The topology of securities cross-holding in the Colombian financial system

Applied Mathematics Seminar
Quantil | November 5, 2020

Carlos León, Banco de la República & Tilburg University

Javier Miguélez, Banco de la República

Corresponding author, e-mail: cleonrin@banrep.gov.co / c.e.leonrincon@tilburguniversity.edu

Disclaimer

Opinions and statements in this article are the sole responsibility of the authors, and do not represent neither those of Banco de la República nor of its Board of Directors. We thank Clara Machado, Serafín Martínez, and Wilmar Cabrera for their comments and suggestions. Any remaining errors are our own.

Latest version here:
https://repositorio.banrep.gov.co/bitstream/handle/20.500.12134/9914/be_1134.pdf

Accepted for publication in Studies in Economics and Finance

Take home messages

- Cross-holding of securities occurs when…
  - Two financial institutions hold securities issued by each other or
  - More than two financial institutions hold securities issued by each other in a circular structure.
- Securities cross-holding may be particularly important for financial stability because of potential contagion and cascades arising from *cyclical interdependencies* and *feedback effects* in the connective architecture of financial systems.
- We study the network topology of bonds, certificates of deposit, and equity issued and held by financial institutions—in proprietary position.
- Infrequent reciprocal and transitive relations suggest securities cross-holding does exist in the Colombian financial system but its extent is particularly low.
- Results suggest that contagion and cascades from securities cross-holding is rather limited.
- However, a conclusive interpretation requires quantifying contagion effects on financial institutions' solvency and adding other sources of connectedness.

Contents

1. Introduction
2. Cross-holding and financial stability (*literature review*)
3. Measuring cross-holding (*methods*)
4. The dataset
5. Main results
4. Final remarks

Contents

Introduction

- Exposures arising from institutions holding securities issued by other financial institutions are often neglected despite their demonstrated contribution to systemic risk (see Poledna, et al., 2015).
- Securities cross-holding may be particularly important for financial stability because of potential contagion and cascades arising from *cyclical interdependencies* and *feedback effects* in the connective architecture of financial systems (see Eisenberg & Noe, 2001, Elsinger, 2009, Gouriéroux, et al. 2012, Elliot, et al., 2014).
- Most literature on networks of securities cross-holding doesn't work on observed data. Noteworthy exceptions are Poledna, et al. (2015) and Hüser & Kok (2019).
- We use a unique dataset of securities (bonds, certificates of deposit, and equity) issued and held by financial institutions—in proprietary position—to measure the extent of securities cross-holding in the Colombian financial system, weekly from 2016 to 2019.
- In Colombia, the outstanding of securities issued and held by financial institutions is about 1.5 times that of secured and unsecured lending among them.

Introduction

- We add to Poledna, et al. (2015) and Hüser & Kok (2019)…
  - We employ network analysis to measure the presence of cyclical interdependencies and potential feedback effects.
  - We study how cross-holding evolves through time.
  - Our dataset comprises banking and non-banking institutions.
- Our contribution…
  - It is the first time that the extent of securities cross-holding is measured based on the quantification of observed reciprocal and transitive holding relations.
  - Based on evidence that relates reciprocal and transitive relations to risk build-up before financial crises (see Squartini, et al., 2013, Squartini & Garlaschelli, 2014, Kawada, 2016, Sahabat, et al., 2017, Alamsyah, et al., 2019, and Cimini, et al., 2019), our work highlights the importance of monitoring the level and dynamics of cyclical interdependencies for early-warning models and other financial stability purposes.
  - Our work is a first step towards measuring the expected systemic losses arising from reductions in the individual and aggregate value of financial institutions due to securities cross-holding (as in Battiston, et al., 2012b, Poledna, et al., 2015).

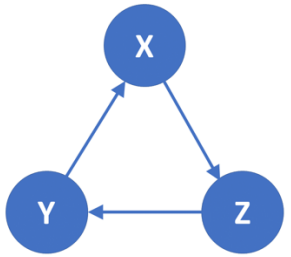
Contents

Cross-holding and financial stability

- Cross-holding occurs when firms own securities issued by other firms (Fedenia, et al., 1994). Two types of cross-holding exist (see Adams, 1999).

a. Direct cross-holding

A shock affecting the value of firm A affects the value of securities issued by A. As firm B holds securities issued by firm A in its portfolio, the value of firm B is affected, and—in turn—the value of securities issued by B may be affected as well, creating a feedback effect that may reach firm A's value—and so on.



b. Indirect cross-holding

When indirect cross-holding exists*, a shock affecting the value of firm X affects the value of firm Z and Y recursively through changes in the value of securities issued by X and Z. The feedback effect arises when the change in the value of firm Y affects firm X—and the recursion continues.

(*) Following Squartini, et al. (2013), there are seven different configurations of circular structures involving three firms.

Cross-holding and financial stability

- Literature about cross-holding in corporate finance is protracted and abundant (see Fedenia, et al., 1994, Adams, 1999, Suzuki, 2002, Clayton & Jorgensen, 2005, Trivedi & Young 2006, Elliott, et al, 2014, He, et al., 2019).
- Most of this literature addresses questions about how cross-holding may induce biases in…
  - Corporate valuation,
  - Asset pricing,
  - Portfolio management,
  - Credit risk,
  - Governance.
- From a financial stability perspective, literature acknowledges that cross-holding is particularly important to explain contagion.

[…]

Cross-holding and financial stability

- From a financial stability perspective, literature acknowledges that cross-holding is particularly important to explain contagion.
  - The *potential feedback effect* created by firms' payoffs and value being dependent on claims on other firms.
  - The feedback effect is enabled by cyclical linkages among firms—*cyclical interdependence* (see Eisenberg & Noe, 2001).
  - The cyclical interdependence creates a channel that amplifies shocks and has the potential to cause cascades through interconnected firms and the wider macroeconomy (see Trivedi & Young, 2006, Elliott, et al., 2014).
  - This cyclical interdependence is a general feature of financial system architectures (Eisenberg & Noe, 2001) that was revealed in the global financial crisis (Gouriéroux, et al. 2012).
  - The evolution of reciprocal and transitive relations among financial institutions is potentially useful in early-warning models of financial turmoil (see Squartini, et al., 2013, Squartini & Garlaschelli, 2014, Kawada, 2016, Sahabat, et al., 2017, Alamsyah, et al., 2019, and Cimini, et al. 2019).

Cross-holding and financial stability

- Nevertheless, it is well-known that the relation between interconnectedness in financial networks and financial instability is non-monotonic (see Battiston, et al., 2012, Caccioli, et al., 2014, Elliot, et al., 2014, Glasserman & Young, 2016, Caccioli, et al., 2018, Roncoroni et al., 2019).
  - Network connections can have a positive effect by diversifying risk exposures for individual banks, but they can also have a negative effect by creating channels through which shocks can spread (Glasserman & Young, 2016).
  - Low levels of cross-holding circumscribe contagion through a weakly connected system that limits the interdependencies among firms (Elliot, et al., 2014).
  - The relation between interconnectedness and financial stability has been reported as non-monotonic, but also as dependent on several features, such as network architecture, size of shocks, and financial institutions' health (e.g. solvency) and homogeneity.
  - The relation between the extent of cross-holding and financial stability is a complex one—unless cross-holding is inexistent or extremely rare.

Cross-holding and financial stability

- To our knowledge, Poledna, et al. (2015) and Hüser & Kok (2019) are the only using observed data on cross-holding in financial systems.
- In Poledna, et al. (2015)…
  - Use Mexican data and DebtRank methodology (see Battiston, et al., 2012b) to measure systemic risk arising from different types of exposures among banking institutions.
  - They find that the contribution of securities cross-holding to systemic risk is crucial in the Mexican case from 2007 to 2013.
- In Hüser & Kok (2019)…
  - They employ a multi-layer network in which different types of cross-holding networks are studied, individually and in aggregate—in the euro area.

Contents

Measuring cross-holding (methods)

- Network analysis is dedicated to describing and understanding an underlying system, focused on capturing its structure or topology (Börner, et al., 2007).
- Network analysis basics comprise two measures that correspond to both types of cross-holding documented by Adams (1999).
- The *reciprocity coefficient* (r) corresponds to the frequency of direct cross-holding:
  - It measures the frequency with which a linkage from i to j is complemented by the reciprocal linkage, i.e. from j to i.
  - In financial networks, reciprocity is a signature of trust between financial institutions (Cimini, et al., 2019).
  - Interbank reciprocity has been reported to be higher than expected during the build-up of the 2008 crisis and to decrease as the crisis became imminent, therefore with potential to be used in early-warning models (see Squartini, et al., 2013, Squartini & Garlaschelli, 2014, Sahabat, et al., 2017, Cimini, et al., 2019).

Measuring cross-holding (methods)

- Transitivity, commonly referred to as *clustering coefficient* (c), corresponds to the frequency of indirect cross-holding.
  - It measures the frequency with which loops of length three appear in the network.
  - Loops involving three banks are particularly important for systemic risk and contain key information for early-warning models (Squartini, et al., 2013, Squartini & Garlaschelli, 2014, Kawada, 2016, Alamsyah, et al., 2019, Cimini, et al., 2019).
- Additionally, we implement…
  - Density (d) measures the cohesion of the network. It is calculated as the ratio of the number of actual linkages to the maximum possible number of linkages
  - Single-step survival ratio (see Onnela, et al., 2003, León & Miguélez, 2020), which is calculated as the fraction of linkages found common in two consecutive networks.
  - Jaccard index (Jaccard, 1912), which measures how similar networks are in cross section, calculated as the fraction of linkages found common in two networks.

Measuring cross-holding (methods)

- Our network…
  - Let n represent the number of financial institutions in the network at time t, A is an adjacency matrix of dimensions $n \times n \times t$, with elements A_{ijt} such that

$$A_{ijt} = \left\{ \begin{array}{l} 1 \text{ if there is a link from } i \text{ to } j \text{ at time } t, \\ 0 \text{ otherwise.} \end{array} \right\}$$

  - In our case, the adjacency matrix contains four dimensions, A_{ijtp}, with p corresponding to the type of security issued and held by financial institutions i and j, respectively, in period t.
  - We work under a multi-layer network approach.

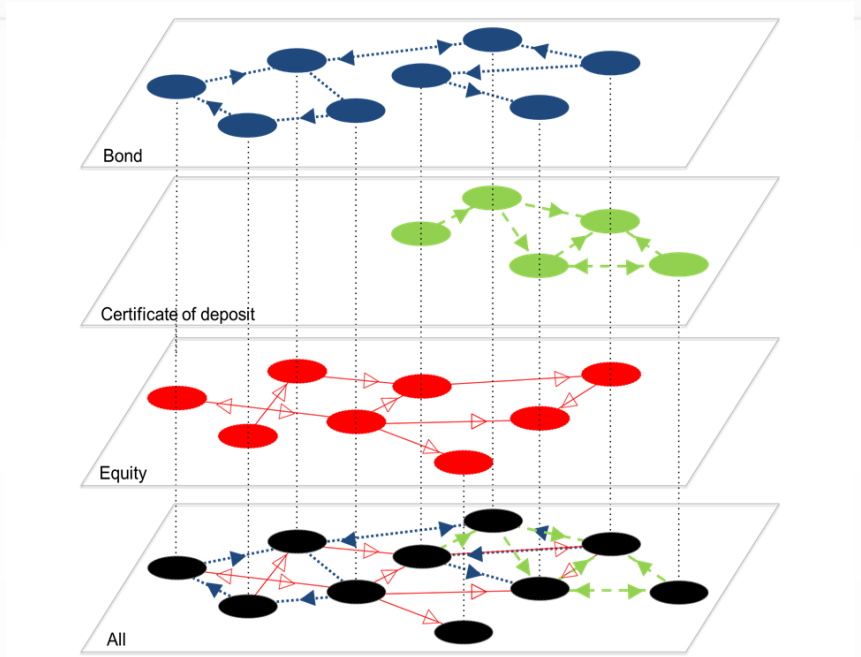


Figure 2. Illustration of a multiplex network of securities issued and held by financial institutions. Arrows are directed from the issuer to the holder. Vertical lines connecting superimposed nodes are financial institutions, whereas each node is a role (i.e. issuer or holder) in the corresponding layer. Source: authors' design.

Contents

The dataset

- We work with data from *Deceval*—the securities depository and settlement system for corporate and non-sovereign government securities, and the securities depository for the equity market.*
- We extract the dataset comprising all securities issued and held—in proprietary position—by institutions supervised by the Financial Superintendence of Colombia (i.e. financial institutions).
- Each register in the securities dataset includes the date, issuer, holder, outstanding value, and type of security.
- 193 weekly observations (i.e. each Friday), from January 8th, 2016 to September 6th, 2019.
- Three types of securities**: certificates of deposit, bonds, and equity.
- Certificates of deposit represent about 59 percent of total outstanding, bonds 19 percent, and equity the remaining 22 percent.

(*) It is owned by the Colombian Stock Exchange - BVC (Bolsa de Valores de Colombia). (**) There are two other types that contribute to about five percent of the total outstanding of securities in the dataset, and they are issued by four financial institutions only.

Contents

Main results

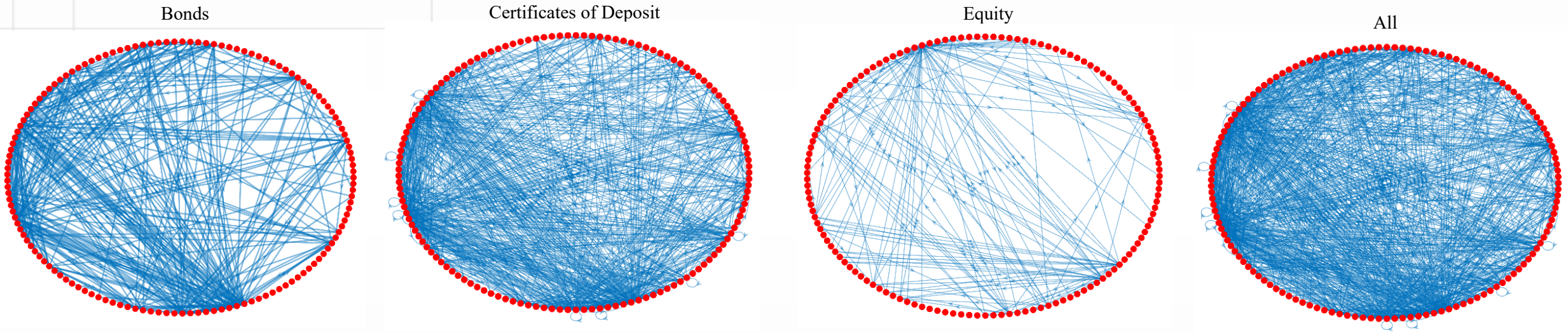


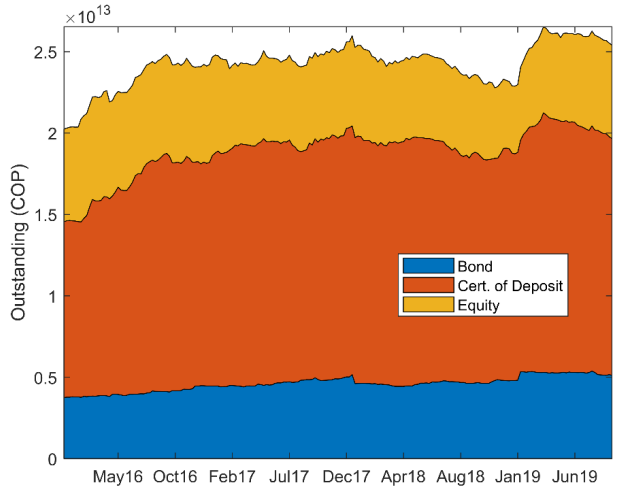
Figure 4. Network graphs of securities issued and held by financial institutions, as of the first week of September 2019. Source: authors' calculations, based on data from Banco de la República and Deceval

Main results

Statistic	Bond	Cert. of Dep.	Equity	All
Contribution to All (× 100)	18.94 [16.91; 20.93]	58.75 [53.60; 61.46]	22.31 [19.05; 28.50]	100.00 [100; 100]
Number of participants [a]	75.19 [71; 79]	103.73 [98; 108]	71.30 [63; 78]	124.65 [120; 129]
Density (× 100) [b]	1.76 [1.67; 1.87]	4.08 [3.82; 4.47]	0.88 [0.74; 1.08]	5.53 [5.27; 5.87]
Reciprocity (× 100) [c]	1.06 [0.04; 1.85]	6.75 [5.69; 7.83]	0.00 [0.00; 0.00]	5.89 [4.66; 7.08]
Transitivity (× 100) [d]	0.01 [0.00; 0.04]	0.27 [0.19; 0.36]	0.00 [0.00; 0.00]	0.30 [0.18; 0.39]
Survival ratio (× 100) [e]	96.74 [94.40; 98.76]	97.39 [96.12; 98.42]	97.25 [93.93; 99.40]	97.55 [96.36; 98.62]

Table 1. Networks' average statistics calculated on 193 weeks from January 2016 to September 2019; percentiles 5 and 95 are reported in brackets. [a] Number of nodes with at least one linkage in the network; [b] fraction of possible linkages observed in the network; [c] fraction of linkages that are reciprocated; [d] fraction of transitive relations observed in the network; [e] fraction of linkages that survived in two consecutive periods. Source: authors' calculations, based on data from Banco de la República and Deceval.

The most contributive network (by value) is the one corresponding to certificates of deposit (58.75 percent), followed by equity (22.31 percent) and bonds (18.94 percent).

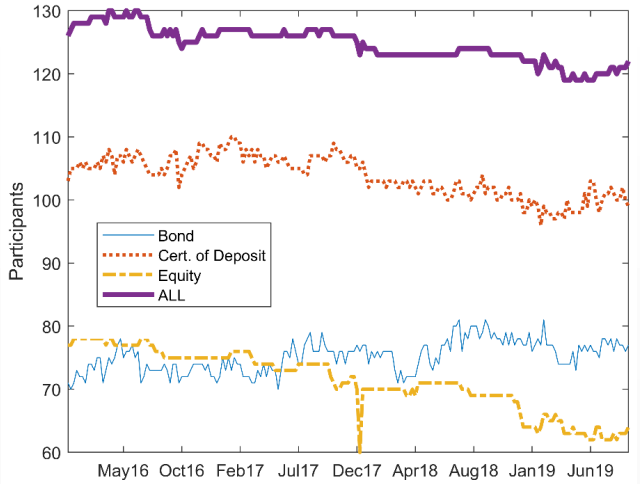


Main results

Statistic	Bond	Cert. of Dep.	Equity	All
Contribution to All (× 100)	18.94 [16.91; 20.93]	58.75 [53.60; 61.46]	22.31 [19.05; 28.50]	100.00 [100; 100]
Number of participants [a]	75.19 [71; 79]	103.73 [98; 108]	71.30 [63; 78]	124.65 [120; 129]
Density (× 100) [b]	1.76 [1.67; 1.87]	4.08 [3.82; 4.47]	0.88 [0.74; 1.08]	5.53 [5.27; 5.87]
Reciprocity (× 100) [c]	1.06 [0.04; 1.85]	6.75 [5.69; 7.83]	0.00 [0.00; 0.00]	5.89 [4.66; 7.08]
Transitivity (× 100) [d]	0.01 [0.00; 0.04]	0.27 [0.19; 0.36]	0.00 [0.00; 0.00]	0.30 [0.18; 0.39]
Survival ratio (× 100) [e]	96.74 [94.40; 98.76]	97.39 [96.12; 98.42]	97.25 [93.93; 99.40]	97.55 [96.36; 98.62]

Table 1. Networks' average statistics calculated on 193 weeks from January 2016 to September 2019; percentiles 5 and 95 are reported in brackets. [a] Number of nodes with at least one linkage in the network; [b] fraction of possible linkages observed in the network; [c] fraction of linkages that are reciprocated; [d] fraction of transitive relations observed in the network; [e] fraction of linkages that survived in two consecutive periods. Source: authors' calculations, based on data from Banco de la República and Deceval.

- The certificates of deposit network is also the one displaying the highest average number of participants.
- The number of participants of each network is somewhat stable throughout the period under analysis, except for the equity network, which displays a clear decreasing trend.

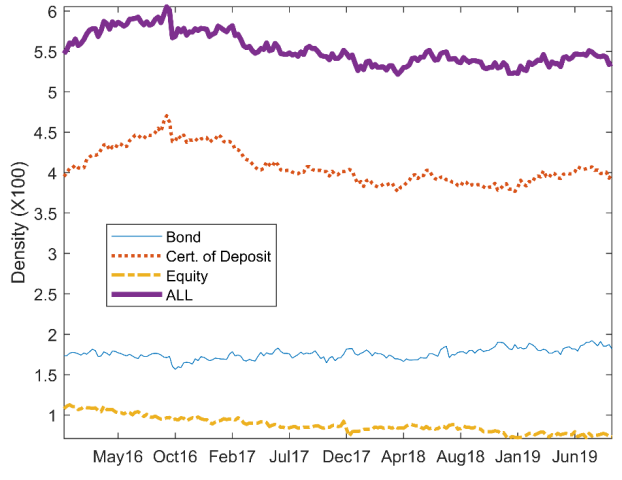


Main results

Statistic	Bond	Cert. of Dep.	Equity	All
Contribution to All (× 100)	18.94 [16.91; 20.93]	58.75 [53.60; 61.46]	22.31 [19.05; 28.50]	100.00 [100; 100]
Number of participants [a]	75.19 [71; 79]	103.73 [98; 108]	71.30 [63; 78]	124.65 [120; 129]
Density (× 100) [b]	1.76 [1.67; 1.87]	4.08 [3.82; 4.47]	0.88 [0.74; 1.08]	5.53 [5.27; 5.87]
Reciprocity (× 100) [c]	1.06 [0.04; 1.85]	6.75 [5.69; 7.83]	0.00 [0.00; 0.00]	5.89 [4.66; 7.08]
Transitivity (× 100) [d]	0.01 [0.00; 0.04]	0.27 [0.19; 0.36]	0.00 [0.00; 0.00]	0.30 [0.18; 0.39]
Survival ratio (× 100) [e]	96.74 [94.40; 98.76]	97.39 [96.12; 98.42]	97.25 [93.93; 99.40]	97.55 [96.36; 98.62]

Table 1. Networks' average statistics calculated on 193 weeks from January 2016 to September 2019; percentiles 5 and 95 are reported in brackets. [a] Number of nodes with at least one linkage in the network; [b] fraction of possible linkages observed in the network; [c] fraction of linkages that are reciprocated; [d] fraction of transitive relations observed in the network; [e] fraction of linkages that survived in two consecutive periods. Source: authors' calculations, based on data from Banco de la República and Deceval.

- The certificates of deposit network exhibits the highest density, on average 4.08 percent. The bond and equity networks display particularly low average densities, about 1.76 and 0.88 percent.
- The sparseness of the four networks suggests that financial institutions tend to hold securities issued by a few of their peers, mostly in the form of certificates of deposit, rarely in the form of equity*.



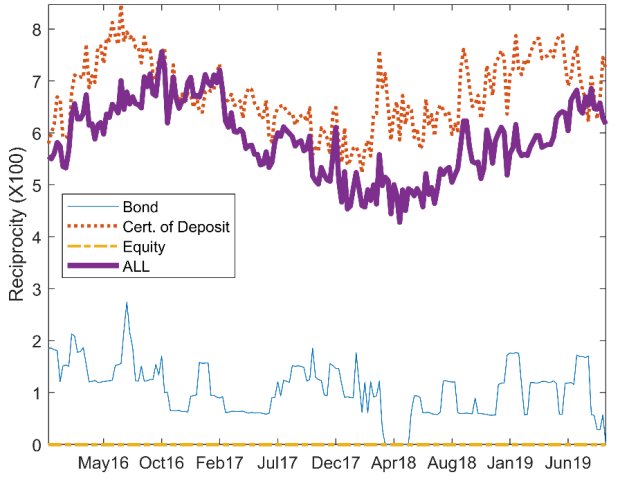
(*) High sparseness is expected because there are some legal restrictions to financial institutions holding equity issued by themselves.

Main results

Statistic	Bond	Cert. of Dep.	Equity	All
Contribution to All (× 100)	18.94 [16.91; 20.93]	58.75 [53.60; 61.46]	22.31 [19.05; 28.50]	100.00 [100; 100]
Number of participants [a]	75.19 [71; 79]	103.73 [98; 108]	71.30 [63; 78]	124.65 [120; 129]
Density (× 100) [b]	1.76 [1.67; 1.87]	4.08 [3.82; 4.47]	0.88 [0.74; 1.08]	5.53 [5.27; 5.87]
Reciprocity (× 100) [c]	1.06 [0.04; 1.85]	6.75 [5.69; 7.83]	0.00 [0.00; 0.00]	5.89 [4.66; 7.08]
Transitivity (× 100) [d]	0.01 [0.00; 0.04]	0.27 [0.19; 0.36]	0.00 [0.00; 0.00]	0.30 [0.18; 0.39]
Survival ratio (× 100) [e]	96.74 [94.40; 98.76]	97.39 [96.12; 98.42]	97.25 [93.93; 99.40]	97.55 [96.36; 98.62]

Table 1. Networks' average statistics calculated on 193 weeks from January 2016 to September 2019; percentiles 5 and 95 are reported in brackets. [a] Number of nodes with at least one linkage in the network; [b] fraction of possible linkages observed in the network; [c] fraction of linkages that are reciprocated; [d] fraction of transitive relations observed in the network; [e] fraction of linkages that survived in two consecutive periods. Source: authors' calculations, based on data from Banco de la República and Deceval.

- Direct securities cross-holding is scarce in all networks, including the aggregate.
- The certificates of deposit network shows the highest average reciprocity (6.75 percent). Bonds and equity show particularly low levels of reciprocity, about 1 and 0 percent, respectively.*
- It is fair to say that direct cross-holding of securities in the Colombian financial system is low and stable throughout the period under analysis.



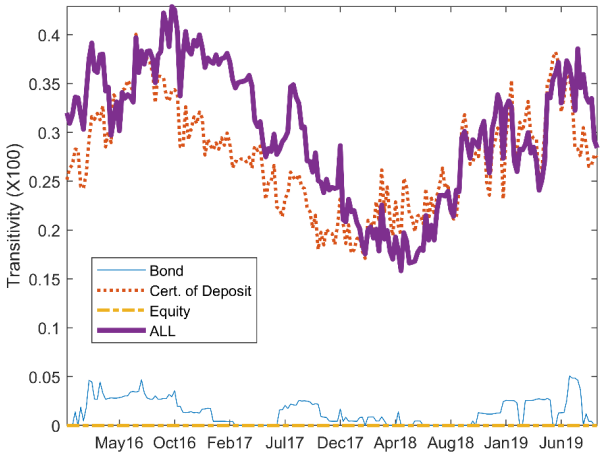
(*) Again, legal restrictions to financial institutions holding equity issued by their peers may explain the null reciprocity in the corresponding network.

Main results

Statistic	Bond	Cert. of Dep.	Equity	All
Contribution to All (× 100)	18.94 [16.91; 20.93]	58.75 [53.60; 61.46]	22.31 [19.05; 28.50]	100.00 [100; 100]
Number of participants [a]	75.19 [71; 79]	103.73 [98; 108]	71.30 [63; 78]	124.65 [120; 129]
Density (× 100) [b]	1.76 [1.67; 1.87]	4.08 [3.82; 4.47]	0.88 [0.74; 1.08]	5.53 [5.27; 5.87]
Reciprocity (× 100) [c]	1.06 [0.04; 1.85]	6.75 [5.69; 7.83]	0.00 [0.00; 0.00]	5.89 [4.66; 7.08]
Transitivity (× 100) [d]	0.01 [0.00; 0.04]	0.27 [0.19; 0.36]	0.00 [0.00; 0.00]	0.30 [0.18; 0.39]
Survival ratio (× 100) [e]	96.74 [94.40; 98.76]	97.39 [96.12; 98.42]	97.25 [93.93; 99.40]	97.55 [96.36; 98.62]

Table 1. Networks' average statistics calculated on 193 weeks from January 2016 to September 2019; percentiles 5 and 95 are reported in brackets. [a] Number of nodes with at least one linkage in the network; [b] fraction of possible linkages observed in the network; [c] fraction of linkages that are reciprocated; [d] fraction of transitive relations observed in the network; [e] fraction of linkages that survived in two consecutive periods. Source: authors' calculations, based on data from Banco de la República and Deceval.

- Indirect securities cross-holding is lower than direct cross-holding.
- The three individual networks display lower levels of transitivity, with bonds and equity being zero or close to zero.
- Akin to reciprocity, transitivity levels suggest that indirect cross-holding is uncommon and stable throughout the period under analysis.

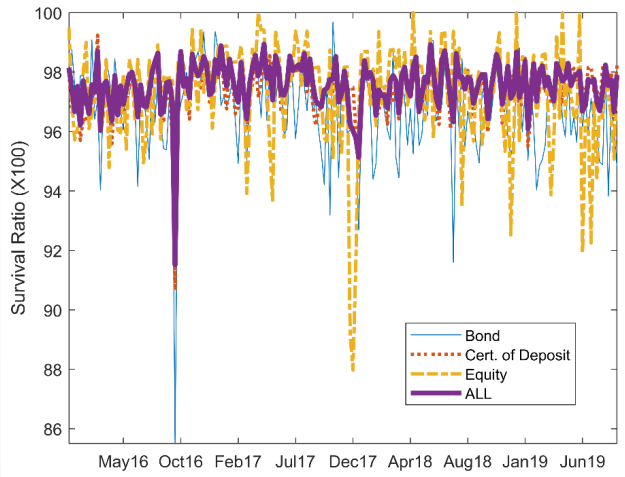


Main results

Statistic	Bond	Cert. of Dep.	Equity	All
Contribution to All (× 100)	18.94 [16.91; 20.93]	58.75 [53.60; 61.46]	22.31 [19.05; 28.50]	100.00 [100; 100]
Number of participants [a]	75.19 [71; 79]	103.73 [98; 108]	71.30 [63; 78]	124.65 [120; 129]
Density (× 100) [b]	1.76 [1.67; 1.87]	4.08 [3.82; 4.47]	0.88 [0.74; 1.08]	5.53 [5.27; 5.87]
Reciprocity (× 100) [c]	1.06 [0.04; 1.85]	6.75 [5.69; 7.83]	0.00 [0.00; 0.00]	5.89 [4.66; 7.08]
Transitivity (× 100) [d]	0.01 [0.00; 0.04]	0.27 [0.19; 0.36]	0.00 [0.00; 0.00]	0.30 [0.18; 0.39]
Survival ratio (× 100) [e]	96.74 [94.40; 98.76]	97.39 [96.12; 98.42]	97.25 [93.93; 99.40]	97.55 [96.36; 98.62]

Table 1. Networks' average statistics calculated on 193 weeks from January 2016 to September 2019; percentiles 5 and 95 are reported in brackets. [a] Number of nodes with at least one linkage in the network; [b] fraction of possible linkages observed in the network; [c] fraction of linkages that are reciprocated; [d] fraction of transitive relations observed in the network; [e] fraction of linkages that survived in two consecutive periods. Source: authors' calculations, based on data from Banco de la República and Deceval.

- The survival ratio shows that linkages are rather stable from one week to the next throughout the period.
- Both the main topological features of the networks (i.e. low density, reciprocity, and transitivity) and the relations between financial institutions are stable over time.

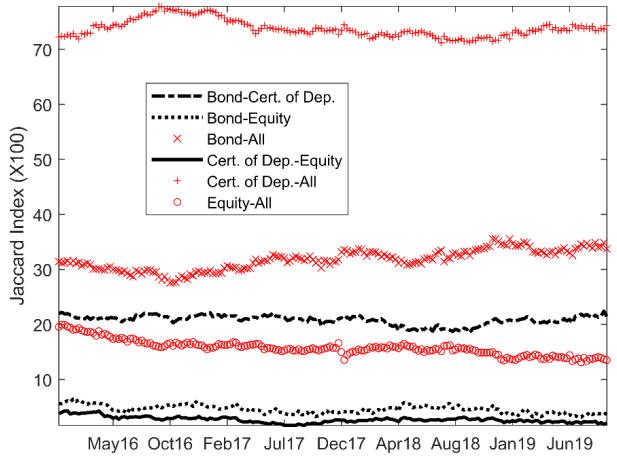


Main results

- The most similar pair of individual networks are those corresponding to bonds and certificates of deposit, with an average Jaccard index of about 0.21.
- Dissimilarity across individual networks suggests that it is somewhat unlikely that distress in one layer will spread to others through common connective patterns among nodes.
- Most of the connective patterns among nodes in the aggregated network is inherited from the certificates of deposit network

	Bond	Cert. of Dep.	Equity	All
Bond	1.00			
Cert. of Dep.	0.21	1.00		
Equity	0.05	0.03	1.00	
All	0.32	0.74	0.16	1.00

Table 2. Average Jaccard index. Source: authors' calculations, based on data from Banco de la República and Deceval.



Main results

- A test: The distributions of density, reciprocity, and transitivity attained from randomized networks are compared with that from observed networks using a two-sample K-S test (at 99 % confidence).*

	Density (× 100) [a]		Reciprocity (× 100) [b]		Transitivity (× 100) [c]	
	Observed	Randomized	Observed	Randomized	Observed	Randomized
Bond	1.76	1.75	1.06†	1.15	0.01†	0.00
Cert. of Dep.	4.08	4.08	6.75†	4.74	0.27†	0.29
Equity	0.88	0.87	0.00†	2.26	0.00†	0.00
All	5.53	5.53	5.89	5.23	0.30	0.36

Table 3. Observed average density, reciprocity, and transitivity against a null randomized model. [a] Fraction of possible linkages observed in the network; [b] fraction of linkages that are reciprocated; [c] fraction of transitive relations observed in the network. † Null hypothesis of equal distribution of observed and randomized data is rejected at 99 percent confidence (i.e. p-value < 0.01) with Kolmogorov-Smirnov non-parametric two-sample test. Source: authors' calculations, based on data from Banco de la República and Deceval.

- Although differences are not statistically negligible in individual networks, it is evident that average reciprocity and transitivity in observed and randomized networks are particularly low, and not distant from zero in the bond and equity networks.

(*) Limited randomization of the networks by randomly reallocating linkages from issuer to holder financial institutions in each observation while preserving the exact number of linkages of each network. Performed 100 times for each of the 579 individual networks.

Main results

- Results suggest that cyclical interdependencies and potential feedback effects prompted by reciprocal and transitive relations among financial institutions holding each other's securities are uncommon in the Colombian case.
- Furthermore, the observed cyclical interdependencies and potential feedback effects are not too different from what would result from a random allocation of linkages among issuers and holders of securities.

Contents

Final remarks

- Securities cross-holding among financial institutions is a latent source of contagion and instability as they prompt cyclical interdependencies and potential feedback effects in financial networks.
- Our dataset encompasses holdings of bonds, certificates of deposit, and equity issued and held by financial institutions in Colombia, from 2016 to 2019.
- The value of securities issued and held by Colombian financial institutions is sizeable: about 1.5 times that of secured and unsecured lending among them.
- Evidence suggests that reciprocal and transitive exposures are uncommon through the period under analysis—even when cross-holding across different types of securities is considered.
- Consequently, potential contagion effects related to the network topology of the securities cross-holding in the Colombian financial system are rather low.

Final remarks

- The low density, reciprocity, and transitivity circumscribe contagion by means of a weakly connected system (see Simon, 1962) that limits the interdependence among firms holding each other's securities.
- Nevertheless, there is a major caveat:
  - We focus on the topology of the network—we disregard the monetary value of exposures and their size with respect to financial institutions' balance sheets.
  - Studying how exposures caused by securities issued and held by financial institutions may impact the financial system's solvency (as in Battiston, et al., 2012b, Poledna, et al., 2015) is a compulsory research path from the financial stability viewpoint.
- Other challenges pending:
  - Adding exposures networks (i.e. cross-holding, overlapping portfolios, lending…).
  - Including the real sector.

The topology of securities cross-holding in the Colombian financial system