Liquidity and Counterparty Risks Tradeoff in Money Market Networks

14th Simulator Seminar

Seminar on Quantitative Analysis of FMIs

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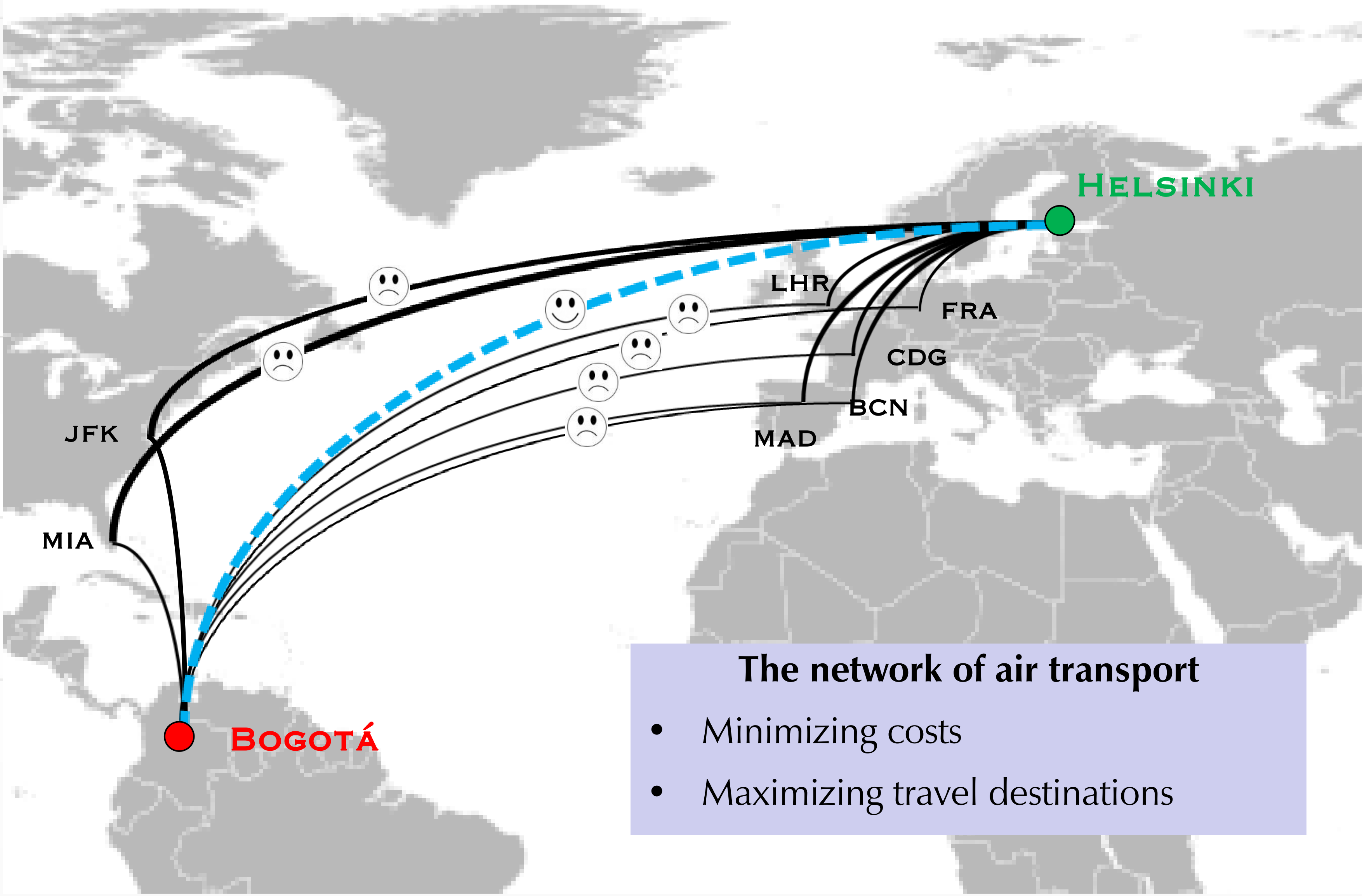
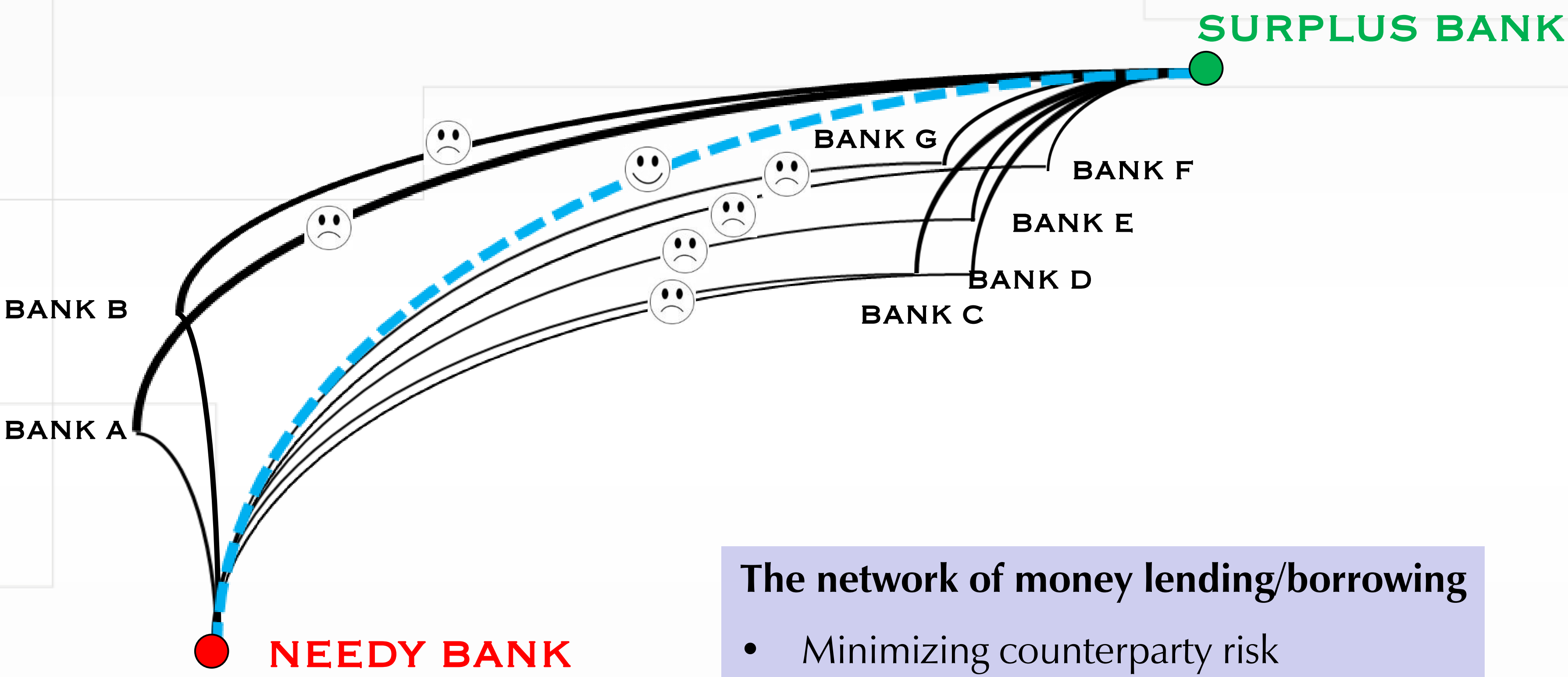


The network of air transport

- Minimizing costs
- Maximizing travel destinations



The network of money lending/borrowing

- Minimizing counterparty risk
- Maximizing access to liquidity

Take home messages

- We examine how liquidity is exchanged in different types of Colombian money market networks (secured, unsecured, and central bank's repo).
- **We suggest that financial networks follow a network optimization problem between minimizing distances and minimizing connections, and this reveals how the market deals with liquidity risk and counterparty risk, respectively.**
- We find:
  - Different types of money market networks diverge in their centralization and in how they balance counterparty risk and liquidity risk.
  - Evidence of *liquidity cross-underinsurance* (Castiglionesi & Wagner, 2013).
  - Unsecured displays lower liquidity risk, but access is discriminatory (a type of liq. underinsurance)
  - Collateral reduces *underinsurance* (by increasing access, but liquidity risk remains)
  - Central bank's role in mitigating liquidity risk (Acharya et al., 2012).

Agenda

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- Centralization of networks and the money market
  - Centralization of networks
  - Money market networks' centralization
- The dataset
- Main results
  - Main properties of the networks
  - The tradeoff between liquidity risk and counterparty risk
- Final remarks

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Introduction

- During the great financial crisis of 2007-08 liquidity risk and counterparty risk increased rapidly as liquidity was rationed amid financial institutions' weakening (see Acharya et al., 2012; Acharya & Merrouche, 2013; Abbassi et al., 2015)
- Understanding the relationship between liquidity risk and counterparty risk has gained importance since the great financial crisis.
- **Counterparty risk**: related to the costs of not being able to collect liquidity lent to counterparties (e.g. due to default or illiquidity)
- **Liquidity risk**: related to the costs of not being able to find enough counterparties willing to provide liquidity (e.g. due to hoarding or risk aversion)
- We argue that there is an implicit tradeoff between minimizing counterparty risk and liquidity risk…

Introduction

- About counterparty risk…
  - Financial institutions establish a few dedicated lending relations (Cocco et al., 2009; Afonso et al., 2013; Temizsoy et al., 2015) to minimize exposure and costs.
  - The sparse and inhomogeneous nature of financial networks (Boss et al., 2004; Soramäki et al., 2007; Battiston et al., 2012; León & Berndsen, 2014; etc.) may be the result of financial institutions minimizing risk exposure. This contradicts the "diversification network" of Allen & Gale (2000).
  - The recent case for CCPs is related to avoiding excessive exposures among financial institutions (by concentrating them in a single dedicated FMI).
- About liquidity risk…
  - Financial institutions pursue a plural set of counterparties they can borrow from.
  - A complete network (i.e. maximum connectedness) maximizes bilateral liquidity insurance in the sense of Castiglionesi & Wagner (2013) by getting all agents directly available to each other.
  - The case for anonymous market-makers platforms is related to fostering liquidity among homogeneous agents.
- By minimizing counterparty risk we create liquidity risk… and vice versa.

Introduction

- Financial markets are among many other adaptive systems that may be better understood by means of network analysis (Holland, 1998; Sornette, 2003; Haldane, 2009; Farmer et al., 2012).
- We examine how the connective structure of money market networks reveal the way the market balances counterparty risk and liquidity risk.
- Our examination is based on
  - Measuring the centralization (Freeman, 1979) of different types of money market networks (central bank's repos, secured, unsecured).
  - Exploring how network centralization is related to the tradeoff between counterparty risk and liquidity risk under a simple network optimization process suggested by Ferrer i Cancho & Solé (2003). Also related to social and economic networks formation by Hojman & Szeidl (2008).
- This is an empirical contribution to theoretical literature (e.g. Allen & Gale, 2000; Castiglionesi & Wagner, 2013; Castiglionesi & Eboli, 2015).

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CENTRALIZATION

- Centrality (*point centrality*) is a well-known measure of importance or popularity of nodes in a network. Several types (e.g. degree, strength, betweenness, closeness, PageRank, Katz, hub & authority centrality).
- Centralization (*structural centrality*) is a less common concept, related to the tendency of a single node to be more central than the others (i.e. dominance).
- A centralization index C_x for any *n*-vertex graph for any *x*-centrality measure (Freeman, 1979):

Largest value of C_x for any vertex in the network

Value of C_x for *i*-vertex in the network

$$C_x = \frac{\sum_{i=1}^{n}[c_x(\bar{v}) - c_x(v_i)]}{\check{C}_{x,n}}$$

Maximum sum of differences for *x*-centrality for a network of *n*-vertexes

$$0 \leq C_x \leq 1$$

Two extreme cases of centralization:

- Star networks
- Complete networks

(Freeman 1977,1979; de Nooy et al., 2005; Everett & Borgatti, 2007)

CENTRALIZATION

Two key concepts for characterizing the connective structure of networks:

Density (d)

- The ratio of observed edges to possible edges

$$d = m/\big(n(n-1)\big)$$

- It measures the cohesion of the network.
- Sparse network ~ low density

Average geodesic distance (l)

- The average of l_i, which is the mean of the shortest number of links between i and all other reachable participants j.

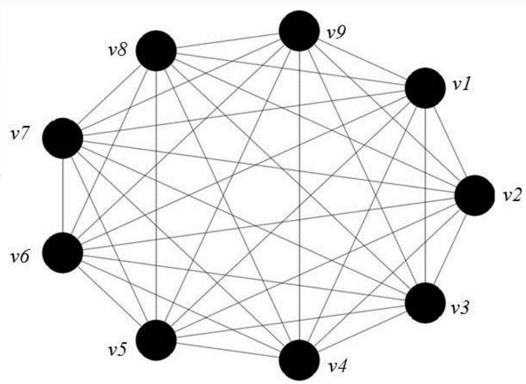
$$l_i = \frac{1}{(n-1)} \sum_{j\,(\neq i)} g_{ij}$$

- It reflects the global structure of the network, it depends on the way the entire network is connected, and cannot be inferred from any local measurement (Strogatz, 2003)

Centralization

Complete network
(min. centralization)

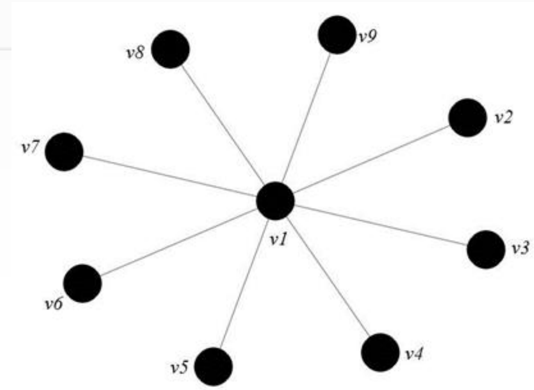
$C_x = 0$



- Minimal centralization
- No dominant vertex (homogeneous)
- **Maximal density, d=1** (fully connected)
- **Minimal average distance, $l = 1$** (no intermed.)

- Absent any cost of linkages, it is the most efficient network (Castiglionesi & Eboli, 2015)
- Connectivity is maximized (Verma et al., 2016)

Star or wheel network
(max. centralization)



$C_x = 1$

- Maximal centralization
- A single dominant vertex (inhomogeneous)
- **Minimal density, $d \sim 0$** (max. sparseness)
- **Average distance, $l \sim 2$** (a single intermediary)

- The most efficient structure for a given number of links (de Nooy et al., 2005)
- Maximize aggregate welfare because they support trading at the lowest linking cost (Babus, 2012).

Centralization

- Centralization is relevant to the way groups get organized to solve at least some kinds of problems (Freeman, 1979).
- Network's centralization may be the result of an **optimization process**, by which a tradeoff between conflicting objectives is resolved.
- A general case of **optimization process** by Ferrer i Cancho & Solé (2003), designed for distribution networks (e.g. transport, communications):
  - Minimizing distance among participants in a network (l)
  - Minimizing the density of the network (d)

This is a non-simple task as it involves…

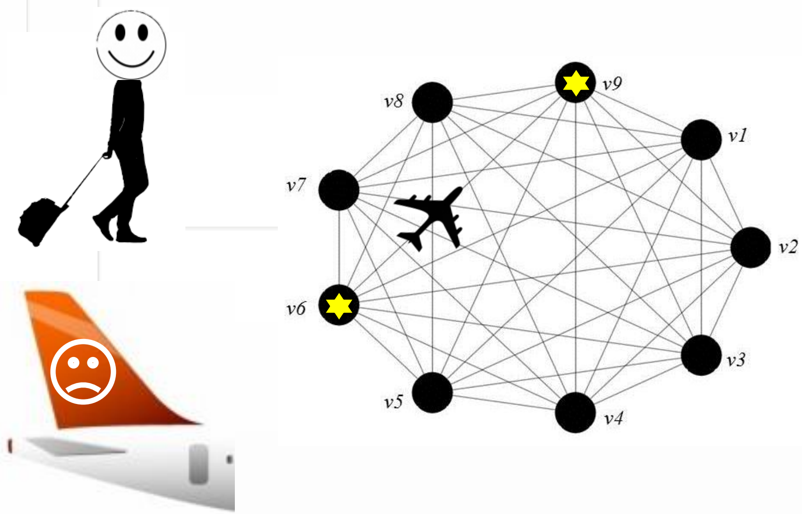
- The number of links in the network (for d)
- The way links are distributed (for l)

Centralization

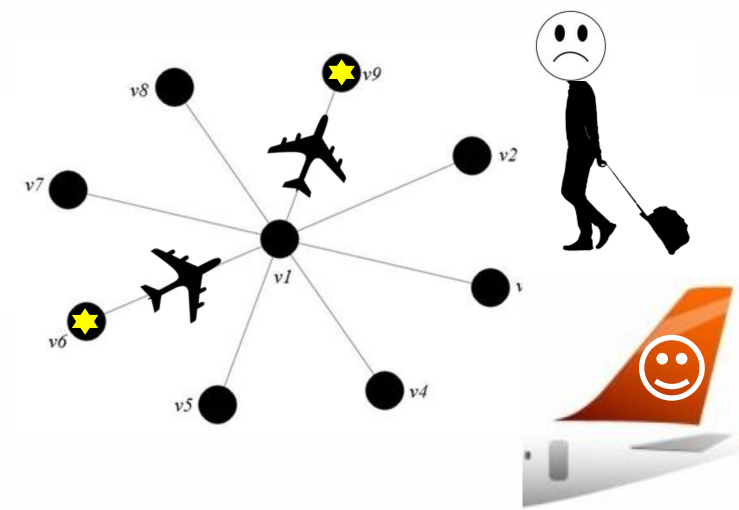
Usual case study

Airlines networks: point-to-point flights *vs.* hub & spoke flights

Minimizing distances by ***maximizing the number of links***



Minimizing costs by ***minimizing the number of links***



Complete network
Maximal density, d=1
Minimal avg. distance, $l = 1$

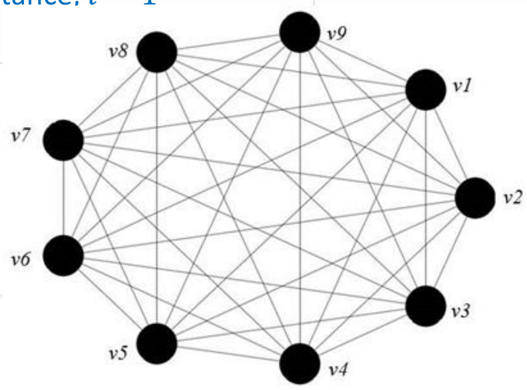
- **Poisson networks**
- **Scale-free networks**
- **Core-periphery networks**

Star network
Minimal density, d~0
Average distance, l~2

Centralization

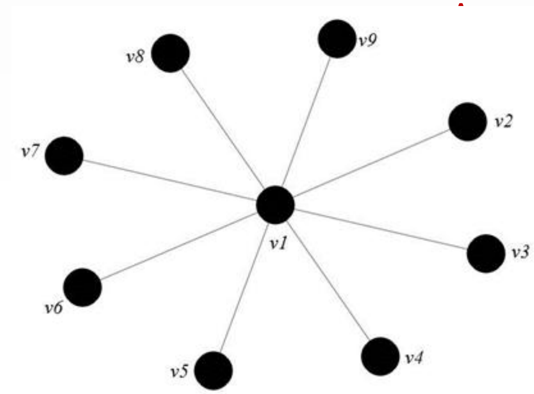
Feasibility of complete and star networks

Complete network
Maximal density, d=1
Minimal avg. distance, $l = 1$



- Complete networks are **costly**.
- Complete networks correspond to systems in which every element is connected to each other in a feedback loop, and thus they are **hopelessly unstable** (Simon (1962) & Anderson (1999))..

Star network
Minimal density, d~0
… e distance, l~2



- Star networks and **single-point-of-failure risk**.
- Real networks are not centralized as a star. There are **hierarchies of hubs** that keep networks together… (Barabasi, 2003).

The adaptive actions of individual agents lead the system away from the critical regimes and more toward what an omniscient designer attempting to balance risk and stability would create (Miller & Page, 2007)

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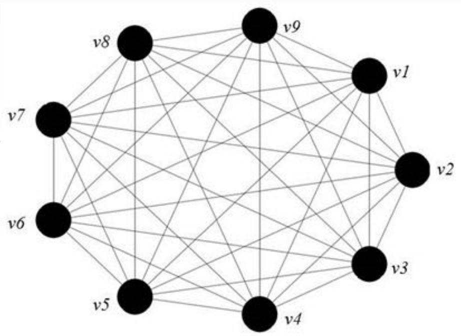
Money market centralization

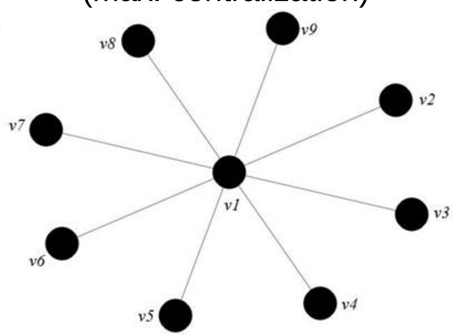
Complete network
(min. centralization)



- Maximal availability of counterparties for exchanging liquidity (**minimal liquidity risk**)
- **Maximal counterparty** risk exposure

- Costs and risks turn a complete network into an inefficient one (Castiglionesi & Eboli, 2015).
- Costs and risks foster a sparse money market in the form of liquidity cross-underinsurance (Castiglionesi & Wagner, 2013)

Star or wheel network
(max. centralization)



- Full coverage of liquidity risk with the **minimum expected losses** (Castiglionesi & Eboli, 2015)
- Trading at the lowest linking cost (Babus, 2012)

- Single-point-of-failure risk and non-substitutability
- Competition for market hub position (collecting fees, market power, systemic importance subsidies, etc.).

Money market centralization

- Two conflicting objectives in money markets:
  - Minimizing liquidity risk by minimizing the average distance among counterparties (l)
  - Minimizing counterparty risk by minimizing the density (d)

Again, this is a non-simple task as it involves…

- The number of links in the network (for d)
- The way links are distributed (for l)

- Related to Castiglionesi & Eboli (2015) model: a network shape that maximizes liquidity transfer with the smallest counterparty exposure.
- Financial networks' stylized facts: sparse and inhomogeneous structures, somewhere between complete and star networks
  - Core-periphery structures (Craig & von Peter, 2014; in 't Veld & van Lelyveld, 2014)
  - Scale-free networks (Boss et al., 2004; Soramäki et al., 2007)
  - Modular scale–free (León & Berndsen, 2014)
  - Incomplete and clustered nature of credit networks (see Battiston et al., 2012)

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The Dataset

- Several types of bilateral liquidity transactions between financial institutions from Colombian FMIs:
  - Secured, between financial institutions (banking and non-banking institutions)
  - Secured, with the central bank, via repos with banking and non-banking inst.
  - Unsecured, between financial institutions (banking and non-banking institutions)

- Most literature deals with unsecured liquidity exchanges for its market discipline contents (e.g. Furfine, 2001)
- Some literature deals with secured between financial institutions; collateral does not offset counterparty risk (e.g. King, 2008; Gorton & Metrick, 2012)
- A few deal with central bank lending (e.g. Georg & Poschmann, 2010)
- We cover the three types to compare how they balance liquidity and counterparty risks in the Colombian case…

The Dataset

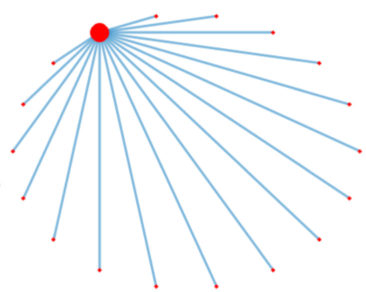
- Our dataset:
  - Daily consolidated bilateral transactions between May 2 2013 and October 30 2015 (609 days; 96,874 consolidated transactions from secured, unsecured an CB's repos)
  - We cover 99.1% of all money market transactions (by value)

- Our centrality measures are among the simplest:
  - Degree centrality: number of links; related to the potential for liquidity distribution in the network (see Freeman, 1979)
  - Closeness centrality: how close to other counterparties; related to the efficiency for liquidity distribution in the network (see Freeman, 1979)
  - *We use non-weighted networks and centrality measures as we care about the connective structure only.*

The Dataset

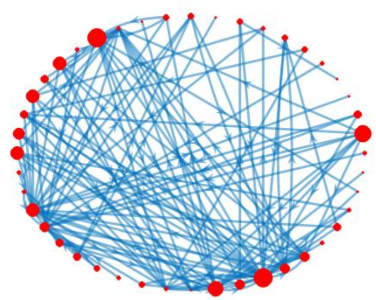
A randomly selected day in the Colombian money market …

CB's Repo Market



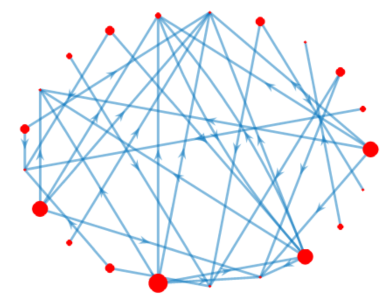
l=1.89 | *d*=0.11

Secured Market



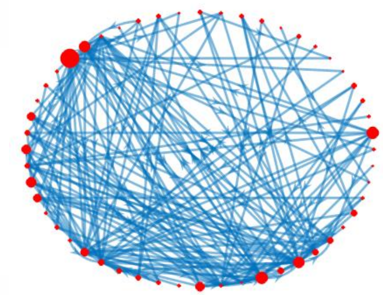
l=2.63 | *d*=0.06

Unsecured Market



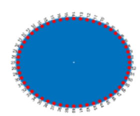
l=1.22 | *d*=0.08

All Money Market
(the aggregation)



l=2,65 | *d*=0.06

(*) All networks are non-weighted. Nodes' diameter correspond to the degree (number of connections. The direction of the arrows (arcs) correspond to the direction of the funds (from lender to borrower); in the central bank's repo market no direction is reported. Central bank's network is considered a non-directed network as the monetary policy stance in this period is expansionary (i.e. no financial institution used reverse monetary repos).). The average distance (*l*) and the density (*d*) are also reported.



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Main properties of the networks

- Networks are sparse and inhomogeneous, concurrent with stylized facts well-documented in related literature (except CB’s, obvioulsy)

Network Statistic	CB’s Repo (CB)	Secured (S)	Unsecured (U)	All Money Market (MM)
Number of participants (n)	17.53 [4.50]	42.59 [3.42]	17.59 [2.68]	52.73 [3.37]
Density (d)	0.13 [0.05]	0.07 [0.01]	0.10 [0.02]	0.06 [0.01]
Average distance (l)	1.88 [0.05]	2.62 [0.24]	1.29 [0.23]	2.63 [0.21]
Degree centralization (DC)	1.00 [0.00]	0.18 [0.03]	0.14 [0.04]	0.14 [0.03]
Closeness centralization (CC)	1.00 [0.00]	0.46 [0.03]	0.16 [0.06]	0.45 [0.03]
Assortativity coefficient (r)	-0.21 [0.06]	0.41 [0.09]	0.75 [0.11]	0.45 [0.07]

Table 2. Mean and standard deviation (in brackets) of selected network statistics. All statistics are calculated on the number participating institutions for each market for each date in the sample (i.e. matrix dimensions varies throughout the sample). Figure 3 (see Appendix) displays time-series plots of selected network statistics.

Non-large

Sparse

Core-periphery connective structure (exc. CB’s)

MAIN PROPERTIES OF THE NETWORKS

- Cross section features are rather intuitive, and correspond to the nature of each market.

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- Unsecured and CB's are the less populated
- Secured is the most populated

- A few exchange liquidity without collateral (small club of banks)
- Collateral allows to exchange liquidity among diverse agents (banking & non-banking), akin to Allen et al. (1989).
- A few banks and non-banks demand CB's liquidity (stigma? precautionary?)

Main properties of the networks

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- Secured is sparser than unsec. (!)
- Secured is the most sparse (!!)
- CB's repo is the least sparse (!!!)

- Collateral does not offset counterparty risk (Gorton & Metrick, 2012; King, 2008)
- But collateral grants access to all types of agents, akin to Allen et al. (1989).
- Unsecured is about credit institutions enjoying last-resort lending and TBTF guarantees (small club of banks)
- CB lending/borrowing is not counterparty risk-related.

Main properties of the networks

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- Distance among agents in unsecured is visibly lower
- Collateral does not result in low distances among agents
- CB's role makes all agents get closer

- Liquidity risk is lower in unsecured, but access is limited (liq. undersinsurance)
- Collateral allows more diverse agents to find liquidity, but distance is high (liq. underinsurance)
- CB's repo allows exchanging liquidity easily (this is CB's goal)

Main properties of the networks

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- Centralization is extreme in CB's repos (by construction, a star)
- Secured is second most centralized (!)
- Unsecured is the less centralized (!)

- Collateral does not offset counterparty risk (Gorton & Metrick, 2012; King, 2008)
- Secured mixes all types of agents, and makes the network more centralized around a few agents
- Unsecured is about credit institutions enjoying last-resort lending and TBTF guarantees, thus it is more descentralized.

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Liquidity risk *vs.* counterparty risk

- Analogous to Ferrer i Cancho & Solé (2003), we suggest that the structure of money market networks may result from an optimization process:
  - Minimizing liquidity risk by minimizing the average distance to counterparties (l)
  - Minimizing counterparty risk by minimizing the density (d)

Again, this is a non-simple task as it involves…

- The number of links in the network (for d)
- The way links are distributed (for l)

The connective structure of money market networks reveals how financial institutions balance counterparty and liquidity risks

Liquidity risk *vs.* counterparty risk

Graphically, the relation between density and average distance

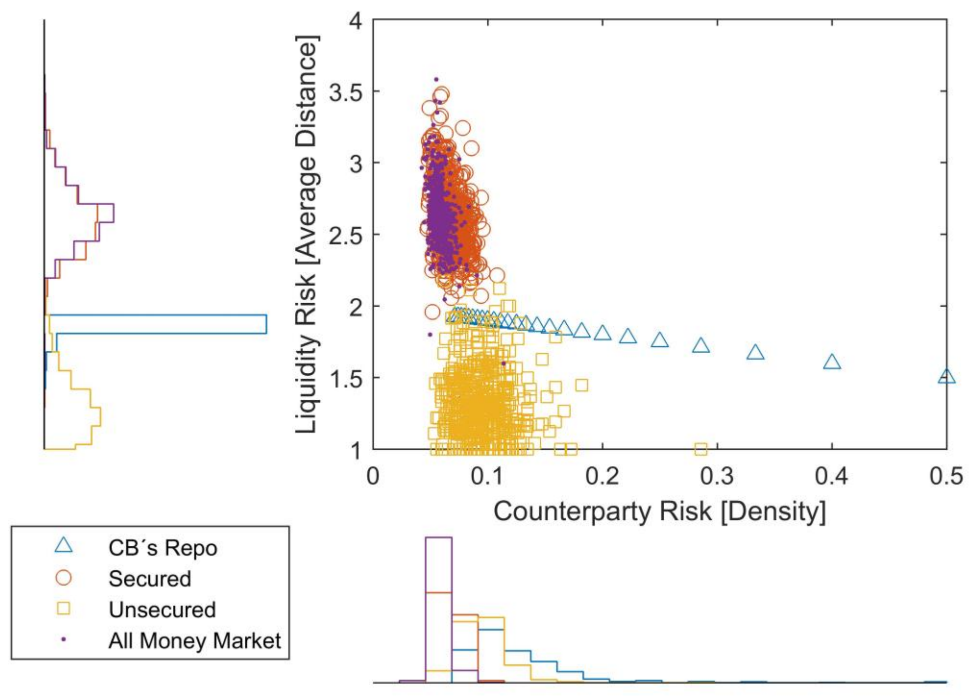


Figure 2. Counterparty risk (x-axis) and liquidity risk (y-axis) tradeoff. Each marker corresponds to the combination between density and average distance calculated on observed daily networks for the four markets.

Unsecured
- **A small club of banking institutions**
- **Lower counterparty risk aversion (higher density)**
- **Lower liquidity risk (lower distance)**

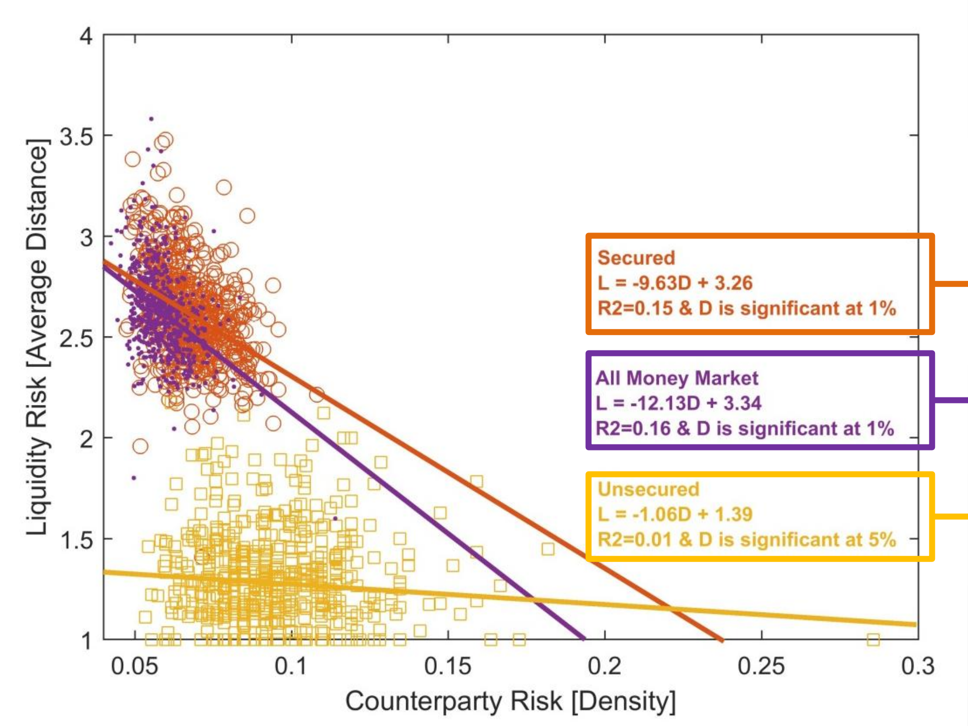
Secured
- **A diverse mix of banking and non-banking institutions**
- **Higher risk aversion (lower density)**
- **Higher liquidity risk (higher distance)**

Central bank's repos
- **A wide spectrum of densities (monetary considerations first)**
- **The number of borrowers varies a lot**
- **Liquidity risk is low (but… in fact it is even lower!)**

All money market (unsecured + secured + central bank)
- Very similar to secured market
- Low density (counterparty risk aversion)
- High distances (underinsurance)

Liquidity risk *vs.* counterparty risk

Numerically, the relation between density and average distance*



- Negative and very significant relation between density and average distance
- The higher the density, the lower the distance
- This is an explanatory tradeoff

- Negative and very significant relation between density and average distance
- The higher the density, the lower the distance
- This is an explanatory tradeoff

- Negative and mildly significative relation between density and average distance
- Increasing the density has a slight impact on average distance
- This is a not-too-much explanatory tradeoff

(*) Central bank's repo network is not reported. As the relation between density and distance in a star network is linear and fixed, it yields a "perfect regression".

Agenda

- Introduction
- Centralization of networks and the money market
  - Centralization of networks
  - Money market networks' centralization
- The dataset
- Main results
  - Main properties of the networks
  - The tradeoff between liquidity risk and counterparty risk
- Final remarks

Final remarks

- We examine how liquidity is exchanged in different types of Colombian money market networks (secured, unsecured, and Central Bank's repo).
- We examine the tradeoff between liquidity risk and counterparty risk, and its relation with money market networks' centralization.
- We suggest financial networks follow a simple network optimization problem between liquidity risk (minimizing distances) and counterparty risk (minimizing density).
- Findings are important as they contribute to the understanding of the liquidity and counterparty risks tradeoff.

Final remarks

- What we find:
  - Different types of money market networks diverge in their centralization and in how they balance counterparty risk and liquidity risk.
  - Evidence of *liquidity cross-underinsurance* (Castiglionesi & Wagner, 2013).
  - Unsecured displays lower liquidity risk, but access is discriminatory (a type of liq. underinsurance)
  - Collateral reduces *liquidity cross-underinsurance* (by increasing access, but liquidity risk remains)
  - Central bank's role in mitigating liquidity risk (Acharya et al., 2012).

- This is an empirical contribution to theoretical literature on the connective structure of financial networks (e.g. Allen & Gale, 2000; Castiglionesi & Wagner, 2013; Castiglionesi & Eboli, 2015).

Final remarks

- Interestingly, our conceptual framework may serve to "translate" an accepted depiction of the great financial crisis (see Acharya et al., 2012; Temizsoy et al., 2015) into network parlance:

1 – Surplus banks rationed liquidity amid increased uncertainty about counterparty risk: *surplus banks reduced the density of the network*

2 – Liquidity rationing resulted in the difficulty of needy banks to access liquidity: *needy banks were pushed distant away from liquidity*

3 – Central banks intervened as lenders of last resort to restore access to liquidity: *central banks pulled (back) needy banks closer to liquidity*

Final remarks

- What are we missing?
  - The impact of mandatory central clearing and settlement for secured lending with sovereign collateral (starting October 2015 for SEN; January 2016 for MEC)
  - Density and average distance as proxies for counterparty and liquidity risk is appealing… what about other network measures (e.g. clustering, reciprocity, assortativity)?
  - Are density and average distance explanatory variables of the cost of liquidity in the money market?

Based on León C., & Sarmiento, M. (2014) Liquidity and Counterparty Risks Tradeoff in Money Market Networks, *Borradores de Economía*, 936, Banco de la República.

http://www.banrep.gov.co/sites/default/files/publicaciones/archivos/be_936.pdf

https://pure.uvt.nl/ws/files/11271343/2016_017.pdf

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