COMPARING SYSTEMIC RISK MEASURES

DURING A FINANCIAL CRASH

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DECLARATION OF ORIGINALITY

I, İnan Kılıç, certify that

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ABSTRACT

Comparing Systemic Risk Measures

During a Financial Crash

This paper investigates 2000 Turkish Banking Crisis utilizing market based and network based systemic risk measures. In this investigation, MES, SRISK and ΔCoVaR are taken as market based measures whereas Degree centrality, Closeness centrality and Betweenness centrality are evaluated as financial network measures. The analyses are performed for 12 Turkish Banks and the performance of the inherently different systemic risk measures in identifying and detecting the stress of the banking sector are compared with an event study. The findings suggest that different systemic risk measures point out different systemically important financial institutions (SIFI). Empirically, we derive that (1) SRISK is capable of capturing a too-connected-to-fail bank, Demirbank, despite its market based nature and that (2) MES is the only measure providing statistically significant results for market, too-connected-to-fail banks and too-big-to-fail banks together.

ÖZET

Finansal Bir Çöküş Sırasında

Sistemik Risk Ölçümlerinin Karşılaştırılması

Bu tez, piyasa temelli ve ağ temelli sistemik risk ölçümlerini kullanarak 2000 Türk Bankacılık Krizi'ni incelemektedir. Bu incelemede MES, SRISK ve ΔCoVaR piyasa temelli ölçümler, Derece merkezliği, Yakınlık merkezliği ve Arasındalık merkezliği ağ temelli ölçümler olarak değerlendirilmiştir. Analizler, 12 Türk bankası için gerçekleştirilmiş ve doğası gereği farklı olan sistemik risk ölçümlerinin, bankacılık sektöründeki stresi belirleme ve tespit etmedeki performansları bir vaka çalışması ile karşılaştırılmıştır. Bulgular, farklı sistemik risk ölçümlerinin, farklı sistemik olarak önemli finansal kurumlara (SIFI) işaret ettiğini göstermektedir. Ampirik olarak, (1) SRISK'nin piyasa temelli doğasına rağmen, batmak-için-çok-ilişkili olan Demirbank'ı yakalayabildiğini ve (2) MES'in sektör, batmak-için-çok-ilişkili bankalar ile batmak-için-çok-büyük bankaların hepsi için istatistiksel olarak anlamlı sonuçlar veren tek ölçüm olduğunu belirledik.

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CHAPTER 1

INTRODUCTION

In recent history, financial systems have experienced various global or local crises. In particular, the dynamics of the financial crash in 2008 have renewed attention of the literature and highlighted the need of understanding and monitoring systemic risk. This interest inspired a large body of research on the analytic tools used in measuring systemic risk with different perspectives.[1]

Although the aftermath of a crisis or a systemic event is generally a macroprudential concern, the threats to the financial stability might be resulting from either macroprudential or microprudential applications. Suitably, two main approaches have been adopted in the development of systemic risk measures, called macroprudential and microprudential analytics. Although they have differences in terms of supervisory scope, they have a feature in common: serving as an early warning mechanism.

Macroprudential approach yields systemic risk measures concentrating on aggregate imbalances in the entire financial system. These measures attempt to identify, measure, or detect the growing tension in the system which is frequently reflected in the macroeconomic indicators. For this reason, using macroeconomic time series is a common practice in calculating such measures, nevertheless, aggregating micro-level measures is also an applicable method.

[1] Bisias et al. (2012) surveys 31 different systemic risk measures.

Additionally, microprudential approach focuses on such measures with the goal of assessing the individual contribution of an institution or an entity to the overall financial system. These measures attempt to identify risky institutions and determine the severity of the threat by a given institution. In micro level, a wide variety of measurement techniques have been introduced and organized under two categories. These are Market Based Approach and Financial Network Approach (Supervisory Approach). The former uses publicly available market data, such as stock returns or balance sheets, which reflects valuable information about publicly traded banks. On the contrary, the latter relies on data provided by financial institutions to only regulators, such as transaction data in the interbank market.

In this study, Marginal Expected Shortfall (MES), SRISK and Delta Conditional Value at Risk (ΔCoVaR) are investigated as market based measures. On the other hand, Degree Centrality, Closeness Centrality and Betweenness Centrality are evaluated as financial network measures.

In the last several decades many major financial turmoils such as 2008 Financial Crisis have been investigated from various systemic risk perspectives. However, 2000 Turkish Banking Crisis has little attention in terms of systemic risk in the literature due to the lack of data availability and rudimentary literature about systemic risk at the time of the crisis. As the first objective, this research fills this gap by applying several systemic risk measures to the Turkish banking sector for the period of 1998-2000.

Naturally, market based measures are not able to capture the characteristics of the network side and financial network measures lack the market characteristics as well. Hence, the second objective of this study is to compare and contrast aforementioned systemic risk measures in order to determine whether these measures are consistent with each other in detecting and measuring systemic risk on the Turkish banking sector turmoil in 2000. In doing so, it anatomizes all these measures to identify banks which contribute more to systemic risk.

The contribution of this study is twofold. Firstly, it is the first application of market based measures and financial network measures together to the Turkish banking sector. Secondly, this study carries the advantage of comparing these inherently different systemic risk measures evaluating the stress in the market from different perspectives.

The remainder of the study is organized as follows: Chapter 2 introduces the relevant studies in both economics and finance literature. Chapter 3 describes the historical data employed in the econometric calculations of systemic risk measures. Chapter 4 outlines the general definitions and methodologies of the considered methods to measure systemic risk. It also contains the main empirical findings. Chapter 5 presents the comparison results of the measures. Finally, Chapter 6 summarizes and concludes the research.

CHAPTER 2

LITERATURE REVIEW

There are different types of risks that individual institutions in a financial sector face such as market risk, credit risk, liquidity risk or operational risk. However, the financial crisis in 2008 has extended the focus of economists from individual bank risks to systemic risk and expand the literature with the goal of measuring systemic risk.

Despite the increasing number of studies, there is still no solely recognized definition for systemic risk. For instance, The European Central Bank (ECB) defines it as the probability that the default of one institution will make other institutions default. In turn, Bliss and Kaufman (2006) defines it as the risk of occurrence of a chain reaction of bankruptcies. Similar to definition, the assessment and measurement of systemic risk varies extensively. Nevertheless, Bisias et al. (2012) provides an overview of various systemic risk measures and their taxonomy.

Due to the complexity of the financial system which stems from the high degree of interdependence and interconnectedness, two main approaches has been adopted in the literature in order to find a proxy for systemic risk.

As popular market based systemic risk measures, it is worth to highlight Marginal Expected Shortfall (MES) of Acharya et al. (2010), SRISK of Acharya et al. (2012) and ΔCoVaR of Adrian and Brunnermeier (2011). Other than these, many other examples can be found which discuss, implement and generalize systemic risk measures in the literature.[2]

On the network side, it thrives with Allen and Gale's (2000) analysis on the resilience of a financial system to contagion where the institutions are treated as nodes, the transactions are used for the links between the nodes and they are connected in various topology of network. Henggeler-Muller (2006) suggests different network exploration tools to analyze the inner workings of the financial network using degree, closeness, betweenness etc. Furthermore, Kuzubaş et. al (2014) employ aforementioned tools to investigate the performance of different network centrality measures in order to assess the systemically important financial institutions (SIFI) exploiting data from the Turkish Interbank market during Turkish banking crisis in 2000.

It is essential to analyze and compare their performance in order to find out the most reliable systemic risk measure. Pankoke (2014) states that simple systemic risk indicators are more suitable indicators than sophisticated risk measures. Similarly, Rodríguez-Moreno and Peña (2013) provides similar results concluding that CDS based measures outperform stock market based measures. In addition, Benoit et al. (2013) presents a theoretical and empirical comparison of market based measures by deriving the conditions under which the different measures lead to similar rankings of systemically important financial institutions (SIFI). Recently, the studies which compares the explanatory power of systemic risk measures in the assessment of systemic risk are continuing to grow in number.[3]

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[2] See for instance Danielson et al. (2012) and Ergun and Girardi (2013)
[3] See for instance Huang et al. (2009) and Idier et al. (2014)

Turkish banking crisis caused significant losses in Turkish banking sector and unstabilized the banks' balance sheets. The damage is taken due to vulnerabilities in the political and economic states, and the history of the crisis can be summarized as follows. Russia had been an important trading partner for Turkey in 1990s. Its entry into a crisis in 1998 negatively impacted the confidence of foreign investors in Turkey. The devastating effects of 1999 Marmara earthquake created additional pressures on the budget, further deteriorating the economic performance of Turkey. Unhealthy and fragile nature of the Turkish economy was tried to be controlled with the IMF's stabilization program. The fundamental component of this program was a pre-announced crawling peg exchange-rate regime. Although the program's focus was on macroeconomic imbalances (i.e. high inflation, low capital inflow etc.), the vulnerabilities in the financial sector were failed to be addressed. The liquidity crisis in November 2000 amplified the concerns about the weakness of the banking system. Primarily, The Central Bank of the Republic of Turkey (CBRT) closed its emergency credit lines to banks in order to keep domestic asset level stable. Hence, the interbank rate jumps to 873%. Thereafter, banks begin to stop lending their interbank credits to the vulnerable banks. Demirbank, a highly interbank credit dependent mid-size private bank, became unable to borrow in the interbank market. As a result, Demirbank fails and taken over by the Savings Deposit Insurance Fund (SDIF)[4] on 6 December 2000, driving the banking sector into a systemic crisis. Hence, the nature of this systemic crisis provides a unique basis for the measurement of both market based and network based systemic risk measures.

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[4] SDIF is a government body responsible for ensuring savings deposits in the Turkish banks and strengthening and restructuring banks if necessary.

In addition, extensive investigations on Turkish banking crisis in 2000 are established by Saltoglu and Danielson (2003), Saltoglu and Yenilmez (2015), and Van Rijckeghem and Üçer (2005).

CHAPTER 3

DATA DESCRIPTION

The analysis of systemic risk in this research is focused on banks performing in Turkey during and before the 2000 Turkish Banking Crisis. Therefore, the dataset is set up for the banks in Turkey covering the crisis and pre-crisis periods. In order to maintain a concrete illustration of the scope of the analysis, Table 1 presents the details about the data utilized in this study.

For the market based systemic risk measures, we use daily market equity data for the banks and market index, which are taken from DataStream and the balance sheet information for the banks collected through the open web source of The Bank Association of Turkey.

Table 1. Details About Data Types

Data Type	**Measure Type**	**Source**	**Frequency**	**Start**	**End**
Equity Return	Market Based	DataStream	Daily	Jan 1, 1997	Dec 31, 2000
Equity Index	Market Based	DataStream	Daily	Jan 1, 1997	Dec 31, 2000
Market Capitalization	Market Based	DataStream	Daily	Jan 1, 1998	Dec 31, 2000
Balance Sheet	Market Based	Website of Banks Association of Turkey	Quarterly	Q4:1997	Q4:2000
Interbank Transaction	Network Based	Istanbul Stock Exchange	Daily	Jan 1, 2000	Dec 31, 2000

For the network based systemic risk measures, we employ data from Turkish overnight money market including interbank lending and borrowing transactions obtained from the electronic interbank market of Istanbul Stock Exchange. We consider the banks as nodes and transactions are taken as links between the nodes for the analysis.

In 2000, there were almost 90 banks performing in Turkey, but this number was dynamically changing because of the fact that banks were going bankrupt or merging together. 16 of them were open to public so that they can be traded in the stock market. However, since some series for several banks contains so many missing values or no values at all, 12 banks were utilized with the purpose of keeping the integrity and comparability of the results. The abbreviations of the banks are introduced in Table 2.

Table 2. Code List of the Banks

Code	Name of Banks
ISC	Türkiye İş Bankası A.Ş.
YKB	Yapı ve Kredi Bankası A.Ş.
AKB	Akbank T.A.Ş.
GAR	Türkiye Garanti Bankası A.Ş.
DEM	Demirbank T.A.Ş.
FIN	Finans Bank A.Ş.
FOR	Fortis Bank A.Ş.
TPR	Toprakbank A.Ş.
TEB	Türk Ekonomi Bankası A.Ş.
ALT	Alternatifbank A.Ş.
ICBC	ICBC Turkey Bank A.Ş.
TSKB	Türkiye Sınai Kalkınma Bankası A.Ş.

In order to comprehend the size of this study, it is better to peak at the market capitalizations of the banks under the scope as shown in Figure 1.

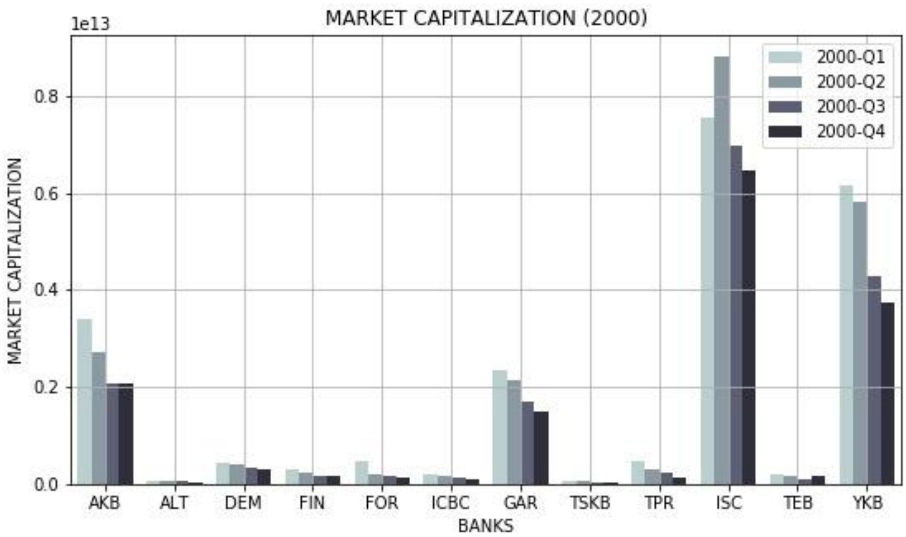

Fig. 1 Market capitalization of banks in 2000

In order to understand the distress in the Turkish economy before and during the crisis, it is wise to first look at the market index in Turkey. BIST 100 is an index created to measure the price and return performances of the top 100 firms' stocks traded on Istanbul Stock Exchange. Figure 2 demonstrates the price of BIST 100. As the graph indicates, there is a drastic upward trend in 1999, which makes the market more volatile. Also, the downward trend in BIST100 index in 2000 reveals the deterioration in the economy.

On the other hand, the interbank market volume kept increasing during 2000 until the default of Demirbank on December 6, 2000. Figure 3 shows the total amount of transactions in the overnight money market in 2000 and emphasizes the sharp fall in December 2000. In addition, Figure 4 presents the daily interest rate in the overnight money market and the drastic jump at the same time the volume shrinks.

Fig. 2 BIST100 index value from Jan 1, 1998 to Dec 31, 2000

Fig. 3 Interbank total transaction volume in 2000

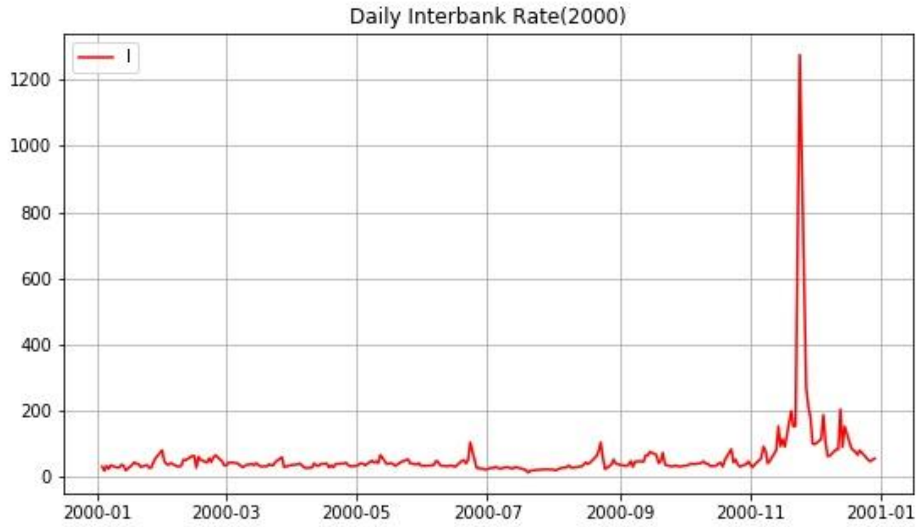

Fig. 4 Interest rate in interbank money market in 2000

While comparing the systemic risk measures, the main idea is to determine the performance of the measures in identifying systemically important institutions. These institutions might have a great size that may have an impact on the whole market (too-big-to-fail) or might have too many transactional connections which pose a threat to many other institutions (too-connected-to-fail). In this perspective, ISC, YKB, AKB, GAR might be considered as too-big-to-fail according to Figure 1 whereas DEM might be considered as the only too-connected-to-fail institution as the main actor of the crisis.

CHAPTER 4

SYSTEMIC RISK MEASURES

With the renewed interest on systemic risk after the sub-prime crisis, a wide spectrum of approach has been developed in order to measure systemic risk and identify threats to the stability of financial system. In this research, two different methodologies have been investigated.

4.1 Market based systemic risk measures

The first strand of literature relies on market based indicators to measure systemic risk and identify systemically important financial institutions. The most popular microprudential sophisticated systemic risk measures are Marginal Expected Shortfall (MES), SRISK, and Delta Conditional Value at Risk (ΔCoVaR).

4.1.1 MES

The MES is a systemic risk measure originally developed by Acharya et al. (2010). It is defined as the bank's expected equity loss given that the market experiences the worst α% days, which is also called that the market is in a tail event. As the name suggests, MES is a concept based on Expected Shortfall (ES) and it measures the marginal contribution of a bank to the systemic risk. Banks with lower MES are the ones that contribute the most to the market loss, thus they are more likely to be systemically risky.

Additionally, MES does not attempt to measure the probability of a potential crisis but concentrates on the individual contribution of a bank to the aggregate risk in the market. Therefore, it can be concluded that it investigates the expected magnitude of a crisis rather than the likelihood.

The calculation applied can be represented as:

$$MES^{i}_{\alpha\%}(t) = \sum_{t-261}^{t} \frac{\left[r^{i}_{t} |\, I_{\alpha\%,261}\right]}{261\,\frac{\alpha}{100}}$$

where $MES^{i}_{\alpha\%}(t)$ is the MES of bank i at time t with the chosen α, r^{i}_{t} is the return of bank i at time t, and $I_{\alpha\%,261}$ stands for an indicator function for the $\alpha\%$ worst days for the market returns.[5]

Empirically, BIST 100 index is taken as the market indicator and everyday the quantile α of the distribution of the market returns are discovered in the last 261 days, fixing the significance level α equal to 5% in consistent with the original MES of Acharya et al. (2010). Then the average of the returns of the institution is calculated as MES. As a robustness check, α is taken as 1% and the results does not present a contradiction

The MES method is applied and results shown in Figure 5 and Figure 6. They show how the equity returns of the banks contribute to the market when it is in a slump. Considering the difference between the MES of Demirbank and the average MES in the market, we observe that Demirbank generally contribute less to the tails of the market returns than the average. Besides, the overall contribution was high in 1999 and then it was in a downward trend until the end of November 2000. With regard to the sharp increase in MES approaching the collapse of the market, one can

[5] The theoretical representation of the measures will have i corresponding to the bank and t indicating the time throughout the paper in order to ensure consistency.

conclude that the change in MES of Demirbank was more drastic than the average of the banks, yielding that Demirbank was more sensitive to the tail events eventhough the contribution was lower than the average.

Fig. 5 MES for Demirbank and the average of the banks

Since MES does not take the size of the institutions into consideration, MES only gives an indication about the role of an institution in a tail event. However, if we look at the quarterly average MES of the banks throughout 2000, we notice that 4 largest banks have the lowest MES values. The reason is that their weights in the market are so large and their loss generally coincides and even lead to the tail events in the market. In other words, MES performs well in identifying institutions which are too-big-to fail. Remarkably, the change of MES between the quarters are smaller in high capitalized banks yielding the fact that the low capitalized banks are more sensitive to the most negative stock market returns.

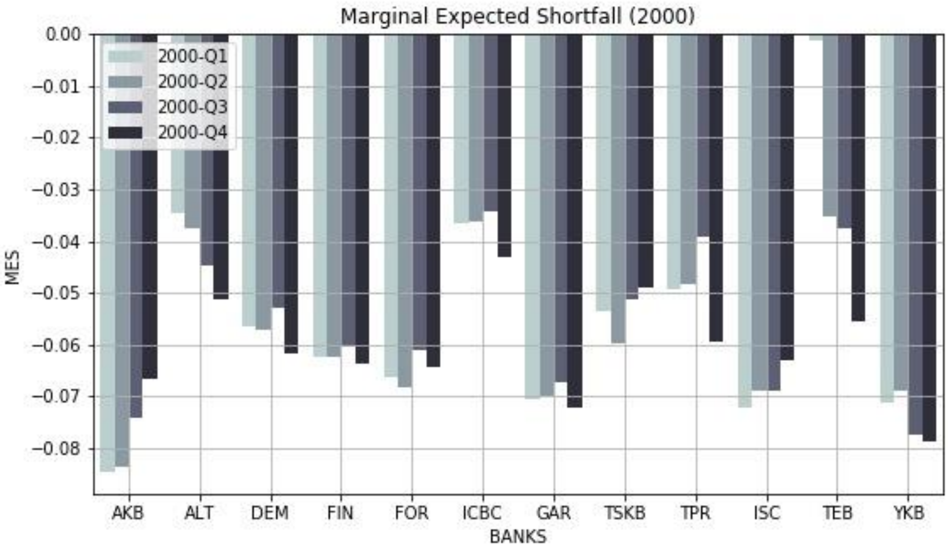

Fig. 6 Quarterly average MES for banks

Additionally, Table 3 contains the descriptive statistics of MES for the banks in 2000. We observe that mean MES of 4 largest banks are all lower than the mean MES of the market, -5.8%. Remarkably, note that even their maximum MES values are smaller than the mean MES of the market. On the other hand, Demirbank's contribution is close to the market average in terms of mean and standard deviation.

Table 3. Descriptive Statistics for MES in 2000

Bank	Count	Mean	Std	Min	25%	50%	75%	Max
AKB	260.0	-0.077	0.008	-0.088	-0.084	-0.081	-0.070	-0.057
ALT	260.0	-0.042	0.009	-0.073	-0.044	-0.043	-0.036	-0.028
DEM	260.0	-0.057	0.005	-0.075	-0.059	-0.056	-0.054	-0.042
FIN	260.0	-0.062	0.003	-0.070	-0.063	-0.062	-0.061	-0.053
FOR	260.0	-0.065	0.007	-0.086	-0.067	-0.067	-0.057	-0.051
ICBC	260.0	-0.038	0.008	-0.066	-0.038	-0.036	-0.034	-0.027
GAR	260.0	-0.070	0.005	-0.087	-0.071	-0.069	-0.067	-0.061
TSKB	260.0	-0.053	0.009	-0.073	-0.058	-0.056	-0.047	-0.038
TPR	260.0	-0.049	0.011	-0.075	-0.055	-0.052	-0.040	-0.023
ISC	260.0	-0.068	0.005	-0.079	-0.071	-0.067	-0.063	-0.060
TEB	224.0	-0.037	0.018	-0.077	-0.049	-0.036	-0.034	0.000
YKB	260.0	-0.074	0.006	-0.088	-0.076	-0.075	-0.068	-0.067
AVERAGE	260.0	-0.058	0.004	-0.073	-0.059	-0.057	-0.056	-0.051

4.1.2 SRISK

SRISK is basically an extension of MES, which is also proposed by Acharya et al. (2012). It ameliorates the MES by taking into account the liabilities and the size of the banks. A bank's SRISK corresponds to the expected capital shortfall of the bank conditional on a crisis affecting the whole market. In other words, it implies additional capital required by the bank to survive during the crisis. In this manner, if a bank has the largest capital shortfall (i.e. the highest SRISK), it is considered as the greatest contributor to the crisis and the most systemically risky institution.

Replicating the work of Acharya et al. (2012), we define the SRISK as:

$$SRISK_t^i = max\big(0\,;\ kD_t^i - (1-k)\big(\,1 - LRMES_t^i\,\big)\,A_t^i\,\big)$$

where k is the capital ratio (equity as a fraction of total liabilities) which is set to 8% as in Acharya et al. (2012), D_t^i is the total liabilities, and A_t^i is the market capitalization or market value of equity. $LRMES$ corresponds to the Long Run MES and is approximated by:

$$LRMES_t^i = 1 - e^{-18*-MES_t^i}$$

This approximation represents the bank's expected loss over a six-month horizon, obtained conditionally on the market falling by more than 40% within the next six months.[6]

Notice that SRISK is an increasing function of the debt of the bank and a decreasing function of the market capitalization. Similar to MES, SRISK does not

[6] For more details, see Acharya et al. (2012).

account for the probability of crisis to occur. Also, by its nature, it always takes non-negative values.

As represented in Figure 7 and Figure 8, SRISK of almost all banks are quite low until the crisis. Demirbank's SRISK starts to increase only 2 days before its collapse, which coincides with the total increase in SRISK of the all banks. Also looking at the Table 4, contrary to the results presented in MES, high capitalized banks, AKB, GAR, ISC, and YKB all yields zero risk each day during 2000 in terms of SRISK. This leads to the conclusion that SRISK fails in terms of identifying too-big-to-fail banks. Nevertheless, the high sensitivity of the low capitalized banks forms resemblance to MES.

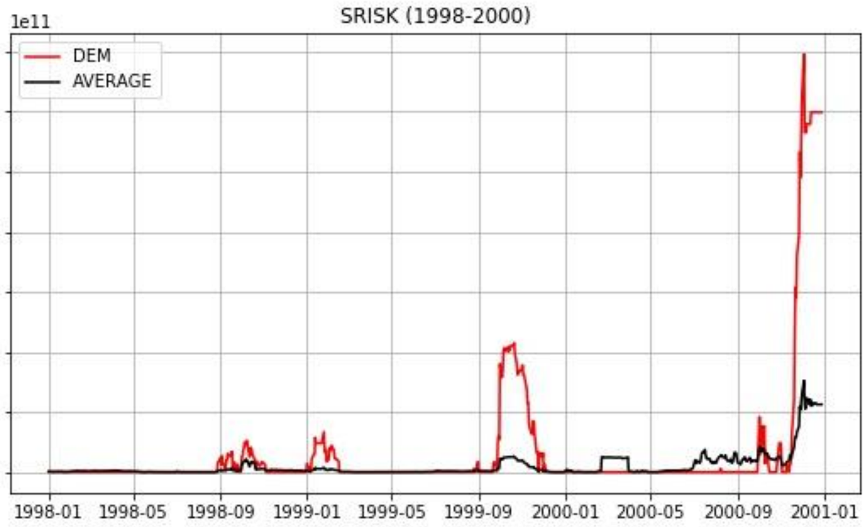

Fig. 7 SRISK for Demirbank and the average of the banks

Although Demirbank has zero SRISK for the first 3 quarters of 2000, it has a major jump at the last quarter and has the highest SRISK among the banks after November 20, 2000. It is also worth to note that the standard deviation of SRISK for Demirbank is almost 5 times larger than the standard deviation of the market, which indicates the drastic change of SRISK for Demirbank. Therefore, it is evident that SRISK is able detect Demirbank, the too-connected-to-fail bank, 13 trading days before its collapse.

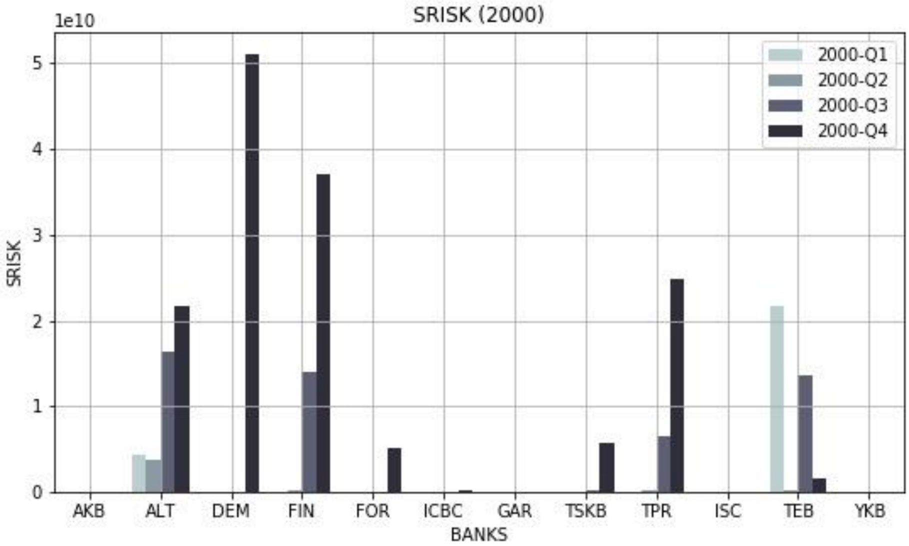

Fig. 8 Quarterly average SRISK for banks

Table 4. Descriptive Statistics for SRISK in 2000

Bank	Count	Mean	Std	Min	25%	50%	75%	Max
AKB	260.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ALT	260.0	1.1e+10	8.2e+09	0.0	4.4e+09	1.1e+10	1.9e+10	3.0e+10
DEM	260.0	1.3e+10	3.5e+10	0.0	0.0	0.0	0.0	1.4e+11
FIN	260.0	1.3e+10	1.9e+10	0.0	0.0	7.4e+08	1.9e+10	7.5e+10
FOR	260.0	1.3e+09	4.4e+09	0.0	0.0	0.0	0.0	3.2e+10
ICBC	260.0	7.1e+07	7.1e+08	0.0	0.0	0.0	0.0	9.4e+09
GAR	260.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TSKB	260.0	1.5e+09	2.6e+09	0.0	0.0	0.0	2.5e+09	1.1e+10
TPR	260.0	7.9e+09	1.6e+10	0.0	0.0	0.0	5.6e+09	6.1e+10
ISC	260.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TEB	260.0	9.3e+09	1.6e+10	0.0	0.0	0.0	1.3e+10	5.0e+10
YKB	260.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AVERAGE	260.0	4.8e+09	6.4e+09	0.0	4.2e+08	3.7e+09	4.9e+09	3.0e+10

4.1.3 ΔCoVaR

The ΔCoVaR is a systemic risk measure introduced by Adrian and Brunnermeier (2011). The main idea is to measure the value at risk (VaR) of a market, conditional on the state of a particular institution. It indicates the difference between the VaR of the market conditional on the distress of a certain bank i and the VaR of the market conditional on the median state of the bank i. Thus, it quantifies how much a bank contributes to the systemic risk.

Assuming q as the quantile, $CoVaR$ is derived from the equation:

$$Pr\left(r^j \leq \ CoVaR_q^{j|i} \mid r^i = VaR_q^i \ \right) = q$$

Bank i's contribution to the risk of j is defined as:

$$\Delta CoVaR_q^{j|i} = \ CoVaR_q^{j|i} - \ CoVaR_{50\%}^{j|i}$$

where $CoVaR_{50\%}^{j|i}$ stands for the VaR of bank j's asset returns when bank i's returns are at their median (i.e. 50th percentile). For the calculation of the systemic risk bank j is treated as the market, in our case BIST100. As a result, $\Delta CoVaR$ applied in this paper, is the difference between the $CoVaR$ of the system at a 5% level and the $CoVaR$ of the system at a 50% level. The smaller the $\Delta CoVaR$, the higher the systemic risk contribution.

Figure 9 and Figure 10 show the results of the application of $\Delta CoVaR$ on the Turkish banks during 2000. As the graphs indicate, the $\Delta CoVaR$ results of Demirbank is quite similar to the behaviour of the average $\Delta CoVaR$ results of the banks. It is explicitly low (around -5%) in 1999 and then it starts to rise up to -2% until the crisis. However, the collapse at the time of the crisis is not sufficient to lower the quarterly calculated $\Delta CoVaR$ values, that is why $\Delta CoVaR$ does not decrease in the last quarter for most of the banks.

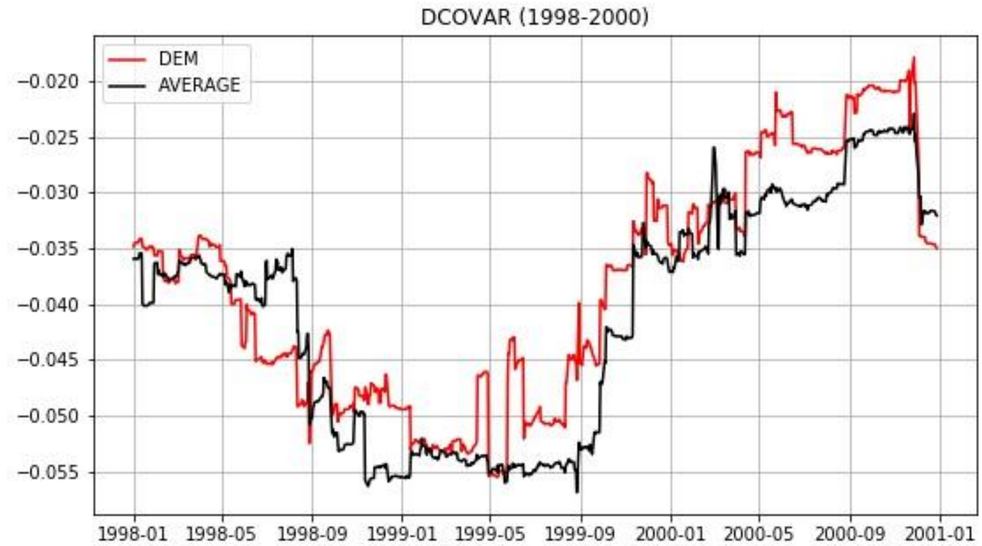

Fig. 9 ΔCoVaR for Demirbank and the average of the banks

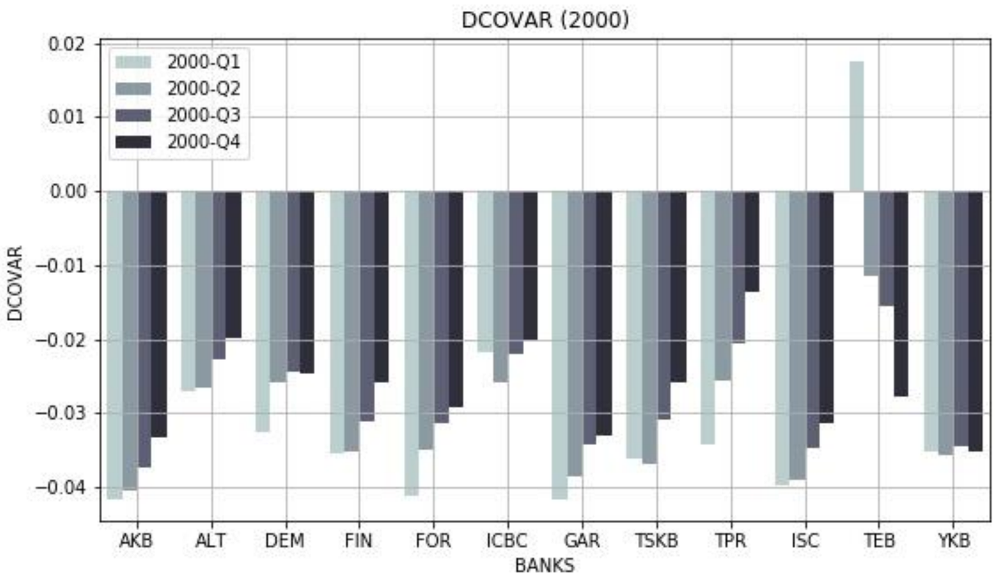

Fig. 10 Quarterly average ΔCoVaR for banks

Similar to MES, greater sized institutions have greater contribution to the systemic risk according to the $\Delta CoVaR$ findings. According to the results in Table 5, mean $\Delta CoVaR$ of 4 largest banks are all smaller than the mean $\Delta CoVaR$ of the market, -3%. It is also clear that the impacts on the whole banking sector caused by a shock on a particular institution strongly emerges in the earlier periods of the crisis.

Table 5. Descriptive Statistics for ΔCoVaR in 2000

Bank	Count	Mean	Std	Min	25%	50%	75%	Max
AKB	260.0	-0.038	0.004	-0.045	-0.041	-0.040	-0.035	-0.028
ALT	260.0	-0.024	0.004	-0.034	-0.027	-0.025	-0.020	-0.016
DEM	260.0	-0.027	0.005	-0.036	-0.031	-0.026	-0.022	-0.018
FIN	260.0	-0.032	0.005	-0.040	-0.035	-0.034	-0.028	-0.020
FOR	260.0	-0.034	0.005	-0.046	-0.039	-0.034	-0.029	-0.023
ICBC	260.0	-0.023	0.006	-0.034	-0.026	-0.025	-0.017	-0.011
GAR	260.0	-0.037	0.004	-0.045	-0.040	-0.037	-0.032	-0.029
TSKB	260.0	-0.032	0.006	-0.039	-0.037	-0.035	-0.028	-0.018
TPR	260.0	-0.024	0.008	-0.042	-0.031	-0.024	-0.016	-0.009
ISC	260.0	-0.036	0.004	-0.044	-0.040	-0.037	-0.032	-0.030
TEB	223.0	-0.014	0.018	-0.044	-0.021	-0.016	-0.014	0.074
YKB	260.0	-0.035	0.003	-0.042	-0.036	-0.035	-0.033	-0.031
AVERAGE	260.0	-0.030	0.004	-0.037	-0.032	-0.031	-0.025	-0.023

4.2 Network based systemic risk measures

The second approach focuses on financial network. Although there are several algorithms and tools developed in order to determine the systemic importance of a node in a network. However, only network centrality measures are applied in this research. Also note that this part is a basic replication of the result attained by Kuzubaş et al. (2014).

4.2.1 Degree centrality

Degree centrality indicates the number of transaction (links) an institution (node) make in the market. Degree can be described as the count of the total transaction (both borrowed or lended). Since every transaction has a borrower and lender side, there are two versions of the measure: in-degree is the number of in-coming links and out-degree is the number of out-going links. Typically, we are interested in in-degree, because in-coming links are initiated by other nodes in the network and the focus is on the borrowing characteristics of the financial institutions.

As it appears in Figure 11 and Figure 12, Demirbank is evidently the most dominant borrower in the market. The increasing trend in the third and the last quarter of 2000 presents the increasing systemic risk of Demirbank in the market before the crisis declared. Also ISC, a too-big-to-fail bank, has considerably large degree centrality in the market, nonetheless, after the second quarter it seems to start decreasing its borrowing in the interbank market.

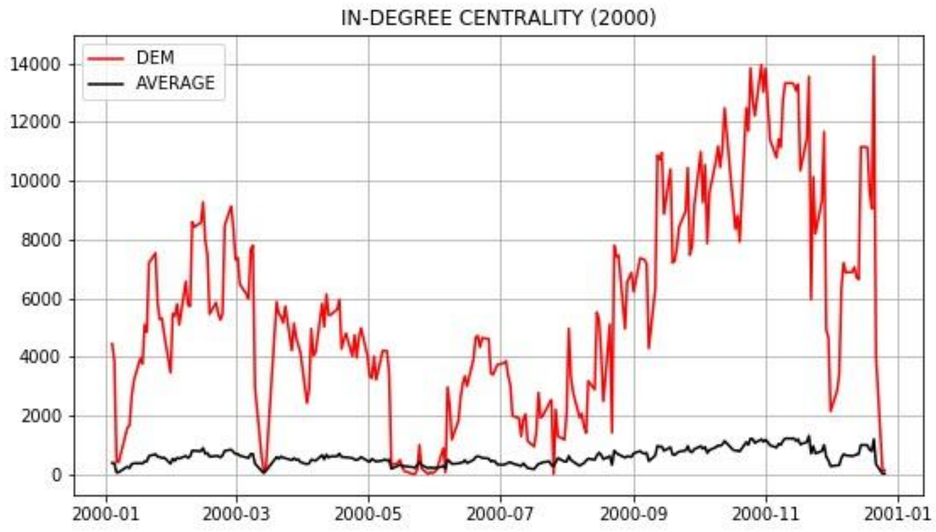

Fig. 11 Degree centrality for Demirbank and the average of the banks

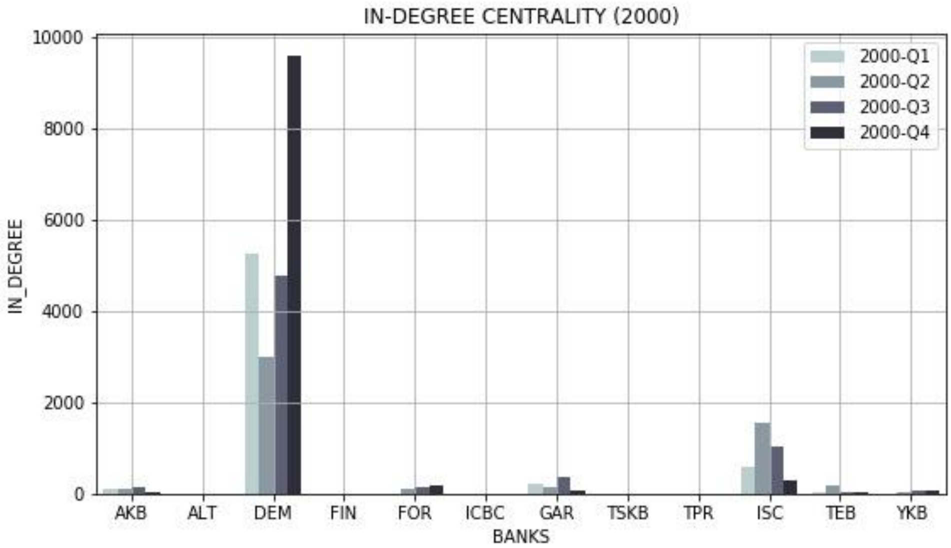

Fig. 12 Quarterly average degree centrality for banks

Table 6. Descriptive Statistics for Degree Centrality in 2000

Bank	Count	Mean	Std	Min	25%	50%	75%	Max
AKB	251.0	102.37	218.49	0.00	0.00	0.0	115.00	1300.00
ALT	251.0	2.11	6.69	0.00	0.00	0.0	0.00	35.00
DEM	251.0	5638.88	3649.67	0.00	2982.50	5110.0	7830.00	14240.00
FIN	251.0	0.68	4.37	0.00	0.00	0.0	0.00	50.00
FOR	251.0	112.89	173.54	0.00	0.00	40.0	170.00	1245.00
ICBC	251.0	0.00	0.00	0.00	0.00	0.0	0.00	0.00
GAR	251.0	200.58	344.46	0.00	0.00	0.0	265.00	1800.00
TSKB	251.0	0.00	0.00	0.00	0.00	0.0	0.00	0.00
TPR	251.0	0.78	7.05	0.00	0.00	0.0	0.00	95.00
ISC	251.0	870.86	750.30	0.00	232.50	720.0	1290.00	3335.00
TEB	251.0	87.79	169.60	0.00	0.00	0.0	112.50	930.00
YKB	251.0	45.68	138.75	0.00	0.00	0.0	0.00	870.00
AVERAGE	251.0	588.55	270.11	11.67	391.25	562.5	750.83	1301.25

According to the statistics in Table 6, it is worth to note that the mean degree centrality of Demirbank is 9.6 times larger than the average degree centrality in the market and it is greater than the maximum degree centrality of all banks in consideration, which leads to the conclusion that Demirbank on average borrows much more than the maximum borrowing realized by other banks. Notably, for many banks 75% quartile is 0, meaning that they have not borrowed in the interbank market for 188 days out of 251 days. However, Demirbank does not borrow only 4 days throughout this period.

4.2.2 Closeness centrality

Closeness centrality is a measure calculated as the reciprocal of the total number of the shortest paths between a node and all other nodes. It depends on the distance of each institution to every other institution in the network. In a financial sense, the more central an institution is, the closer it is to all other institutions in the network. Mathematically, closeness centrality is computed for bank I as:

$$C(b_i) = \left[\sum_{j=1}^{n} d\left(b_i, b_j\right) \right]^{-1}$$

where d is the path distance between banks i and j.

Figure 13 and Figure 14 suggest that Demirbank is above market in terms of the closeness centrality except in the 4 days in which Demirbank did not make an interbank transaction. Similar to degree centrality, closeness centrality highlights DEM and ISC, but here the distinguishability of these two from other banks is not as clear as it is in degree centrality.

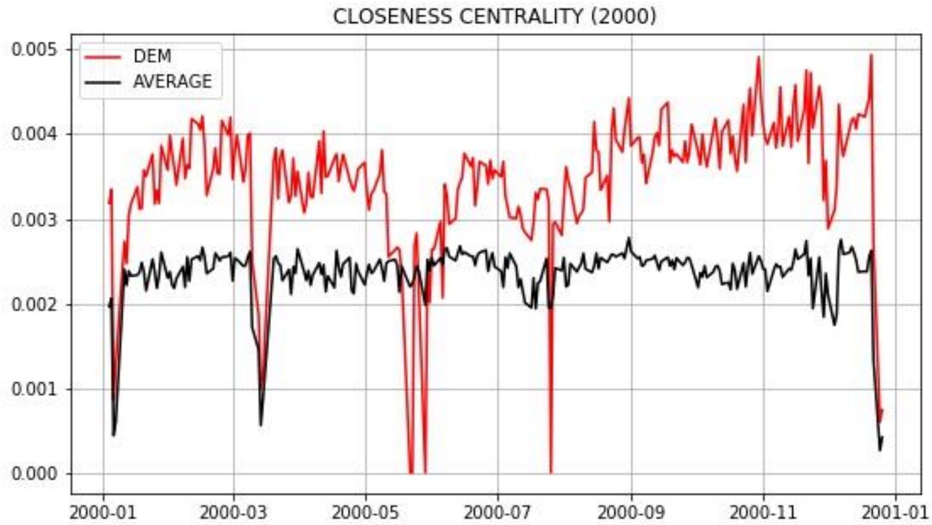

Fig. 13 Closeness centrality for Demirbank and the average of the banks

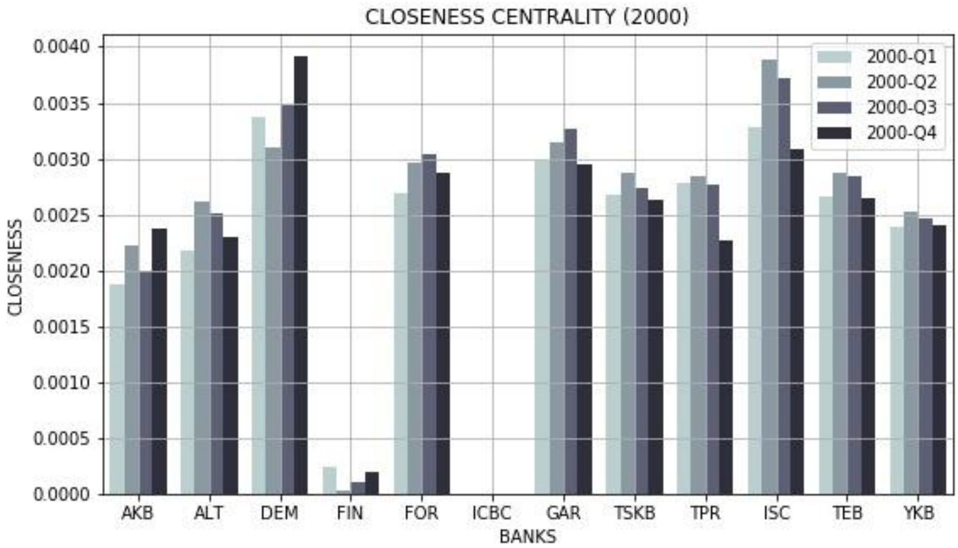

Fig. 14 Quarterly average closeness centrality for banks

Table 7 gives the basic statistics about closeness centrality. For 2000, the most obvious observation is that FIN and ICBC negatively differentiated from the others meaning that they are not close to others, this way, any distress in other banks will hit them late.

Table 7. Descriptive Statistics for Closeness Centrality in 2000

Bank	Count	Mean	Std	Min	25%	50%	75%	Max
AKB	251.0	0.00212	0.00110	0.00000	0.00206	0.00260	0.00285	0.00329
ALT	251.0	0.00241	0.00060	0.00000	0.00239	0.00256	0.00269	0.00297
DEM	251.0	0.00346	0.00079	0.00000	0.00321	0.00359	0.00394	0.00494
FIN	251.0	0.00014	0.00056	0.00000	0.00000	0.00000	0.00000	0.00299
FOR	251.0	0.00290	0.00044	0.00000	0.00286	0.00295	0.00307	0.00362
ICBC	251.0	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
GAR	251.0	0.00309	0.00040	0.00067	0.00299	0.00310	0.00325	0.00409
TSKB	251.0	0.00273	0.00039	0.00000	0.00269	0.00280	0.00290	0.00311
TPR	251.0	0.00267	0.00055	0.00000	0.00265	0.00279	0.00292	0.00314
ISC	251.0	0.00350	0.00056	0.00067	0.00322	0.00351	0.00385	0.00469
TEB	251.0	0.00275	0.00042	0.00000	0.00269	0.00283	0.00293	0.00328
YKB	251.0	0.00245	0.00077	0.00000	0.00244	0.00268	0.00286	0.00315
AVERAGE	251.0	0.00235	0.00035	0.00026	0.00230	0.00243	0.00253	0.00278

4.2.3 Betweenness centrality

Betweenness centrality is a measure of detecting the amount of effect a node has over the links in a network. Usually, it is used to determine the nodes that serve as a bridge between the clusters in the network. In a financial network, if an institution has a high betweenness centrality, it means that it may have an high impact on the transactions took place in the network.

The mathematics of betweenness centrality for bank i can be expressed as:

$$B(b_i) = \sum_{j<k}^{n} \frac{g_{jk}(b_i)}{g_{jk}}$$

where g_{jk} is the number of shortest paths between j and k and $g_{jk}(b_i)$ is the number of shortest paths between banks j and k that bank i resides on.

As Figure 15 and Figure 16 show, Demirbank has a quite low betweenness centrality because it is the main actor of in the transactions in the borrowing side. Other than several spikes, it has zero betweenness centrality. However, ISC makes transaction in the interbank market as being both lender and borrower side. Since it is also the largest capitalized bank among others it becomes a significant bank in the whole banking sector.

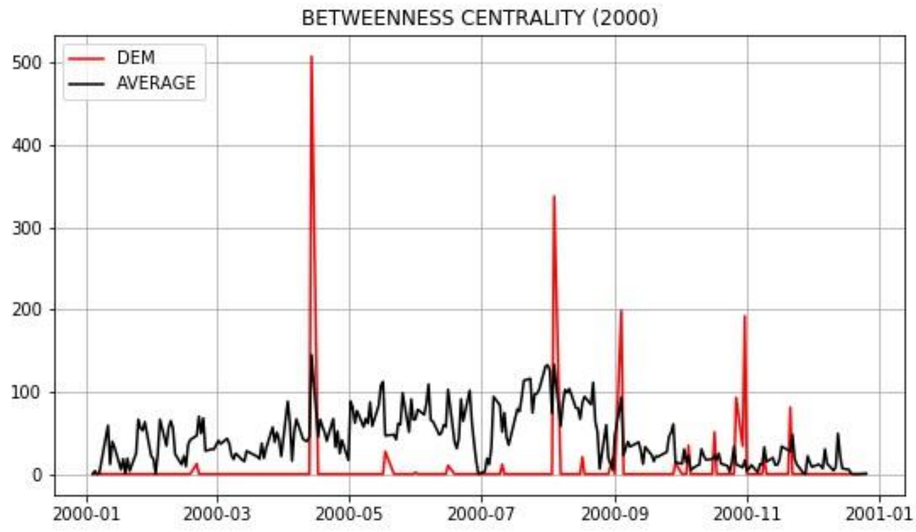

Fig. 15 Betweenness centrality for Demirbank and the average of the banks

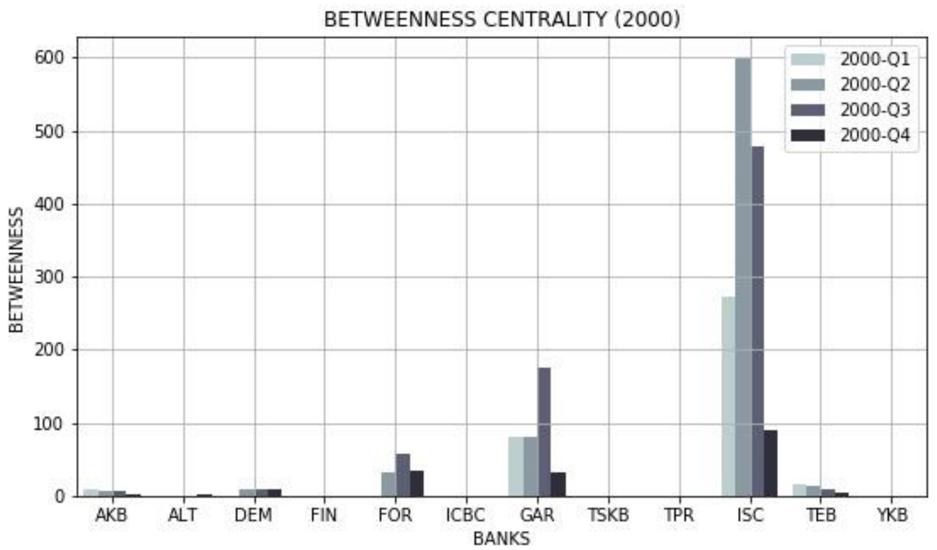

Fig. 16 Quarterly average betweenness centrality for banks

According to Table 8, the mean betweenness of ISC is 8.6 times larger than the mean betweenness of the market. Also note that, there are only 4 banks which have values other than zero in their 75% percentile, namely FOR, GAR, ISC and TEB. For the rest, it means that they have zero betweenness for at least 188 days. On the other hand, ISC has only 25 days having zero betweenness.

Table 8. Descriptive Statistics for Betweenness Centrality in 2000

	count	**mean**	**std**	**min**	**25%**	**50%**	**75%**	**max**
AKB	251.0	6.077	31.079	0.0	0.000	0.000	0.000	310.833
ALT	251.0	0.341	3.588	0.0	0.000	0.000	0.000	55.000
DEM	251.0	6.640	42.867	0.0	0.000	0.000	0.000	507.417
FIN	251.0	0.000	0.000	0.0	0.000	0.000	0.000	0.000
FOR	251.0	31.627	48.044	0.0	0.000	2.000	46.500	223.667
ICBC	251.0	0.000	0.000	0.0	0.000	0.000	0.000	0.000
GAR	251.0	93.176	150.416	0.0	0.000	0.000	144.292	741.583
TSKB	251.0	0.000	0.000	0.0	0.000	0.000	0.000	0.000
TPR	251.0	0.145	2.170	0.0	0.000	0.000	0.000	34.333
ISC	251.0	363.425	282.247	0.0	132.875	313.750	565.167	1181.667
TEB	251.0	10.493	25.994	0.0	0.000	0.000	5.250	175.833
YKB	251.0	0.457	3.840	0.0	0.000	0.000	0.000	42.833
AVERAGE	251.0	42.698	32.254	0.0	16.979	36.611	63.406	144.922

CHAPTER 5

COMPARISON OF SYSTEMIC RISK MEASURES

We have introduced both market based and network based systemic risk measures and their applications on the pre-crisis period of Turkish Banking Crisis of 2000 as much as data allowed. Rather than looking at the results of these measures individually, we can compare them in a framework to attain a broader perspective.

It is worth to remember that ISC, YKB, AKB, GAR might be considered as too-big-to-fail according to Figure 1 whereas DEM might be taken as the only too-connected-to-fail institution being the main actor of the crisis, as discussed in the previous chapters.

In the applications of the measures to the Turkish banking system, market based measures cover the period of 1998-2000, whereas network based measures focuses only on the year of 2000 because of the limitation that interbank transaction data spans only the year of 2000. Therefore, the comparison period is kept limited with the results of the measures attained for 2000. For comparison, 2 methodologies are taken into consideration. The first approach focuses on the rankings of the banks. The second approach analyze the correlations of the measures whereas the third one investigates the crisis from an event study perspective.

5.1 Rankings

The most practical way of measuring the performance of systemic risk measures is to rank the banks in terms of contribution to the distress in the system. This analysis is similar to the ranking discussion of Benoit et al. (2013). Table 9 and Table 10 show the rankings of the banks for the first and the last quarter of 2000. The second and the third quarters are omitted because they mainly show the transition between the first and the last quarters. Therefore, the focus of the rankings is restricted to the change of SIFIs for each measure between the first and the last quarters of 2000.

Table 9. Rankings of the Banks in the First Quarter of 2000

2000 - Q1						
RANK	**MES**	**DCOVAR**	**SRISK**	**IN_DEGREE**	**CLOSENESS**	**BETWEENNESS**
1	AKB	AKB	TEB	DEM	DEM	ISC
2	ISC	GAR	ALT	ISC	ISC	GAR
3	YKB	FOR		GAR	GAR	TEB
4	GAR	ISC		AKB	TPR	AKB
5	FOR	TSKB		TEB	FOR	DEM
6	FIN	FIN		YKB	TSKB	YKB
7	DEM	YKB		FIN	TEB	FOR
8	TSKB	TPR		FOR	YKB	
9	TPR	DEM			ALT	
10	ICBC	ALT			AKB	
11	ALT	ICBC			FIN	
12	TEB	TEB				

Table 10. Rankings of the Banks in the Last Quarter of 2000

2000 – Q4						
RANK	**MES**	**DCOVAR**	**SRISK**	**IN_DEGREE**	**CLOSENESS**	**BETWEENNESS**
1	YKB	YKB	DEM	DEM	DEM	ISC
2	GAR	AKB	FIN	ISC	ISC	FOR
3	AKB	GAR	TPR	FOR	GAR	GAR
4	FOR	ISC	ALT	GAR	FOR	DEM
5	FIN	FOR	TSKB	YKB	TEB	TEB
6	ISC	TEB	FOR	TEB	TSKB	AKB
7	DEM	TSKB	TEB	AKB	YKB	ALT
8	TPR	FIN	ICBC	ALT	AKB	TPR
9	TEB	DEM		TPR	ALT	
10	ALT	ICBC		FIN	TPR	
11	TSKB	ALT			FIN	
12	ICBC	TPR				

The primary finding of the ranking analysis is that different systemic risk measures identify different systemically important financial institutions. MES and

$\Delta CoVaR$ performs well in identifying too-big-to-fail institutions in both quarters with containing at least 3 banks with greatest sizes in their top 4 of the list. SRISK is not capable of determining any SIFI in the first quarter, nevertheless it appoints DEM to the top in the last quarter. In-degree centrality and closeness centrality are both good at distinguishing Demirbank (a too-connected-to-fail bank) in both quarters. Also, they are able to detect the banks with high market capitalization in their second and third rank. Additionally, betweenness is able to capture both types of SIFI, ranking them in the top 4.

As a result, there is not a sole bank simultaneously identified as a SIFI by the six measures. Only DEM is simultaneously detected by degree centrality and closeness centrality in both quarters. Also, SRISK accomplished to identify DEM in the last quarter but this is not the case for MES, $\Delta CoVaR$ or betwenness centrality. The rankings for MES, $\Delta CoVaR$ or betwenness centrality clearly tilted towards the largest banks.

5.2 Consistency of measures

Although the systemic risk measures suggests different SIFIs, the consistency of rankings should also be investigated. Therefore, for each measure we compute the Kendall rank order correlation coefficient between the top ranking obtained at time t and the top ranking obtained at time t-1. The correlations are 0.99 for MES, 0.69 for SRISK, 0.92 for $\Delta CoVaR$, 0.72 for degree centrality, 0.54 for closeness centrality, and 0.41 for betweenness centrality. All the results are statistically significant. This finding points out that the rankings produced by the market based and network based measures are quite stable through time. Especially the high correlation in MES and $\Delta CoVaR$ indicates the strong stability in the rankings of these measures.

5.3 An event study

The aim of this analysis is to examine and compare the performance of the systemic risk measures by utilizing an event study approach. In our study the event is the collapse of Demirbank. The event window (or sometimes called crisis period) covers the days from November 22 to December 20.[7] Since the crisis period is determined and systemic risk measures are already calculated, their performance can be measured testing the systemic risk measures for the hypothesis that systemic risk measures are significantly different before and during the crisis for each bank. Two suitable techniques for comparison are one sample t-test and Wilcoxon sign-ranked test. For a systemic risk measure, they both take two series of the same bank, one for the pre-crisis period and one for the crisis period. The main idea for both of the tests is that if the event had no effect the difference between the series is not significant and the null hypothesis holds. The results for the tests are shown in Table 11, Table 12, Table 13, and Table 14. For example, the average MES of the market decreased by 5.042% in the crisis period compared to the pre-crisis period and the result is statistically significant at the 0.05 level of confidence. To be consistent in the comparison, all significance comments are based on the 0.05 level of confidence.

[7] The selection of the date November 22 is based on the study of Saltoglu and Yenilmez (2015). They selected this date as the start date of a sub-period of their analysis. Since it is 10 trading days before the collapse of Demirbank, December 6, another 10 trading days after the event (up to December 20), is included to be consistent with event study literature.

According to t-test all measures except $\Delta CoVaR$ gives statistically significant results for Demirbank, meaning that they are able to identify Demirbank as a SIFI in the crisis period. On the other hand, all of the too-big-to-fail banks have meaningful results for MES and $\Delta CoVaR$. SRISK yields error for these banks because they have all zero SRISK values throughout the year 2000.

According to Wilcoxon sign-ranked test, again $\Delta CoVaR$ fails to separate the crisis period from pre-crisis period for Demirbank. ISC gives statistically significant results in all measures except SRISK, however other too-big-to-fail banks fails in at least one of the other measures.

Table 11. T-test Results for Market Based Systemic Risk Measures

	MES		**DCOVAR**		**SRISK**	
	t-test	p-value	t-test	p-value	t-test	p-value
AKB	14.471	0.0000	20.064	0.0000	NaN	NaN
ALT	-7.334	0.0000	5.492	0.0000	31.145	0.0000
DEM	-5.090	0.0001	-1.409	0.1742	22.719	0.0000
FIN	-5.686	0.0000	10.974	0.0000	11.967	0.0000
FOR	-2.344	0.0295	3.006	0.0070	7.634	0.0000
ICBC	-5.547	0.0000	-1.744	0.0965	1.667	0.1111
GAR	-3.352	0.0032	3.259	0.0039	NaN	NaN
TSKB	-2.002	0.0590	2.760	0.0121	22.105	0.0000
TPR	-9.413	0.0000	32.961	0.0000	24.405	0.0000
ISC	10.106	0.0000	20.981	0.0000	NaN	NaN
TEB	-11.175	0.0000	-15.186	0.0000	-15.785	0.0000
YKB	-8.102	0.0000	-6.588	0.0000	NaN	NaN
AVERAGE	-5.042	0.0001	1.599	0.1256	18.247	0.0000

Table 12. T-test Results for Network Based Systemic Risk Measures

	IN_DEGREE		**CLOSENESS**		**BETWEENNESS**	
	t-test	p-value	t-test	p-value	t-test	p-value
AKB	0.121	0.9050	-0.418	0.6805	-6,04E+05	0.5528
ALT	-0.549	0.5893	-1.785	0.0895	-inf	0.0000
DEM	2.905	0.0088	4.947	0.0001	-3,71E+22	0.0000
FIN	0.303	0.7649	2.033	0.0555	NaN	NaN
FOR	0.616	0.5447	0.569	0.5760	-6,00E+03	0.9949
ICBC	NaN	NaN	NaN	NaN	NaN	NaN
GAR	0.406	0.6892	2.530	0.0199	-7,40E+04	0.9421

TSKB	NaN	NaN	1.533	0.1410	NaN	NaN
TPR	1.309	0.2055	-1.743	0.0966	1,06E+06	0.3020
ISC	-21.401	0.0000	-10.262	0.0000	-2,62E+07	0.0000
TEB	-2.703	0.0137	-1.617	0.1216	-1,04E+06	0.3096
YKB	3.127	0.0053	-1.080	0.2928	-inf	0.0000
AVERAGE	1.840	0.0807	-0.296	0.7706	-1,06E+07	0.0000

Table 13. Wilcoxon Test Results for Market Based Systemic Risk Measures

	MES		**DCOVAR**		**SRISK**	
	W-test	p-value	W-test	p-value	W-test	p-value
AKB	0.0	0.0001	0.0	0.0001	NaN	NaN
ALT	0.0	0.0001	10.0	0.0002	0.0	0.0001
DEM	13.0	0.0004	63.0	0.0677	0.0	0.0001
FIN	10.0	0.0002	0.0	0.0001	0.0	0.0001
FOR	48.0	0.0186	45.0	0.0142	0.0	0.0001
ICBC	7.0	0.0002	59.0	0.0494	0.0	0.0679
GAR	37.0	0.0062	45.0	0.0142	NaN	NaN
TSKB	65.0	0.0782	45.0	0.0142	0.0	0.0001
TPR	0.0	0.0001	0.0	0.0001	0.0	0.0001
ISC	0.0	0.0001	0.0	0.0001	NaN	NaN
TEB	0.0	0.0001	0.0	0.0001	1.0	0.0000
YKB	0.0	0.0001	1.0	0.0001	NaN	NaN
AVERAGE	18.0	0.0007	87.0	0.3219	0.0	0.0001

Table 14. Wilcoxon Test Results for Network Based Systemic Risk Measures

	IN_DEGREE		**CLOSENESS**		**BETWEENNESS**	
	W-test	p-value	W-test	p-value	W-test	p-value
AKB	101.0	0.6041	98.0	0.5424	22.0	0.0004
ALT	21.0	0.0002	102.0	0.6386	0.0	0.0000
DEM	43.0	0.0117	18.0	0.0007	0.0	0.0000
FIN	21.0	0.0002	95.0	0.4519	NaN	NaN
FOR	72.0	0.1269	95.0	0.4761	95.0	0.4663
ICBC	NaN	NaN	NaN	NaN	NaN	NaN
GAR	115.0	0.9861	52.0	0.0273	91.0	0.3924
TSKB	NaN	NaN	79.0	0.2045	NaN	NaN
TPR	41.0	0.0044	44.0	0.0129	0.0	0.1797
ISC	0.0	0.0000	1.0	0.0001	0.0	0.0000
TEB	42.0	0.0064	63.0	0.0680	41.0	0.0057
YKB	45.0	0.0134	108.0	0.7943	0.0	0.0000
AVERAGE	62.0	0.0630	115.0	0.9861	3.0	0.0001

In terms of average of the market, the results of t-test and Wilcoxon sign-ranked test are statistically significant at the 0.05 level of confidence in MES, SRISK, and betweenness centrality.

For the overall comparison, Table 15 and Table 16 are prepared. In Table 15, the first row of the data presents the answer of whether the measure gives meaningful results for the market according to t-test. The second row gives the answer whether the t-test is successful in detecting Demirbank and the last row contains the number of the too-big-to-fail banks found statistically significant with t-test. Table 16 has the similar information, but in terms of the Wilcoxon sign-ranked test results.

Table 15. Comparison Table Regarding t-test Results

	MES	DCOVAR	SRISK	IN_DEGREE	CLOSENESS	BETWEENNESS
Market	1	0	1	0	0	0
Demirbank	1	0	1	1	1	0
Large Banks	2	1	0	1	1	0

Table 16. Comparison Results Regarding Wilcoxon Test Results

	MES	DCOVAR	SRISK	IN_DEGREE	CLOSENESS	BETWEENNESS
Market	1	0	1	0	0	1
Demirbank	1	0	1	1	1	1
Large Banks	4	4	0	2	2	3

The comparison results regarding both tests suggest that MES is the only measure which gives statistically significant result for market, too-connected-to-fail bank (DEM) and some of too-big-to-fail banks (ISC, YKB, AKB, GAR). SRISK is able to give meaningful results for the market and DEM, $\Delta CoVaR$ is capable of detecting crisis only in too-big-to-fail banks. The test results for degree centrality and closeness centrality miss the market and several too-big-to-fail banks, whereas Betweenness centrality is also able to detect the stress in the market and SIFI only with Wilcoxon test.

CHAPTER 6

DISCUSSIONS AND CONCLUSIONS

Since the size and the complexity of the financial system is continually increasing, the systemic risk concept is getting more and more important. In this study, we have investigated several popular market based and network based systemic risk measures which are currently the focus of both banking regulatory agencies and central banks.

Our findings from the application of the market based and network based systemic risk measures to Turkish banking sector indicate that both MES and $\Delta CoVaR$ are capable of capturing the overall stress in the market starting from the beginning of 1999, which resulted in a catastrophe in December 2000. However, they are not able to detect the network related dimension of the system. Although SRISK is a market based measure, it identifies Demirbank - a too-connected-to-fail institution - as a SIFI. Additionally, degree centrality and closeness centrality measures are able to capture Demirbank, however, they have a deficiency in determining too-big-to-fail institutions as does betweennes centrality. Overall, market based measures fall short in network characteristics of the market, whereas network based measures lack the market characteristics, SRISK being the only exception.

According to the ranking analysis, there is not a sole bank simultaneously identified as a SIFI by all measures. Only DEM is simultaneously detected by degree centrality and closeness centrality in both quarters. Also, SRISK accomplished to identify DEM in the last quarter but this is not the case for MES, $\Delta CoVaR$ or betwenness centrality. Additionally, the rankings for MES, $\Delta CoVaR$ or betwenness centrality clearly tilted towards the largest banks. Additionally, Kendall rank order correlation analysis produce statistically significant result showing that rankings produced by the market based and network based measures are quite stable through time. Especially the high correlation in MES and $\Delta CoVaR$ indicates the strong stability in the rankings of these measures.

With an event study approach, the one sample t-test and Wilcoxon sign-ranked test results yields that MES is the only measure which gives statistically significant result for market, too-connected-to-fail bank (DEM) and some of too-big-to-fail banks (ISC, YKB, AKB, GAR). SRISK is able to give meaningful results for the market and DEM, $\Delta CoVaR$ is capable of detecting crisis only in too-big-to-fail banks. The test results for degree centrality and closeness centrality miss the market and several too-big-to-fail banks, betweenness centrality is also able to detect the stress in the market and SIFI only with Wilcoxon test.

The challenge for a systemic risk measure with a better performance is still ongoing. Therefore, considering the ex-ante comparison of systemic risk measures as a basis, a unifying framework can be produced. With more available data and enthusiastic researchers, we believe, future research will develop a more comprehensive measure which covers the market and network facets of the systemic risk and set a higher target for the challenge.

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