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Resumen

En este trabajo se construye una red de endeudamiento comercial que permite identificar los sectores económicos centrales, suministrar una visión más completa del endeudamiento total de los mismos y de las interrelaciones crediticias entre sectores y de estos con el sector bancario en Uruguay. "Comercio", "Industria manufacturera" y "transporte, almacenamiento y comunicaciones" son sectores centrales en la red de endeudamiento comercial. Utilizando la red de endeudamiento en un ejercicio extremo de tensión, se encuentra que "transporte, almacenamiento y comunicaciones" y "hoteles y restaurantes" son fuertemente afectados en todos los casos, siendo los sectores más expuestos en términos de contagio. "Comercio" y la "Industria manufacturera" son sectores centrales en términos de endeudamiento, pero poseen activos líquidos que les permiten soportar los choques hipotéticos provenientes de otros sectores.

JEL: G17, G32, G33, L14

Abstract

We build a commercial credit network, identify the most central economic sectors in terms of commercial debt, and provide a more complete idea of total indebtedness and financial interlinks between firms and banks in Uruguay. "Commerce", "manufacturing" and "transportation, storage, and communication" are the most central sectors in the commercial credit network. In a stress testing exercise, "transport, communication and storage" and "hotels and restaurants" are deeply affected in all cases. These sectors are the most exposed in terms of contagion. "Commerce" and "manufacturing" are central and have the highest level of indebtedness, but they have a large amount of liquid assets, that allows them to overcome shocks coming from other sectors.

Keywords: Commercial credit network, financial interlinks, financial contagion, financial stability

☆ The views expressed therein are those of the authors and do not necessarily represent the opinion of the Banco Central del Uruguay.

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1 Introduction

In the aftermath of the global financial crisis, a strand of the literature has pointed out to contagion through increasingly complex and interrelated networks as one of the main sources of risk, amplification and propagation of shocks. In recent years, a growing body of literature has studied the structure of these networks and the effects of these structures on the propagation of both microeconomics and macroeconomic shocks. This literature has focused on contagion either between banking institutions or the financial system as a whole. Nevertheless, research on the effects of contagion through commercial indebtedness among firms, industries and economic sectors has deserved less attention (see, for instance, Acemoglu et al. (2005)).

This paper aims to contribute in filling that gap. We propose a study of the network of commercial and banking indebtedness using unique data for Uruguay, a country with a relatively underdeveloped financial sector where a large proportion of firms rely on their own funds or commercial credit to finance their activities. We conduct a survey to a sample of firms, which is representative of the universe of corporates with more than 50 employees in the country, and construct a novel data set with information about commercial and banking interlinks among economic sectors. We provide a series of measures of interconnectedness and identify the most central sectors in terms of commercial debt, and the most central banks in the network. We also perform a stress test exercise consisting in the propagation of a default shock in order to analyze the vulnerability of the network. To the best of our knowledge, there is no previous work of this kind on the potential problems that negative shocks to firms may impose to the banking sector through the contagion between firms via commercial credit.

The data gathered through the survey allow us to build the commercial credit network between economic sectors. We analyze the structure of the network and its main characteristics by using traditional measures such as centrality, size, density, reciprocity and transitivity. As a result, we identify which sectors are the ones most connected in terms of commercial credit and which sectors impose a larger threat to the stability of the network. According to the results, "commerce", "manufacturing industry" and "transportation, storage and communication" are the most central sectors in the commercial credit network, while "real estate" is the less central sector. We also identify a high level of indebtedness of the "commerce" sector with the "manufacturing" sector. With the linkage of the commercial debt network and information from the credit registry we identify the degree of centrality of the banks. The top banks in this ranking are the ones facing higher capital requirements due to their contribution to systemic risk.

In a second stage, we link the survey data with detailed balance sheet data from the Annual Economic Activity survey and with the Credit Registry, a database containing all the loans given to firms by banks. With this information we are able to have a complete picture of the credit network by considering both commercial and banking indebtedness. The complete network allows us the identification of the direct exposition of each banking institution to each economic sector by taking into account not only the direct indebtedness, but also the exposure of the banking institutions to the other sectors by considering the interconnection of sectors through commercial indebtedness. Overall, this effort gives us a useful tool for the analysis of financial stability.

Finally, we perform a stress test exercise to complete our analysis about how credit risk is transferred trough the commercial credit network. More precisely, we assume that a given sector defaults in its obligations and then consider its effects on the other sectors of the network. We assume that firms cannot borrow from the financial system if their current assets are less than their short-term liabilities. Once the trigger sector defaults, current assets of the affected sectors are reduced by an amount equivalent to their credit to the sector that has defaulted. Otherwise stated, we assume an extreme stress scenario where the trigger sector defaults in full and the loss given default is a hundred percent. In turn, sectors suffering contagion from the sector originally going into default will be able to honor their debt if their current assets are larger than their short term liabilities. Otherwise, these sector will also default and the propagation through the commercial network will continue.

When performing the stress test exercise, the sectors "transport, communication and storage" and "hotels and restaurants" are affected by the default of any of the other sectors. These sectors are the most exposed in terms of contagion. Although the "manufacturing" and "commerce" sector are the most central according to centrality measures and have the highest level of indebtedness, they have a large amount of liquid assets in the short term, which allows them to survive all the shocks coming from other sectors.

The rest of the paper is organized as follows. In Section 2, we present related literature. In Section 3, we describe the data. In Section 4, we introduce the different measures used in the literature to describe networks and their topology. We discuss some of the implication of this measures in terms of identify relevant sector and expected propagation results. In Section 5, we present the commercial debt and total debt network structure in Uruguay. In Section 6, we present our stress testing general framework. In Section 7, we present the main results of the exercise over the commercial debt network. Finally, in Section 8, we discuss the main conclusion of this work and further developments that could be carried out with the networks introduced in this paper.

2 Related literature

Since the global financial crisis of 2008, network contagion has gained a particular attention. However the topic is not new. At least since 1932 networks have been applied in different fields of social science (Borgatti et al., 2009). There are three different approaches to network analysis that we use in this paper.

The first one is about topology and network structure. We use different measures that allows us to characterize the commercial and banking credit networks in Uruguay. These measures, which are explained in detail in Section 4, were developed by Freeman (1978), Katz (1953), Taylor (1969), Barabási et al. (2002), Stephenson and Zelen (1989) among others.

Recent literature has centered the discussion about the uses of structure measures and their interpretation. Borgatti (2004) presents a topology of network flows and discusses the measure of centrality of a network that best matches to the type of flow represented in the network. Valenti et al. (2008) analyze the correlation between the different centrality measures. They conclude that in general these measures are positively correlated but the magnitude of the correlation is not high enough as to assume that they are redundant. They provide different information about the importance of a particular node.

There is a theoretical strand of literature about financial contagion through networks. In particular, Acemoglu et al. (2014) develop a unified framework for the study of how network interactions can function as a mechanism for propagation and amplification of microeconomic shocks. The framework nests various classes of games over networks, models of macroeconomic risk originating from microeconomic shocks, and models of financial interactions. Elliot et al. (2014) develop a general model to study financial contagious and cascades of failures among organizations linked trough a network of financial interdependence. They find that integration (greater dependence per organization), and diversification (more counterparties per organization) have different, non monotonic effects on the extent of cascades. Diversification connects the network initially, permitting cascades to travel; but as it increases further, organizations are better insured against another's failures. Integration also faces trade-offs: increased dependence on other organizations versus less sensitivity to own investments. Acemoglu et al. (2015) relate shock magnitude and network structures. According to their results, if negative shocks affecting financial institution are sufficiently smalls, then a more densely connected financial network enhances financial stability. However, when shocks are large enough, a more dense network serve as a mechanism for the propagation of shocks, leading to a more fragile financial system. In this paper, we compare the density and connection measures in terms of the commercial credit network structure based on these ideas.

Finally, other strand of the literature has focused on contagion between either banking institutions or the financial system. Calomiris et al. (2019) investigate the role of contagion on bank distress during the Great Depression mapping in detail the interbank network and examining how network connections affects the risk of bank failure. They find that banks with more correspondents (hence with greater liquidity risk) and banks whose correspondents closed, are more likely to close. Silva et al. (2016) analyze how the Brazilian interbank network evolves with respect to different types of market participants using well-known complex network measures. Souza et al. (2013) analyze the financial institution that operate in the Brazilian interbank market investigating through simulation the potential contagion that they present, the contagion losses and the contagion route associated to financial institution bankruptcies. They also compute the possibility of contagion of other markets triggered by financial institution defaults in the interbank markets. Research on the effects of contagion through commercial indebtedness among different industries or economic sectors has been less developed (Acemoglu et al., 2005).

In this paper we aim to fill that gap. To the best of our knowledge, there is no previous work on the network of commercial and banking indebtedness. Hence, this paper constitutes an original contribution to the knowledge on indebtedness links among Uruguayan firms and the financial sector. We provide, a series of measures of the commercial and banking indebtedness structure at the economic sector level. We also identify the most central sectors in terms of commercial debt and the most central banks in the network. Finally, we perform an exercise of the propagation of a default shock to analyze the vulnerability of the network.

3 Data

We survey a sample of firms that is representative of the universe of Uruguayan firms with more than 50 employees. More precisely, in October 2018 we add specific questions regarding commercial credit to the Survey of Economic Expectations that is monthly collected by the Instituto Nacional de Estadísticas (the national statistic agency) on behalf of Banco Central del Uruguay (the central bank).[1] We collect information on the amount of each firm's commercial debts and credits, and are able to identify each firm's three major debtors and creditors. We can also identify the sector of the economy to which each firm belongs to, allowing us to aggregate the results at the sector level.

With this information, we build a commercial credit network considering a total of twelve sectors in the economy. The survey does not include firms belonging to the primary activity sector, financial intermediation, public sector or real estate activities. Hence, the information about the connections with these sectors is incomplete; interlinks are inferred from the answers of other firms that declare to have debt or credit with firms of the aforementioned sectors. The number of firms in the survey and the total amount of commercial credit and debt outstanding by each sector are in Table 1.

Table 1: Total commercial credit and debt (Uruguayan pesos)

Sector	**Firms**	**Sales credit**	**Commercial debt**
Manufacturing industry	101	65.494.037.217	30.165.504.698
Electricity, gas and water	1	29.244.106	18.172.739
Construction	2	1.269.045.595	494.193.982
Commerce	43	24.454.984.231	21.451.037.893
Hotels and restaurants	8	441.909.218	365.789.382
Transportation, storage and communications	38	10.579.487.571	9.353.670.484
Teaching	9	2.330.114.133	246.611.246
Others	38	16.076.815.742	7.047.796.714
Total	**240**	**120.675.637.813**	**69.142.777.138**

Source: Survey of Economic Expectation, October 2018

[1]The survey is conducted on a sample that is chosen with a statistical criteria in order to ensure that the expansion of the answers is representative of the universe of firms with more than 50 employees in Uruguay.

In Table 2 we show the average debt and credit shares of the three main creditors and debtors. These represent, on average, 45% of total credits and debits, but there is heterogeneity across sectors. In Table 3 we present the total commercial credit that results from the sum of the three major commercial debtors of each sector, and the total commercial debt that results from the sum of the three major creditors of each sector.[2] Figures for the primary activity sector, financial intermediation, public sector and real state activities are inferred from the answers from firms in the other surveyed sectors.

Table 2: Three major creditors and debtors in total (Percentage)

Sector	**Creditors**	**Debtors**
Manufacturing industry	44.4	49.6
Electricity, gas and water	68.9	21.2
Construction	17.9	52.2
Commerce	60.3	30
Hotels and	38.1	86.6
Transportation, storage and communications	48.7	57.8
Teaching	39.1	4.8
Others	45.5	60.7
Average	**45.4**	**45.4**

Source: Survey of Economic Expectation, October 2018

We obtain additional balance sheet information using data from the Economic Activity Survey. Because the latest survey available is from 2014, we update the balance sheet items until 2018 using the Consumer Price Index (CPI). In particular, we are interested in identifying short term assets and short term liabilities other than commercial credit. The total of cash available, temporary investments and other short term liabilities, adjusted by CPI, are presented in Table 4.

[2]For all sectors, except "electricity, gas and water", the total debt and credit is bigger than the result from adding the three major creditors and debtors. For this particular sector (that is represented by only one firm in the survey), we substitute total debt and credit with the result from the sum of the three major creditors and debtors.

Table 3: Commercial credit and debt considering the three major debtors and creditors (Uruguayan pesos)

Sector	Sales credit	Debt
Primary Activities *	1.791.310.985	1.370.693.495
Manufacturing industry	7.563.863.587	4.391.350.620
Electricity. gas and water	287.842.268	873.712.455
Construction	877.426.410	331.366.354
Commerce	3.825.718.914	7.172.426.364
Hotels and restaurants	241.727.909	91.352.714
Transportation. storage and communications	2.716.065.669	729.138.071
Financial intermedation *	117.921.741	1.473.859.781
Real Estate *	1.580.979	300.279
Public sector *	30.713.827	4.787.851.624
Teaching	7.959.769	51.783.967
Others	7.094.123.862	3.282.420.196
Total	**24.556.255.920**	**24.556.255.919**

Source: Survey of Economic Expectation, October 2018

*: Inferred from the answers by firms in surveyed sectors.

Table 4: Short term assets and liabilities (Uruguayan pesos)

Sector	Cash	Temporary Investment	Other short term liabilities
Manufacturing industry	16.999.512.755	6.762.554.557	11.555.202.093
Electricity. gas and water	70.088.439	NA	112.138.566
Construction	188.174.834	NA	575.026.439
Commerce	16.444.577.276	3.198.887.316	7.234.864.743
Hotels and restaurants	920.846.913	1.827.794	745.909.160
Transportation. storage and communications	7.537.318.433	884.691.713	7.692.839.710
Teaching	62.166.078	NA	NA
Others	8.394.321.570	1.420.693.597	8.479.923.827
Total	**50.617.006.298**	**12.268.654.976**	**36.395.904.538**

Source: Survey of Economic Activity 2014 updated to 2018 using CPI

Finally, we also consider banking credit. On top of the 11 banks we define a group of other financial institutions. This group contains information about financial houses, credit management companies and financial intermediation cooperatives. Using this data, we obtain an enlarged network that represents the linkage between economic sectors and each one of those financial institutions. The data about the total financial debt for each economic sector is obtained from the Credit Registry provided by the Superintendency of Financial Services (SSF). For that, we consider the debt with the financial sector of the firms that are included in the survey and, using the corresponding sample weight, we obtain an estimation of the total financial debt for each economic sector.

Financial debt by sector is presented in Table 5.

Table 5: Financial Debt (Uruguayan pesos)

Sector	Financial debt
Manufacturing industry	88.082.844.993
Electricity. gas and water	0
Construction	215.885.823
Commerce	17.327.411.631
Hotels and restaurants	2.948.169.769
Transportation. storage and communications	12.860.617.317
Teaching	672.936.419
Others	8.664.398.114
Total	**130.772.264.066**

Source: Central Risk database, October 2018

4 Network structure measures

The network structure is defined by the nodes and edges that compose it. In the commercial credit network the nodes are the economic sectors and the edges are the linkage between two sectors. 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. Mathematically, one can represent a network by an $n \times n$ adjacent matrix A. The matrix A has elements $\mathrm{A}_{ij} = 1$ if there is an edge between i and j, and 0 otherwise. The matrix is symmetric if there is no direction between nodes, and if there is an edge between i and j then there is also an edge between j and i. In some case, when direction of the relationship between nodes represented by the edge matters, the matrix is not symmetric. This is the situation when we are working with commercial and financial debt between sectors[3]

Centrality measures are one of the most fundamental measures to characterize a network and identify the most important or central node in the network. Centrality measures differ in the concept of what we mean by important or central (Newman, 2008). The simplest centrality measure is *degree centrality* of a node defined as the number of edges attached to it. The degree centrality DG_i of a node i when the matrix A is not symmetric[4] is:

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

[3]If node i owes debt to node j, $A_{ij} = 1$. This does not imply that $A_{ji} = 1$. If node j does not owes a credit to node i, then $A_{ji} = 0$.

[4]When the matrix A is symmetric and direction in the relationship between nodes is not relevant, $DG_i = \sum_{j=1}^{n} A_{ij}$.

When there is a direction defined in the linkage between nodes, we can also define in-degree centrality or out-degree centrality (Donglei, 2012). *In-degree centrality*, defined in Equation 2, only considers the edges that go to node i (all the sectors that owes debt to node i):

$$In - DG_i = \sum_{j=1}^{n}(A_{ji}). \tag{2}$$

Out-degree centrality, defined in Equation 3, only considers the edges that originate in the node i, (all the sectors that i owes to):

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

To compare centrality measures between two or more different networks it is necessary to standardize the values by dividing the result by the total of nodes minus 1.

The node in the network with more degree centrality would be the most central. *Centrality closenness* 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 closenness, defined in Equation 4, 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):

$$CC_i = \frac{1}{\sum d(i,j)}. \tag{4}$$

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. This meassure of centrality is important when we want to consider the importance of a nodes in terms of the flow that is transmitted through that node. If we define g_{kj} as the number of geodesic path between i an j, g_{kij}, as the number of these geodesic path that pass trough node i, then the betweeness centrality of node i is presented in Equation 5:

$$BC_i = \sum_{k}\sum_{j}\frac{g_{kij}}{g_{kj}}. \tag{5}$$

Finally, *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 (Sola et al., 2013).

The Centrality measures can result in different nodes identified as the most central in the network because they consider different definitions about what makes a node central and also assumptions about the manner in which traffic flows through the network. Borgatti (2004) present a typology that point the best centrality measure according to the type of flow in the network and the method of spread. 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. Hence, they provide different information about the importance of a particular node.

Size measures include diameter and mean distance. They are use 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 and the mean distance is the mean of the number of connections that exist between two nodes in the network.

Density of the network, measures the interconnection level between all nodes. Is defined as the proportion of connections in the network over the maximum number of connections that could exist in it.

Reciprocity is the probability that two nodes in a network, where edges have a direction defined from one node to the other, are mutually related.

Finally **transitivity** is the probability that two nodes are connected.

The specific structure of the network has implications about the way that shock propagates. Elliot et al. (2014) show that the way defaults trigger further failures depends on network structure. If integration in a network (defined as the level of exposure of sectors to each other) is intermediate and the network is partly diversified, then the network is more susceptible to widespread financial failures. In terms of network measures, a network with medium values of density, reciprocity and transitivity would be more susceptible to widespread shocks. Moreover, the structure may have different effects for different shocks size as pointed by Acemoglu et al. (2015). A perfect diversified network is optimal for moderate shocks while is the worst possible in the context of a large shock.

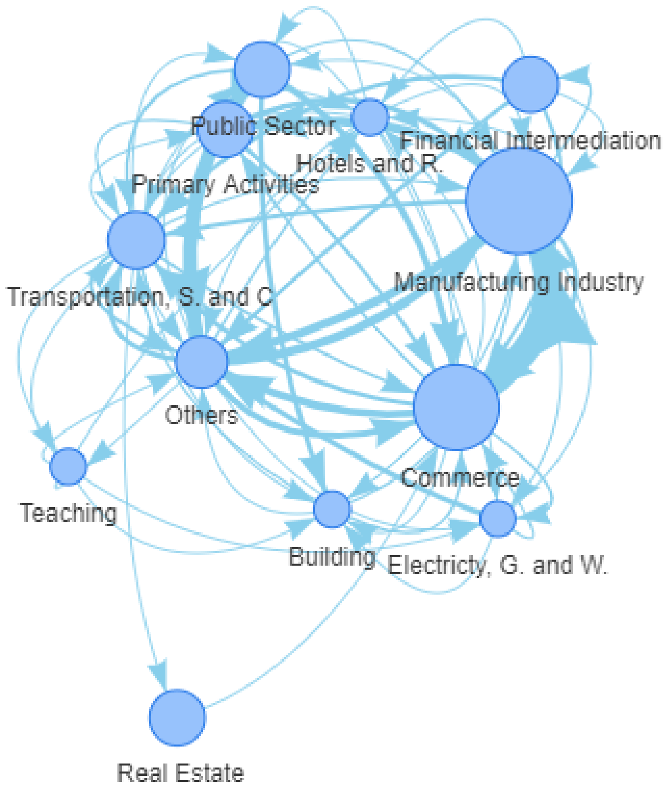
5 Commercial and banking credit networks

For the commercial credit network in Uruguay we define a total of 12 nodes representing primary activities, manufacturing, electricity gas and water, construction, commerce, hotel and restaurants, transportation, storage and communication, financial intermediation, real estate, public sector, teaching and others.[5] The edges represent the debt of one sector to another one. The sectors identified and the linkage between them are obtained from the October 2018 Economic Expectations survey. As mentioned in Section 3, the survey does not include firms belonging to the primary activity sector, financial intermediation, public sector or real estate activities. The information about the connections with these sectors is incomplete, and connections are inferred from the answers of other firms that declare to have debt or are creditors of some firm from these sectors. In general we define node n_i as the economic sector i, and edge e_{ij} as the connection resulting from the fact that sector i owes to sector j.

Figure 1 shows the graph of the network. Edges are directed from the sector that owes the debt to the corresponding creditor sector. The diameter size of the network is 3 and the mean

[5] We follow the Instituto Nacional de Estadística´s (INE) classification.

Figure 1: Commercial credit network in Uruguay



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

distance is of 1.52 edges. The network has a medium density of 0.51, which means that there is approximately a 50% of all possible connections that could exist. The reciprocity level is 0.77 and the transitivity is 0.69. According to Acemoglu et al. (2015), this medium connectivity in the network is better to accommodate large shocks, but the widespread of contagion of a particular sector default may be bigger than in other networks (Elliot et al., 2014).

The results of centrality measures imply that “commerce”, “manufacturing” and “transportation, storage and communication” are the most central nodes. “Real estate” is the less central sector. There is a high correlation between the centrality measures estimated. The “transportation, storage and communication” sector is very central in terms of the connections that it has with other economic sectors but its debt is more diversified and its indebtedness level is smaller than the observed for “commerce” and “manufacturing”. On the other hand, there is a high level of indebtedness from the “commerce” sector to the “manufacturing” sector.

Table 6: Economic sector centrality measures ranking

Sector	**Centrality degree**	**In degree centrality**	**Out degree centrality**	**Closeness centrality**	**Betweeness centrality**	**Eigenvector centrality**
Manufactirung industry	2	2	2	2	3	1
Commerce	3	1	3	3	2	3
Transportation, S. and C.	1	2	1	1	1	2
Others	4	2	3	3	4	4
Hotels and restaurants	5	3	3	3	5	5
Construction	6	4	5	5	6	6
Electricity, G. and W.	7	5	5	6	7	8
Public Sector	7	6	4	4	8	7
Teaching	7	7	4	4	8	11
Primary Activity	7	6	6	6	9	9
Financial Intermediation	7	7	4	4	9	10
Real State	8	8	7	7	9	12

In Table 6 we present a descendent rank, where 1 is the most central node according to the centrality measure. In the Appendix (Table 9) we present the results of all the centrality measures estimated for each economic sector.

In order to analyze the exposition of the banking system to the economic sectors we combine the commercial credit network with the debt to the financial system obtained from the Credit Registry. We only consider the sectors of economic activity for which we have firms answering the survey and we do not consider linkages between the banks, which are relatively not important in Uruguay. A first observation is that for most of the sectors commercial credit is larger than banking credit, as shown by a lower than one median of the ratio of financial to commercial credit (see Table 7). The amount of both types of credit is similar in manufacturing, transportation and teaching sectors. While, in the remaining sectors, the commercial indebtedness is more relevant than the financial debt.

Table 7: Financial to commercial credit ratio (Median)

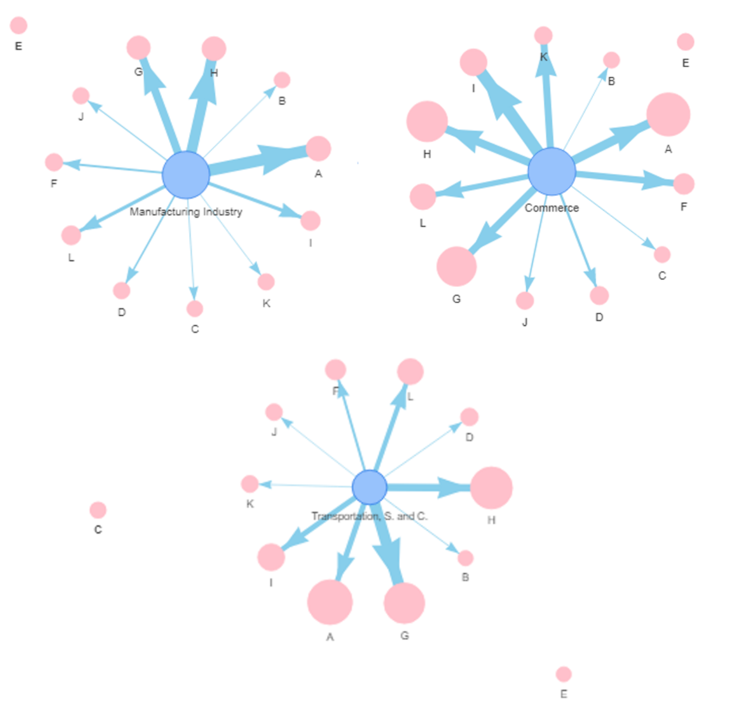
Sector	**Ratio**
Manufacturing industry	0.74
Electricity, gas and water	0.00
Construction	0.35
Commerce	0.45
Hotels and restaurants	0.00
Transportation, storage and communication	1.00
Teaching	1.28
Others	0.30

To obtain the centrality measure of the banks in the network, the interconnections were weighted by the participation of the credit to firms of each institution on the total credit to firms granted by the financial system. As showed in Table 8 the most central banks identified with centrality measures coincide with those that have a higher capital requirement for systemic risk. This result is in line with the findings of Umut et al. (2013) that centrality measures perform well in identifying and monitoring systemically important financial institutions in the Turkish inter-bank market. The banks are ordered in a descendent order according to the centrality measure, where number 1 represents the most central bank. In the Appendix (Table 10) we present the values of the centrality measures estimated for banks.

Table 8: Banking centrality measures ranking

Institution	**Centrality degree**	**Eigenvector centrality**	**High capital requirements for systemic risk**
L	1	2	✓
G	2	3	✓
A	3	4	✓
H	4	5	✓
D	5	7	
F	6	8	
I	7	6	✓
K	8	1	
B	9	9	
J	10	10	✓
C	11	11	
E	12	12	

Figure 2: 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.

In Figure 2 we present the linkages of the most central economic sectors with banking institutions. The size of the nodes and edges represents the amount owed by the sector to each financial institution. The banks with high capital requirements due to systemic risk are also the most exposed to the economic activity sectors that where identified as the most central in terms of commercial indebtedness. This suggests the importance of considering commercial credit networks in order to assess the contribution of individual banks to systemic risk.

6 General stress test framework

To complete our analysis and our understanding about how credit risk is transferred trough the commercial debt network we perform a default contagion exercise. We consider the effects of the default of each sector on the network in a context of financial credit restriction. With this purpose, 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. This is an extreme-case exercise where it is assumed that all firms in the trigger sector default and that loss given default is a hundred percent. Although these assumptions are extreme and unlikely in practice, they allow us to show a type of stress testing analysis that is possible using the credit network.

We build an $n \times n$ matrix A, where element A_{ij} is the total amount owed from sector i to j. Total commercial debt (CD_i) of sector i is given by the Equation 6 and we assume that commercial debt it´s a component of short term liabilities of sector i. Total sales credit (SC_i) for sector i is given by the Equation 7 and we assume that sales credit it´s a component of short term assets of sector i:

$$CD_i = \sum_j A_{ij}, \tag{6}$$

$$SC_i = \sum_i A_{ij}. \tag{7}$$

When a sector i defaults it is assumed that it does not pay the amount owed to the other sectors. The counterpart k will be affected and their total credit sales asset will be reduced by the amount owed by sector i to sector k. The direct effect of the sector i default in total credit of sector k is represented in Equation 8. We use t_0 to refer to the initial moment before the default and t_1 to refer to the moment after the first default:

$$SC_{kt_1} = SC_{kt_0} - A_{ki}. \tag{8}$$

The sector affected will be able to honor its debts if its current assets are larger than their short-term liabilities; if not, these sector will also default and the propagation through the network continues. The financial credit restriction is imposed by the fact that firms can not borrow money from the financial system if their current assets are less than their commercial debt.

We define a matrix S of dimension $n \times 1$ representing short term assets. S_{11} are the short term assets of sector 1. Short term assets are the sum of sales credit, available cash and temporary investments. These last two items are obtained from the Annual Economic Activity survey.

We also define a matrix L of dimension $n \times 1$ representing short term liabilities. L_{11} are the short term liabilities of sector 1. Short term liabilities are the sum of commercial debt and other short term liabilities. These balance sheet items are also obtained from the Annual Economic Activity survey. The default of sector i affects the short term assets of all the other sectors that are creditors of i: its short term assets are reduced by the amount of A_{ki}. A sector k will enter in default in $t = 1$ if

$$S_{k1} - L_{k1} < 0. \tag{9}$$

If this sector defaults, the propagation through the network continues. We perform this exercise simulating the default in $t = 0$ for each node in the network (a total of n simulations). A financial credit restriction is assumed: firms can not borrow money from the financial system if their current assets are less than their commercial debt. As a result of this exercise we can identify the sectors that default, how the default propagates trough the network and the extent of the propagation.

7 Commercial debt stress test results

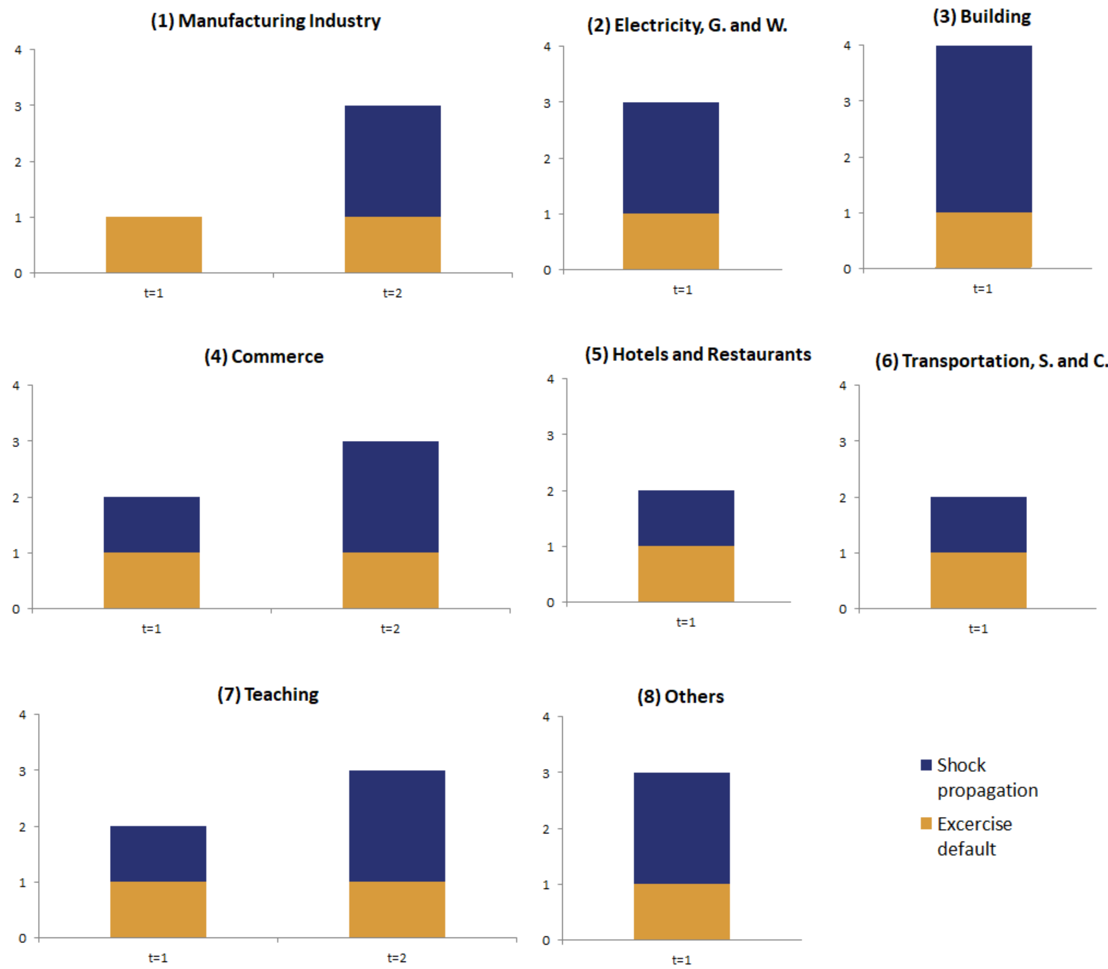
In this section we present the results of the hypothetical, extreme-case default shock exercise introduced in Section 6. Given that we need additional balance sheet information to perform the exercise and that the Annual Economic Activity survey does not include data for the real estate, primary activities, public sector and financial intermediation sectors we exclude these sectors from the analysis.

The results of the default shock propagation are presented in Figure 3.[6] For example, in Figure 3 panel (1) we describe the result of an hypothetical initial default shock of the whole manufacturing sector. The y axis shows the total number of sectors in default, and the x axis the periods of propagation of shocks. This is represented in $t = 1$ by the default of the "exercise default" sector, and also other sectors that enters in default as result of direct contagion ("shock propagation"). We continue adding bars until the shock propagation ends, and no other sectors enter in default. The last bar of each graph is the final propagation period, and indicates the total number of sectors defaulted as a result of the initial default of the sector considered. In panel (1) the default of the manufacturing sector produces as a result of the contagion effect a total of 2 defaults, and the contagion last 2 periods. At the end, there are 3 sectors affected, the manufacturing industry that is in default as result of the exercise, and two other sectors affected by contagion, the first one affected in the period $t = 1$ and the second one affected in the period $t = 2$. These two sectors are "hotels and restaurants" and "transportation, storage and communication".

In all cases, the total time of default propagation is less or equal than 2. This means that at maximum there are second round effects on default contagion in the network. The maximum contagion, by the propagation of the shock is produced when "construction" sector defaults. In

[6] "Electricity, gas and water", "construction" and "others" in the initial moment already have short term assets lower that their short term liabilities. This means, that in a context of bank credit restrictions these sectors will enter into default in all the exercises. For this reason, we focus on the impact of an initial default on each of the remaining sectors.

Figure 3: Defaults by sector



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. We simulate default of all the individual sectors and consider the effects of direct and indirect contagion. Results change according to the sector that is affected first.

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. As consequence of this fact, we do not observe the default of all sectors in this exercise.

8 Conclusion

In this paper we build a commercial debt network at a sectoral level of analysis for Uruguay. Using traditional centrality and structure measures for networks we identify manufacturing industry, commerce and transportation, storage and communication as the most central sectors in the network. We also identify a high level of indebtedness of the commerce sector with the manufacturing sector. We obtain a more complete and complex network adding the sectors' financial debt to banks. This allows us, to estimate the centrality measures for banking institutions. Most of banks are connected with all sectors, except for 4 banks. According to the results, the most central banks identified with centrality measures coincide with those that have higher capital requirements for systemic risk.

Considering simultaneously the financial and commercial debt by economic sector, we obtain a more adequate measure of the indebtedness structure of each sector. Financial to commercial credit ratio is similar to one in manufacturing industry, transportation and teaching sectors. In the remaining sectors, the commercial indebtedness is more relevant than the financial debt.

To complete our analysis and our understanding about how credit risk is transferred trough the network of commercial debt we perform a default contagion exercises among the economic sectors. We consider the effects of the default of each sector on the network in a context of financial credit restriction. With this purpose, we consider that each economic sector, individually, enters into default and affects the creditors sectors, whose current assets are reduced by the amount equivalent to the amount owed by the sector that enters into default. The sector affected will be able to honor their debts if their current assets are bigger than their short term liabilities. If not, these sector will also default and propagation through the network continues. The financial credit restriction is imposed by the fact that firms can not borrow money from the financial system if their current assets are less that their short term liabilities. Although these are extreme and unlikely assumptions in practice, they allows to show a type of stress testing exercise that is possible with the credit network.

As a result of this exercise we find that the sectors of "transport, communication and storage" and "hotels and restaurants" are affected when any of the other sectors default. These sectors are the most exposed in terms of contagion. Although the manufacturing and commerce industry are the most central, according to centrality measures, and with the highest level of indebtedness, they have a large amount of liquid assets in the short term, which allows them to survive all the shocks coming from other sectors.

Because of the relevance of manufacturing industry and commerce, the shock could be amplified considering default of this sector simultaneously with some liquidity shock, affecting one or both sectors. Further development of network analysis in Uruguay include the build up of a commercial debt network at a firm level, and the analysis of the increase in banking credit risk as a result of sector defaults and contagion.

Appendix

Table 9: Economic sectors centrality measures

Sector	Centrality degree	In degree centrality	Out degree centrality	Closeness centrality	Betweeness centrality	Eigenvector centrality
Primary Activity	7	4	3	0,6	0,0	0,5
Manufactirung industry	18	9	9	0,8	0,1	1,0
Electricity, G, and W,	9	5	4	0,6	0,0	0,6
Construction	10	6	4	0,6	0,0	0,6
Commerce	17	10	7	0,7	0,1	0,9
Hotels and restaurants	13	6	7	0,7	0,0	0,8
Transportation, S, and C,	19	9	10	0,9	0,2	1,0
Financial Intermediation	7	2	5	0,6	0,0	0,5
Public Sector	2	1	1	0,6	0,0	0,6
Real State	9	4	5	0,5	0,0	0,1
Teaching	7	2	5	0,6	0,0	0,4
Others	16	9	7	0,7	0,1	0,9

Table 10: Banking centrality measures

Institution	Weigthed eigenvector centrality	In degree centrality
L	0,35	7
G	0,35	7
A	0,32	6
D	0,27	5
F	0,27	5
I	0,29	5
K	0,59	5
B	0,24	4
J	0,24	4
C	0,12	2
E	0,06	1

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