial credit restriction.
- We consider that each economic sector, individually, enters into default and affects the creditor sectors, whose current assets are reduced by the amount equivalent to the amount owed by the sector that enters into default.
- And study the propagation of the shock through the network.
- The sector affected will be able to honor their debts if their short term assets are bigger than their short term liabilities.
- Otherwise, these sector will also default and propagation through the network continues.
Stress test results
Stress test results

- In all cases, the total time of default propagation is less or equal than 2.
- The maximum contagion, by the propagation of the shock is produced when “building” sector defaults. In this situation also defaults “teaching”, “transportation” and “hotels and restaurants” sectors.
- The most exposed sectors to contagion are “transportation, storage and communication” and “hotels and restaurants”. These sectors default by contagion effect in all scenarios.
- Although the “manufacturing” and “commerce” sectors are the most central and with the highest level of indebtedness, they have a large amount of liquid assets in the short term, which allows to survive all the shocks coming from other sectors.
Future work

- We are working with UCL-CEMLA to build a complete commercial debt network at a firm level. Fill in the blank the matrix to get the whole debt network.
- Perform stress test at a firm or economic sector level and understand how the default of firms affects the financial system.
- Unique data to build an unique network that will provide empirical evidence for other works.
- Perform the commercial debt survey again to follow the network through time.
References


Valenti, T., Coronges, K., Lakon, C., Constenbader, E., 2008. How correlated are network centrality measures?