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Network centrality measures and systemic risk: An application to the Turkish financial crisis

Tolga Umut Kuzubaş *, Inci Ömercikoğlu, Burak Saltoğlu

Boğaziçi University, Department of Economics, Natuk Birkan Building, 34342 Bebek, Istanbul, Turkey

HIGHLIGHTS

- Analyze network centrality of systemically important financial institutions (SIFI).
- Data from Turkish Interbank market during the financial crisis in 2000 is used.
- Study the role of Demirbank during the crisis with network centrality measures.
- Centrality measures perform well in identifying and monitoring SIFI.

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ABSTRACT

In this paper, we analyze the performance of several network centrality measures in detecting systemically important financial institutions (SIFI) using data from the Turkish Interbank market during the financial crisis in 2000. We employ various network investigation tools such as volume, transactions, links, connectivity and reciprocity to gain a clearer picture of the network topology of the interbank market. We study the main borrower role of Demirbank in the crash of the banking system with network centrality measures which are extensively used in the network theory. This ex-post analysis of the crisis shows that centrality measures perform well in identifying and monitoring systemically important financial institutions which provide useful insights for financial regulations.

1. Introduction

In the last fifty years, we have experienced various global and local crises. The last financial crash in 2008 has confirmed the central role played by the interbank money markets for the smooth functioning of the financial system and implementation of monetary policy. Macro-prudential policies have led financial regulations to a new paradigm relying on a thorough investigation of the behavior of the systemically important institutions (SIFI) through their role in affecting the entire system in the case of their failures.

Modern financial markets exhibit a high degree interdependence and interconnectedness. Those connections stem from agents balance sheets both for the asset and liability sides. However, the complex structure of the financial system makes it difficult to detect and monitor the institutions which are contributing to the systemic risk. In a comprehensive analysis of these interconnections for finance and insurance sectors, Billio et al. [1] proposed a formal measure which also captures linkages and balance sheet transactions. Besides, a recent study of G-20 shows that systemically important institutions are not only the largest ones but also those which are interconnected and capable of affecting the whole financial system.[1]

* Corresponding author. Tel.: +90 212 3597641; fax: +90 212 287 24 53.
E-mail addresses: umut.kuzubas@boun.edu.tr (T.U. Kuzubaş), inci.omercikoglu@gmail.com (I. Ömercikoğlu), burak.saltoglu@boun.edu.tr (B. Saltoğlu).

[1] See Ref. [2], "Declaration on Strengthening the Financial System".

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There exist several econometric models to measure the systemic risk.[2] However, these tools and existing techniques at best give indirect indications of the system. Considering the fact that modern financial systems have a very complex structure, network representation gives the crucial picture of the whole system. Mapping financial systems to networks, taking financial institutions as nodes, network theory provides a promising framework for analyzing the inner working of interbank money flows.

A growing literature has emerged analyzing the stability of the interbank markets using network topological approach. This literature aims to identify institutions that are possibly systemically relevant because of the repercussions of their bankruptcy on other financial institutions. Therefore, it primarily investigates how different financial network structures respond to the default of a single financial institution to analyze which structures are more fragile and the characteristics of the institutions with a larger effect on the entire system in the case of their failures. Henggeler-Muller [4] argues that a financial institution, which is systemically important in a financial network, has the following characteristics: (i) Possesses many linkages to other members of the network (degree), (ii) The total amount of its assets, liabilities or flow in the network is very large (strength), (iii) Its failure could transmit contagion in a few steps (closeness), (iv) Its counterparts are considered also as relevant (eigenvector and PageRank) and (v) There are many paths which pass through it (betweenness). Therefore, network analysis is becoming an important tool for regulatory institutions and central banks to identify systemically important financial institutions, especially after the 2008 financial crisis. Applications stress the importance of network centrality measures in the ''too interconnected too fail'' context. In a recent paper, Leon and Perez [5], assess the systemic importance for Columbian financial infrastructures by estimating authority and hub centrality. Bravo-Benitez et al. [6], in order to monitor and measure systemic risk, investigate interbank payment system network in Mexico based on network centrality measures. Additionally, recent Basel III regulations put a weight of 20% to interconnectedness of a bank in identification of Global Systemically Important Banks (G-SIB), hence interconnectedness and centrality is becoming an increasingly important tool for regulators to monitor systemic risk.[3]

Allen and Gale [7] investigate the response of the banking system to a contagion when banks are connected under different network structures. Eisenberg and Noe [8] analyze default by firms in an interbank market by introducing a single clearing mechanism. Gai and Kapadia [9] develop a model of contagion using the network approach and assess the fragility of the financial system, depending on the degree of connectivity, and the liquidity of the market. Li et al. [10] introduce a network model and show that simulation of their model replicates features of real interbank networks such as low clustering coefficient and a relatively short average path length, community structures, and a two-power-law distribution of out-degree and in-degree. Soramaki et al. [11] investigate the network topological properties of Fedwire funds service and argue that network is scale-free and characterized by low average path length and low connectivity. Nier et al. [12] study the relationship between network structure and number of defaults in a simulated random network model. In addition to this theoretical literature, an empirical literature studying the interbank networks has emerged which estimate bilateral credit relationships under different banking systems. Upper and Worms [13] conduct an analysis for Germany, Cocco et al. [14] for Portugal, Degryse and Nguyen [15] for Belgium, Wells [16] for UK and Chang [17] and Cajueiro and Tabak [18] for Brazil. Basic premise of the literature is that shocks affecting central institutions are more likely to spread out to the entire system which suggests an intimate link between the position in the network and the contribution to the systemic risk. However, the main limitation of these papers is that they conduct counter-factual analysis based on simulations of the banking system and rely on the presupposition that more central institutions have a larger contribution to systemic risk, however this hypothesis is not tested in a real-life financial crisis. A notable exception along this dimension is Iyer and Peydro-Alcalde [19] where they study the financial contagion due to interbank linkages using detailed balance sheet information from the failure of a large cooperative bank in India and show that interbank linkages act as an important channel of contagion.

In this paper, we also use a novel data set from the Turkish banking crisis in 2000 which serves as a natural experiment to test the ability of network centrality in measuring systemic importance and contribution to systemic risk. The main contribution of our paper is measuring centrality of a financial institution, which is known as the main driving actor of the crisis, and introducing a time perspective where we follow this specific institution's centrality over time. We would like to understand the way in which the centrality of a SIFS (Systemically Important Financial Institution) changes and affects the financial system in a crisis situation. During this crisis, the interbank market reorganized drastically around a SIFS (Demirbank) and the default of this institution leads to a crash in the centralized network around this institution.[4]

The information on the timing of default of Demirbank which triggered the crisis through its default, allows us to compare properties of network measures retrospectively and facilitates the analysis of the performance network centrality measures in detecting and monitoring systemically important institutions. Using the same data set, Saltoglu and Yenilmez [23] modify the Google page rank algorithm and show that most interconnected financial institutions can be detected five months before the crisis. We extend their analysis by introducing a broader set of centrality measures which are commonly used in the literature and assess their effectiveness. We also employ various network investigation tools such as volume, transactions, links, connectivity and reciprocity to gain a clearer picture of the network topology of the interbank market. Another contribution of our paper is to add a time-series dimension to the network analysis. By creating 240 consecutive

2 See Ref. [3].

3 See financial stability report by the Financial Stability Board, http://www.financialstabilityboard.org/publications/r_131111.htm for details.

4 See Refs. [20–22] for an extensive analysis of the Turkish financial crisis in 2000.