ISTANBUL TECHNICAL UNIVERSITY ★ GRADUATE SCHOOL OF ARTS AND SOCIAL SCIENCES

CONSTRUCTING A FINANCIAL STRESS INDEX FOR TURKEY: A MULTIVARIATE GARCH APPROACH

M.A. THESIS

Pınar ŞENOL

Department of Economics

Economics M.A. Program

DECEMBER 2018

ISTANBUL TECHNICAL UNIVERSITY ★ GRADUATE SCHOOL OF ARTS AND SOCIAL SCIENCES

CONSTRUCTING A FINANCIAL STRESS INDEX FOR TURKEY: A MULTIVARIATE GARCH APPROACH

M.A. THESIS

Pınar ŞENOL
(412161025)

Department of Economics

Economics M.A. Program

Thesis Advisor: Prof. Dr. Bülent GÜLOĞLU

DECEMBER 2018

İSTANBUL TEKNİK ÜNİVERSİTESİ ★ SOSYAL BİLİMLER ENSTİTÜSÜ

**TÜRKİYE İÇİN FİNANSAL STRES ENDEKSİ OLUŞTURMA:
ÇOK DEĞİŞKENLİ GARCH MODELLEMESİ**

YÜKSEK LİSANS TEZİ

**Pınar ŞENOL
(412161025)**

İktisat Anabilim Dalı

İktisat Yüksek Lisans Programı

Tez Danışmanı: Prof. Dr. Bülent GÜLOĞLU

ARALIK 2018

Pınar ŞENOL, a M.A. student of ITU Graduate School of Arts and Social Sciences student ID 412161025, successfully defended the thesis/dissertation entitled "Constructing A Financial Stress Index For Turkey : A Multivariate Garch Approach", which she prepared after fulfilling the requirements specified in the associated legislations, before the jury whose signatures are below.

Thesis Advisor :   **Prof. Dr. Bülent GÜLOĞLU**   ....
                          Istanbul Technical University

Jury Members :   **Prof. Dr. Murat YÜLEK**   ....
                        Istanbul Ticaret University

                        Doc. Dr. Resul AYDEMİR   ....
                        Istanbul Technical University

Date of Submission : 16 November 2018
Date of Defense   : 11 December 2018

To my family,

FOREWORD

First of all, I would like to thank my advisor Prof. Dr. Bülent GÜLOĞLU for his contributions, assistance to my work and suggestions for the improvements of thesis.

I am also grateful to my friend Yunus Emre KARAGÜLLE who made my master period more valuable with his contributions. I feel like I won a new brother during this time.

I would like to extremely thank to my grandmother Mesüde ÖZHABEŞ, my mother Sevim ÖZHABEŞ and my brother Egemen ÖNEY for their valuable support during this process and being with me every time of my entire life. I feel myself very lucky and my love is endless for them.

Lastly, very special thanks to go to my husband and my life partner Burak ŞENOL who lightens always my way with his thoughts, encourages me to do everything and has contributed to my success. I can not think what I would do without him in my life.

December 2018   Pınar ŞENOL

TABLE OF CONTENTS

ABBREVIATIONS

ARCH	**:**	Autoregressive Conditional Heteroscedasticity
CCC	**:**	Constant Conditional Correlation
CDF	**:**	Cumulative Distribution Function
CDS	**:**	Credit Default Swap
DCC	**:**	Dynamic Conditional Correlation
EMPI	**:**	Exchange Market Pressure Index
FED	**:**	Federal Reserve System
FSI	**:**	Financial Stress Index
GARCH	**:**	Generalized Autoregressive Conditional Heteroscedasticity

SYMBOLS

R_t **:** Return

V **:** Realized Volatility

H_t **:** Conditional Covariance Matrix

D_t **:** Diagonal Matrix with Time-varying Standard Deviations

R_t **:** Conditional Correlation Matrix

Q_t **:** Positive Definite Matrix

$\rho_{ij,t}$ **:** The Time-varying Correlation Coefficient

α **:** ARCH Term

β **:** GARCH Term

ν **:** Degrees of Freedom for t Distribution

$\$$: United States Dollar

€   : Euro

£   : Great Britain Pound

₺   : Turkish Lira

LIST OF TABLES

LIST OF FIGURES

CONSTRUCTING A FINANCIAL STRESS INDEX FOR TURKEY: A MULTIVARIATE GARCH APPROACH

SUMMARY

Various economic crises have been experienced due to the dynamics of the country as well as the global crises that have lived in the world from past to present. Many of the important studies in economics aimed to estimate these fluctuations in the markets and to examine their relations with each other. In this context, since the early 2000s, financial stress indexes have been established by economists or central banks for various countries. The financial stress indexes created are specific to countries or regions and have some differences. These differences are the methods as well as the data types that are used. In this study, the financial stress indexes created for Turkey. Also, different countries are examined in the literature review.

There is the necessity of constructing a new financial stress index because of the economic fluctuations in Turkey in recent years. The financial stress index of Turkey demonstrates the economic activity after important financial events that are called as financial crisis. The financial stress index which is a continuous variable as a time serie and its extreme values are called financial crises in the literature. The financial stress index can be expected to increase in the case of expected financial loss, risk potential or uncertainty financial conditions.

In this study, the financial stress index of Turkey is generated with using the banking sector, equity market, money market and exchange market variables. The financial stress index of Turkey is constructed on daily basis for the period from 2 January 2007 to 29 November 2017. The data diversity has been expanded in this study when compared to previous studies in Turkey that is why this study has importance for Turkey.

Firstly, the variables of each sector were standardized. Then, the financial stress index for each sector was composed with the equal weighted average method. FSI of Turkey was created again using the four-sector financial stress index data with the same method.

The financial stress index of Turkey is analyzed with banking sector, equity market, money market and exchange market indexes.

Modelling volatility is very important for investors and researchers The Autoregressive conditional heteroscedasticity models (ARCH) are used especially to model volatility clustering. In the market, there are periods of small volatility followed by the periods of high volatility. This phenomenon is called volatility clustering. For volatility clustering, historical volatility models can be used mostly. Most popular model is generalized autoregressive conditional heteroscedasticity (GARCH) model which is generalization of ARCH model.

In this thesis, multivariate GARCH model was used because of the presence of more than one variable when analyzing correlations. A special type of multivariate GARCH model which is dynamic conditional correlation GARCH (DCC GARCH) model was used in this study. DCC GARCH model can be used to estimate conditional correlations between two series.

DCC GARCH model was used to examine the correlation between FSI of Turkey and the markets in Turkey. Conditional correlations give information about volatility spillover. This phenomenon is very important for financial markets. What is observed in financial market is that correlation increase or decrease after financial crisis between two financial markets. If there is a volatility shock in one market, then it affects the other market. If the correlations between two markets are high, it means that there is less risk diversification opportunity between these markets. In other words, hedging between these markets seems not possible. On the contrary, if the correlations between two-time series of financial markets are very low, in that case, it is possible to hedge this portfolio because of the potential of diversification risk.

After generating the FSI of Turkey for the last ten years, the peaks of it are interpreted in terms of important financial events in this study.

In 2008, the giant Lehman Brothers declared its bankruptcy and the whole world paid the price of Lehman's collapse. Billions of dollars had evaporated in stock markets, millions of people were unemployed, many employers had gone bankrupt etc. The Turkish economy was also negatively affected by this fact. As a result of that, FSI of Turkey which is created in this thesis seems to have a peak in 2009.

In 2013, the Federal Reserve System (FED) made a declaration about its tapering decision which is to reduce asset purchases in the beginning of 2014. It means that United States withdraw money from the market and the interest rates will rise for United States. This decision also implied the depreciation of the Turkish Lira because investors wanted to invest in the US. As a consequence of this event, there is another peak in FSI of Turkey for this time interval.

At the end of 2016, after the US presidential election, the perception of uncertainty in international finance world had increased significantly. After election, FED's monetary policy was expected to change with new administration in US. Moreover, the slowdown in global economies and the geopolitical risks had the negative effect on economic activity over foreign trade. In that time, the United Kingdom's decision on leaving the European Union provided also negative effect on global market. On the other hand, the main reason of activity in foreign exchange market is that the uncertainties for future interest rate policies of developed countries. The coup attempt had especially big impact on Turkish economy. Thus, there is another peak in FSI of Turkey at the beginning of 2017.

Moreover, the relationships between the markets which are used to generate the FSI of Turkey are analyzed according to the correlation coefficients gained from DCC GARCH model.

At the last part, the financial stress index of Turkey is interpreted whether it can be used as a sign of financial crisis for Turkey or not. Its extreme values show the financial crisis that the events that suddenly and unexpectedly occur in the economy will produce macroeconomic consequences for the country's economy. Furthermore, firms have serious consequences in that time from the micro perspective.

TÜRKİYE İÇİN FİNANSAL STRES ENDEKSİ OLUŞTURMA: ÇOK DEĞİŞKENLİ GARCH MODELLEMESİ

ÖZET

Geçmişten günümüze dünyada yaşanan küresel krizlerin yanı sıra ülke dinamikleri nedeniyle çeşitli ekonomik krizler yaşanmaktadır. Ekonomi alanında en önemli çalışmalardan biri piyasalardaki bu dalgalanmaları tahmin etmek ve birbiri ile olan ilişkilerini incelemektir. Bu bağlamda 2000'li yılların başından beri çeşitli ülkeler için ekonomistler ya da merkez bankaları tarafından finansal sıkıntı endeksleri oluşturulmuştur. Oluşturulan finansal sıkıntı endeksleri ülkelere ya da bölgelere özgü olup farklılıklara sahiptir. Kullanılan veri tiplerinin yanısıra kullanılan metotlar bu farklılıklar arasındadır. Yapılan bu çalışmada literatür taramasında farklı ülkeler için oluşturulan finansal sıkıntı endeksleri ile birlikte Türkiye için oluşturulmuş finansal sıkıntı endeksleri de incelenmiştir.

Son yıllarda Türkiye'de ekonomik dalgalanmaların görülmesi nedeniyle yeni bir finansal sıkıntı endeksinin oluşturulma ihtiyacı doğmuştur. Türkiye finansal sıkıntı endeksi, finansal kriz olarak adlandırılan önemli finansal olaylar sonrası ülkede yaşanan ekonomik hareketliliği göstermektedir. Finansal sıkıntı endeksi sürekli bir değişkendir ve belirsizliği yansıtmakta olup uç değerleri kriz olarak adlandırılmıştır. Beklenen finansal bir kayıp, risk potansiyeli ya da belirsizlik durumlarında finansal sıkıntı endeksi artış göstermektedir.

Yapılan bu çalışmada, banka sektörü, sermaye piyasası, para piyasası ve döviz piyasasına ait bazı veriler kullanılarak Türkiye için finansal sıkıntı endeksi oluşturulmuştur. Finansal sıkıntı endeksi 2 Ocak 2007'den 29 Kasım 2017'ye kadar olan dönem için günlük olarak hesaplanmıştır. Türkiye finansal sıkıntı endeksi hakkında yapılan daha önceki çalışmalarda kullanılan verilerin genişletilmesi nedeni ile yapılan çalışma Türkiye için önem teşkil etmektedir.

Öncelikle her bir sektöre ait veriler standardize edildi. Ardından eşit varyans ağırlıklandırma yöntemi ile her bir sektör için finansal sıkıntı endeksi oluşturuldu. Dört sektör için oluşturulan finansal sıkıntı endekslerinin eşit varyans ağırlıklandırması ise; Türkiye finansal sıkıntı endeksini vermektedir.

Piyasalar arasındaki finansal sıkıntı endekslerinin birbiri ile olan ilişkileri analiz edilmiştir.

Koşullu değişen varyans modelleri, özellikle oynaklığı modellemek için kullanılmaktadır. Oynaklığı modellemek yatırımcı ve araştırmacılar için önemli bir husustur. Piyasalarda bazen düşük oynaklık dönemlerini yüksek oynaklık dönemleri takip etmektedir. Bu olgu, oynaklığın kümelenmesi olarak adlandırılır. Oynaklığın kümelenmesi için, tarihsel volatilite modelleri kullanılabilir. En yaygın olan model ise; genelleştirilmiş otoregresif koşullu değişen varyans (GARCH) modelidir.

İlişkiler incelenirken birden fazla değişkenin olması sebebi ile çok değişkenli GARCH model kullanılmıştır. Çok değişkenli GARCH modelin özel bir çeşidi olan dinamik koşullu korelasyon GARCH (DCC GARCH) modeli bu çalışmada kullanılmıştır. DCC GARCH modeli, iki seri arasındaki koşullu korelasyonları tahmin etmek için kullanılabilir.

DCC GARCH modeli, Türkiye'nin sıkıntı endeksi ile Türkiye piyasa verileri arasındaki korelasyonu incelemek için kullanılmıştır. Koşullu korelasyonlar volatilite yayılımı hakkında bilgi verir. Bu olgu finansal piyasalar için çok önemlidir. Finansal piyasada gözlenen, finansal kriz sonrası iki finansal piyasa arasındaki korelasyonun artması veya azalmasıdır. Bir piyasada volatilite şoku var ise; o zaman bu şok diğer piyasayı da etkiler. İki pazar arasındaki korelasyonlar yüksekse, bu pazarlar arasında daha az risk çeşitlendirme fırsatı olduğu anlamına gelir. Başka bir deyişle, bu pazarlar arasında riskten korunma mümkün görünmemektedir. Aksine, finansal piyasalara ait iki zaman serisi arasındaki korelasyonlar çok düşük ise, bu durumda, çeşitlendirme riskinin potansiyelinden dolayı bu portföyün riskten korunması mümkündür.

Son on yıl için Türkiye finansal stres endeksi yaratıldıktan sonra uç noktaları önemli finansal olaylar açısından bu çalışmada yorumlanmıştır.

Dev Lehman Brothers 2008 yılında iflası ilan etti ve tüm dünya Lehman Brothers'ın çöküşünün bedelini ödemiştir. Pek çok işveren iflas etmiş, milyonlarca insan işsiz kalmış ve borsalarda milyarlarca dolar yok olmuşlardır. Türkiye ekonomisi de bu durumdan olumsuz etkilenmiştir. Bu tezde oluşturulan Türkiye'nin FSI'sı 2009 yılında zirveye ulaşarak küresel krizin Türkiye'de de etkili olduğunu göstermektedir.

2013 yılında Federal Rezerv Sistemi sıkılaştırıcı para politikası kararını ilan etti. Bu karar 2014 yılı başından itibaren varlık alımlarını azaltmak idi. Bu karar Amerika'nın piyasadan para çekmesi ve faiz oranlarının Amerika için artması anlamına gelmektedir. Bu durum yatırımcıların Amerika'ya yönelmesi ve TL'nin değer kaybetmesi anlamına gelmektedir. Bu durumun bir sonucu olarak oluşturulan finansal sıkıntı endeksinde bu zaman aralığı için başka bir zıplama görülmektedir.

2016 yılı sonunda Amerika'da yapılan başkanlık seçimi sonrasında uluslararası finansal dünyada belirsizlik algısı önemli ölçüde arttı. Seçim sonrasında Amerika yönetimiyle birlikte değişen maliye ve dış ticaret politikasında yaşanabilecek değişimlerin, FED para politikasının değişimi bekleniyordu. Küresel ekonomilerdeki yavaşlama ve jeopolitik riskler dış ticaret üzerinde negatif etkiye sahipti. Aynı zamanda İngiltere'nin Avrupa Birliği'nden ayrılma kararının da pazardaki olumsuz etkisi görülüyordu. Gelişmiş ülkelerin gelecek dönem faiz politikalarına yönelik belirsizlikler döviz piyasalarının iniş çıkışına neden olarak gösterilmekteydi. Ayrıca Türkiye'deki darbe girişiminin ekonomimize büyük etkisi olduğu bilinmektedir. Bu nedenlerden dolayı 2017 yılı başlarındaki finansal sıkıntı endeksinde bir zıplama görülmektedir.

Ek olarak finansal stres endeksini oluştururken kullanılan piyasa endeksleri korelasyon katsayılarına göre analiz edilmiştir.

Son kısımda Türkiye finansal stres endeksinin Türkiye için finansal kriz göstergesi olarak kullanılıp kullanılmayacağı yorumlanmıştır. Uç değerleri aniden ve beklenmedik bir şekilde meydana gelen ve makroekonomik sonuçları olan finansal krizi göstermektedir. Dahası firmalar açısından da ciddi sorunların meydana geldiği zaman dilimi anlamına gelmektedir.

1. INTRODUCTION

Global financial crisis has been affecting developed and developing countries day by day. The Turkish economy can provide responses to the financial crisis like other developing countries. The Turkish economy has experienced many crises in the last decades.

It is known that the country's economies are affected by different sectors in the globalizing world. Nowadays, especially after 2007-2009 global financial crisis, financial stability role seems to gain importance again on these sectors. There are several reasons why the goal of countries is to have financial stability. One of them is that there is rapid development and change of financial systems nowadays. Financial interactions are growing with the technological innovations, financial services and instruments that are altering. Thus, the regulation and controlling of these developments in financial markets have become difficult. The other reason is that the financial system and real economy have more complex relations and it is hard to determine how they affect each other.

In economics, measuring financial stress and developing stress indexes have become a major working area to identify and observe the financial risks. Financial stress indexes can be calculated for various purposes. One of them is to provide the evaluation of macroeconomic conditions and monetary policy implementations. The other one is to contribute to the determination of the sources of vulnerabilities in financial markets. Moreover, profit maximizing firms may face many risks in the economic cycle. There are some ways to minimize or avoid these risks for them. Firms can use such financial stress index and take precautions about rising risk by hedging. On the other hand, the intercountry comparison is not one of the purpose, so there is no common prototype financial stress index for all countries. That is why there is no unique calculation methodology of financial stress index.

The financial stress index can be found to succeed in reflecting crisis period and directing the economic activities. It can be said that the financial stress index reflects the local or global financial crisis in periods where it is getting increasing.

Despite the increasing number of these studies in Turkey recently, they have some drawbacks. When the literature is examined for Turkey, financial stress index is calculated on four basic indicators: banking sector, foreign exchange market, stock market and public sector. However, the number of variables used in the previous studies about FSI of Turkey are very few and they do not give all information about their periods. Furthermore, the GARCH model has not been used before. Therefore, this study is expected to contribute to this working area with the data diversity and the modelling type. This study can help to predict the period when the financial crises come.

This study is organized as follows: Section 2 gives information about the literature about financial stress indexes. Section 3 introduces variables and their descriptive statistics for each sector that are used and how returns and realized volatilities are calculated. In section 4, standardization of data, stationarity results and methodology are presented. Lastly, in section 5 and 6, the findings are shown and results are interpreted, respectively.

2. LITERATURE REVIEW

There are various researches in the literature about building financial stress index. However, there is no consensus definition for it. Financial stress index is calculated as a continuous variable and its extreme values are defined as financial crises (Illing and Ying, 2003). On these periods, there is probably uncertainty for fundamental value of assets and high pressure on economic agents because of changing expectations (Hakkio and Keeton, 2009). Financial stress causes uncertainty on the market and this situation leads to decline in the value of financial assets.

Illing and Ying (2003) conducted a survey to figure out which variables are suitable to create FSI based on Canadian experiences rather than literature. They used high frequency daily data and their FSI index was consisting of banking, debt, equity and foreign exchange market variables. Factor analysis, credit weights, variance-equal weights, transformations using sample cumulative distribution functions (CDFs), generalized autoregressive conditional heteroscedasticity (GARCH) modelling approaches are applied and the credit-weighted FSI was chosen as the best index for Canada. Alteration of the index is evaluated whether stress on financial market is decreasing or increasing.

Sandahl et al. (2011) computed the financial stress index of Sweden with equal-weighted method. Their variables which were TED spread, bond spread, volatility of equity market and volatility of foreign exchange market were daily from 1 January 1997 to 30 June 2007. The reason for choosing equal-weighted method is that it is very easy to interpret and understand. The peaks and lower points of Sweden stress index were interpreted as the significant financial events.

Park and Mercado (2013) examined the four sectors to create the FSI for 25 emerging economies and 15 advanced economies. They used the banking sector β coefficient which is like:

$$\beta = \frac{\text{cov(r,m)}}{\text{var(m)}} \tag{1.1}$$

where r and m were returns of the banking sector stock and the whole market stock price index, respectively. If the β coefficient is very high, then it means that there is great banking sector's stress. In other words, if the β coefficient is bigger than one, then the banking sector is riskier relatively because the volatility of returns of bank stocks is higher than the volatility of returns of whole market (Park and Mercado, 2013). For foreign exchange market, exchange market pressure index (EMPI) is selected, as stock market volatility obtained from GARCH(1,1) process is used for equity market. Moreover, sovereign differences between local government bonds and United States treasuries with maturity of 10-years are used in this paper to measure the depth stress. There are two methods to combine variables into one index in this paper. One of them is variance-equal weights approach, and the other one is principal component approach. Two methods were applied for the emerging countries of Asia, Europe, America and also for the advanced countries. Park and Mercado (2013) described existence of financial stress that the value of the financial stress index exceeds its long-run trend.

Nagy et al. (2016) worked on creating Financial Systemic Stress Indicator with variables belonging to foreign exchange market, bond market, equity market, money market and banking sector. The stress indicators were transformed into their cumulative distribution function (CDF). Then, the Exponential Weighted Moving Average method was used to aggregate the sub-indices as single financial stress index which shows economically important events in the literature for Romania.

Cambón and Estévez (2016) measured Financial Market Stress Index for Spain. In this paper, six segments which are money market, bond market, equity market, foreign exchange market, financial intermediaries and derivative market are considered as influencing the financial system. Each segment has three indicators and cumulative distribution functions of each indicator had calculated for aggregation step. Then, basic portfolio theory is applied to aggregate them as FMSI of Spain. This procedure is like footprint of the paper of (Holló, Kremer and Duca, 2012). After constructing FMSI, the threshold vector autoregression model is used to evaluate the strength and length of financial shocks.

MacDonald et al. (2017) generated Financial stress index for European countries separately to investigate the spread effect between these economies because Eurozone crisis could be better interpreted in this way.

Banking sector, money market, bond market and equity market indicators were chosen to be caused uncertainty and crisis. Firstly, the all variables are standardized and the FSI of each country is built with the variance-equal method. Secondly, the FSI of Europe is calculated with the same method to investigate the whole region. After all, the full BEKK model that is a variant of multivariate GARCH model is applied to examine the spillover effects between markets and countries in Europe.

Çevik et al. (2012) evolved an index showing the change in the Turkish economy. The principal components analysis was preferred to sum up the variables and generate the financial stress index for Turkey. As stock market volatility, bond spreads, exchange market pressure index called EMPI and banking sector probability increase the FSI of Turkey, trade activity and growth rate of external debt in short term decrease it. After generating the index, it is interpreted that peaks of index shows Russian Crisis in 1998, Banking Crisis in Turkey and 11 September attack in 2001, Iraq War in 2003, respectively. The connections between financial stress and economic activity are examined by impulse response functions of VAR model. As a result of their study, FSI gives not only a quantitative way to understand the significant economic activities but also it opens new doors for policy makers to choose the best policy.

Ekinci (2013) studied to calculate a financial stress index for Turkey with a daily frequency from August 2002 to January 2013. His index includes equally weighted four market data which are banking sector, public sector, stock market and foreign exchange market. For banking sector, interbank cost of borrowing that is the difference between three-month Turkish libor rate and the Central Bank of Turkey policy rate was used as a sub-index. Five-year USD credit default swap spreads of Turkey was chosen as a sub-index for public sector. Percent change per year of the returns of Istanbul Stock Exchange that was multiplied by minus one was an indicator for stock market. Lastly, percent change per year of the US Dollar closing price was used for foreign exchange market. All variables are standardized and aggregated to get financial stress index for Turkey. According to this research, the created FSI can be categorized into six periods as the high, the normal, the global crisis, the low, the decreasing and increasing stress periods. As an example of these periods, the high stress period was the time interval from 2002 to 2003 that is affected by 2001 banking crisis and the beginning of Iraq War and disarmament of Iraq.

The financial stress index is 5.36 very high on this period. It was high due to the public sector sub-index on that time which was 2.59 while the other sub-indexes were lower than 2, so public sector was the main reason of financial stress on that time.

Kaya and Kılınç (2016) followed the literature to generate a financial stress index for Turkey between 2002 and 2015. They used five-year credit default swaps, stock returns, exchange market pressure index (EMPI), interbank cost of borrowing as variables of financial stress index for Turkey. The method of calculation was the same with Ekinci (2013). In addition to the measurement of the financial pressure, the relationship between financial pressure and real economy was investigated in that study. The real economy was represented by the industrial production index, foreign trade rate and domestic credit utilization rate. First, the stationarity conditions were checked to measure the relationship of real economy and financial pressure. After that, granger causality test was applied and VAR model was chosen to analyze them. Kaya and Kılınç (2016) concluded that an increase in financial stress may increase systematic risk and negatively affect economic activities. As a result, research findings showed that financial stress index can be a tool to help policy makers in decision making.

As Hakkio and Keeton (2009) suggested that an important purpose of FSI is to show the way for policymakers to decide whether policymakers should be worry about when FSI is very high or low. That is why many researches are conducted by so many countries, a group of countries and institutions like Canada, United Kingdom, Sweden, Spain, Romania, Indonesia, Greece, European countries, a group of emerging countries, IMF etc.

3. DATA

In this thesis, spanning the period from 02 January 2007 to 29 November 2017, the daily data, which was collected from Thomson DataStream and Bloomberg which was used to generate Financial Stress Index of Turkey.

The first contribution of this thesis is the calculation of financial stress index of Turkey based on four market-level indicators. These markets are consisting of Banking Sector, Equity, Money and Exchange Market. The reason for choosing these markets is that they are thought to be more reflection of the financial stress level in Turkey.

The second contribution of this thesis is to analyze the spillover effects between markets in Turkey representing the financial stress level. Each market consists of different variables and the data contains 2847 observations for each variable. Table 3.1 shows the markets and their variables.

Table 3.1: Variables of markets for calculation of FSI of Turkey.

Banking Sector	Equity Market
Dividend Yields	Dividend Yields of BIST100
Market Value	Market Value of BIST100
Turnover by Volume	Price/Earning Ratio
Price/Earnings Ratio	Returns of BIST100
Returns of Bank Equities	Realized Volatility BIST100
Beta Coefficient	
Realized Volatility of Bank Equities	

Money Market	Exchange Market
Realized Volatility of Treasury Bill 3M	Realized Volatility of $/₺
Realized Volatility of Government Bond 5Y	Realized Volatility of €/₺
Refinancing Rate-2Y Government Bond Yield	Realized Volatility of £/₺
Refinancing Rate-5Y Government Bond Yield	

Based on MacDonald et al. (2017) followed the most of variables are chosen for the banking sector, the equity market and the money market. The foreign exchange market has also very significant place for the Turkish economy. The most well-known economic effect of exchange rate is its effect on foreign trade. It is known that an increase in the exchange rate contributes theoretically to increasing exports, reducing imports and ensuring external equilibrium. That is why the exchange market variables are included to calculate the financial stress index.

Banking sector contains seven variables which are considered as they affect the banking sector conditions. Firstly, excessive dividend yield means increasing risk for fundamentals of banking sector which shows that there is negative relation between them. Secondly, there is negative relation between market value and financial risk presence. If there is uncertainty, market value will tend to decrease. Turnover by volume is an important sign for the sensitivity of banks. In theory, the price earnings ratio (P/E) explains how much investors are willing to pay for bank's stock based on its current earnings. High P/E ratio denotes higher profitability of bank. Thus, the higher P/E ratio, the more financial stress. Lastly, the other three variables which are Returns of Bank Equities, Beta Coefficient and Realized Volatility of Bank Equities demonstrate the risk perception and the volatility of the banking sector.

The returns are calculated with the equation (3.1) and the realized volatilities are calculated with equation (3.2) as follows:

$$R_t = (\log(x_t) - \log(x_{t-1})) * 100 \tag{3.1}$$

where x_t is the closing price of asset or currency.

$$V = 100 * \sqrt{\frac{252}{n} \sum_{i=1}^{n} R_t^2} \tag{3.2}$$

where 252 is the number of trading days of the year and n is 21 which is the number of trading days of the month.

The equity market comprises of five variables which are dividend yields, market value, P/E ratio, return and realized volatility of BIST100 index in Turkey. The variables used are the same for the banking sector.

For the money market, there are four variables. The three-month treasury bill realized volatility shows the market volatility risk. Moreover, the five-year government bond realized volatility depicts market's risk aversion. Refinancing rate has been taken as

Turkey one-week repo lending rate. Finally, the difference between refinancing rate and government bond (two-year and five-year) is used as sign of getting worse of liquidity situation, so negative values of these spreads illustrate higher financial stress.

Foreign exchange market including three variables that are realized volatilities of the Turkish Lira exchange rate vis-à-vis the US dollar (USD/TRY), Turkish Lira exchange rate vis-à-vis the Euro (EURO/TRY) and Turkish Lira exchange rate vis-à-vis the British Pound (GBP/TRY) is very significant for those institutions heavily dependent on foreign liabilities and also for those with a high exposure to foreign assets.

The descriptive statistics of FSI for each market are shown in Table 3.2. As it can be seen from this table, there are 2847 observations. The skewness of all market indexes is positive. All market FSI series have positive kurtosis which means that they have heavy tails and sharper peaks than normal distribution. Furthermore, the ARCH tests are statistically significant that allow to use ARCH models because of existence of ARCH effects. Additionally, the Ljung-Box Q and Q^2 are also statistically significant.

Table 3.2: Descriptive statistics of FSI of sectors.

	FSI of Banking Sector	FSI of Equity Market	FSI of Money Market	FSI of Exchange Market	FSI of Turkey
Mean	0.01262	0.0000	0.0000	0.0000	0.003155
Median	-0.03455	-0.25448	-0.2014	-0.2170	-0.093149
Maximum	1.9679	4.1269	2.2998	6.1325	2.6061
Minimum	-0.73582	-2.0202	-0.84001	-1.4683	-0.65316
Std. Dev.	0.28604	0.43342	0.56339	0.95072	0.41686
Skewness	1.2422**	2.2202**	1.5894**	2.3639**	2.2094**
Kurtosis	2.8681**	10.490**	2.0667**	9.2014**	7.6286**
Jarque-Bera	1707**	15393**	1705**	12695**	9219.8**
ARCH 1-5	163.10**	320.23**	24248**	24718**	6078.5**
ARCH 1-10	90.812**	179.60**	12095**	13584**	3065.1**
Q(20)	15011.1**	24863.6**	41674.9**	40799.5**	43265.5**
Q^2(20)	4875.76**	8699.32**	37252.4**	34342**	38388.9**
Observations	2847	2847	2847	2847	2847

4. METHODOLOGY

4.1 Constructing of financial stability Index

As first step, each variable is standardized to avoid inaccurate measurement issues. The value of one variable is subtracted from its mean, and then divided by its standard deviation. After standardization, all indicators of each market are aggregated with equally weighted based on variance-equal aggregation method to calculate financial stress index on market level as shown equation (4.1). Subsequently, the financial stress index of Turkey is calculated by equal weighted aggregation all these market level financial stress indexes and it is shown as equation (4.2).

$$FSI_t^{market\,j} = \sum_{i=1}^{k} \frac{1}{k}\, x_{it}^{j\,standardized} \qquad (4.1)$$

where j is the market type, k is the number of variable of market and x_i is the variable of market.

$$FSI_t^{Turkey} = \frac{1}{4}\left(FSI_t^{bank} + FSI_t^{equity} + FSI_t^{money} + FSI_t^{exchange}\right) \qquad (4.2)$$

Before modelling, as second step, the stationarity of FSI's for each market is checked with NG-Perron Stationarity Test. Stationarity means that characteristic of stochastic process or moment does not change over time.

Time series should be stationary otherwise well-known spurious regression problem would occur. The results of tests are presented in Table 4.1. FSI of banking sector, equity market, money market and exchange market are stationary. Moreover, the FSI of Turkey seems to be stationary. Thus, there is no problem to analyze time series in terms of stationarity.

Table 4.1: Ng-Perron test results.

Null Hypothesis: The serie has a unit root
Exogenous: Constant
Sample:1/02/2007 - 11/29/2017
Included Observation: 2847

Ng-Perron Statistics:	MZa	MZt	MSB	MPT
BANK_FSI	-31.5092	-3.91391	0.12422	0.94963
EQUITY_FSI	-29.4818	-3.83930	0.13023	0.83129
MONEY_FSI	-11.1835	-2.35093	0.21021	2.24650
EXCHANGE_FSI	-16.4808	-2.85918	0.17349	1.53037
TURKEY_FSI	-20.3628	-3.18742	0.15653	1.21556
Asymptotic Critical Values*:	-13.800***	-2.580***	0.174***	1.780***
	- 8.100**	-1.980**	0.233**	3.170**
	- 5.700*	-1.620*	0.275*	4.450*

*, **, and *** indicate the significance at the 10 percent, 5 percent, and 1 percent levels, respectively.

4.2 Multivariate GARCH Models

Engle (1982) was the first to show that the assumption of constant variance of time series could not be achieved and developed the Autoregressive Conditional Heteroskedasticity (ARCH) model. For this model, the time series must have a fixed variance in order to achieve full success in forecasting.

Bollerslev (1986) extended the work of Engle by the modelling of the conditional variance as an ARMA process in order to create a longer memory and more flexible delay structure. The ARCH model was expanded to Generalized Autoregressive Conditional Heteroskedasticity (GARCH) model which allows more memory and more flexible delay structure in that study. GARCH model is used for modelling in this study. The main purpose of using the GARCH models is to estimate and predict future volatility. There are two general types of GARCH model which are univariate and multivariate GARCH models. Only one unique time series is needed for the univariate GARCH models, while more than one time series are used for multivariate GARCH models. Using multivariate GARCH series it is possible to analyze volatility spillovers and dynamic correlation between markets.

14

Baillie and Bollerslev (1992) developed the Constant Conditional Correlation (CCC) GARCH model to model the multivariate GARCH structure. In this way, using the univariate models, multivariate models can be created, where there is more detailed analysis.

In this thesis, a special type of multivariate GARCH which is called Dynamic Conditional Correlation (DCC) GARCH model is used to analyze and forecast volatility and spillover effects of Financial Stress Index of Turkey.

DCC GARCH model is the generalization of Constant Conditional Correlation (CCC) GARCH model. Conditional correlations obtained by CCC GARCH model are constant, in other words, conditional correlations are not changing over time. That is the main restriction of CCC GARCH model which makes model easy to estimate. Moreover, DCC GARCH model is appropriate for the forecasting of volatility that varies over time. On the other hand, one of the most significant benefit of the DCC GARCH model is that the number of parameters in the correlation process does not depend on the number of series to be correlated, so large correlation matrices can be computed during estimation.

DCC GARCH model is estimated by two-steps. Firstly, the GARCH parameters are estimated and residuals are obtained from any Univariate GARCH model like GARCH(1,1). Secondly, the time-varying correlation matrix is estimated with using residuals which are obtained from the first step (Engle, 2002).

$$H_t = D_t R_t D_t \qquad (4.3)$$

where D_t represents a diagonal matrix with time-varying standard deviations on the diagonal, R_t is the conditional correlation matrix and H_t represents nxn conditional covariance matrix.

$$D_t = \text{diag}\left\{\sqrt{h_{it}}\right\} \qquad (4.4)$$

$$R_t = \text{diag}\{Q_t\}^{-1} Q_t \text{diag}\{Q_t\}^{-1} \qquad (4.5)$$

Q_t is a positive definite matrix and it is also symmetric:

$$Q_t = (1 - l_1 - l_2)\overline{Q} + l_1(z_{t-1}z_{t-1}') + l_2 Q_{t-1} \qquad (4.6)$$

$\overline{Q}$ represents nxn unconditional correlation matrix of the standardized residuals z_{it}. The parameters l_1 and l_2 are positive and $(l_1 + l_2)$ is smaller than one. Thus, the DCC GARCH model is mean reverting.

The components of H_t for GARCH(1,1) model is that:

$$h_{it} = w_i + \alpha_i \varepsilon_{i,t-1}^2 + \beta_i h_{i,t-1} + \gamma_i DU_{i,t} \tag{4.7}$$

where $DU_{i,t}$ is a vector of dummy variables for country i at time t.

Then time-varying correlation coefficient $\rho_{ij,t}$ can be obtained as follows:

$$\rho_{ij,t} = \frac{(1-l_1-l_2)\overline{Q}+l_1(z_{t-1}z_{t-1}')+l_2 Q_{t-1}}{\sqrt{(1-l_1-l_2)\overline{Q}+l_1 z_{i,t-1}^2+l_2 Q_{t-1}}\sqrt{(1-l_1-l_2)\overline{Q}+l_1 z_{j,t-1}^2+l_2 Q_{t-1}}} \tag{4.8}$$

5. RESULTS

The created FSI of Turkey comprised of four sector variables is illustrated in figure 5.1. As shown in Figure 5.1, there is a peak in September 2008 due to Lehman Brothers' bankruptcy and global world crisis for FSI of Turkey. After this crisis shock, this stress index seems to decrease. However, it is rising after FED's tapering decision in 2013. In addition, there is another fluctuation in the second half of 2016 because of coup attempt in Turkey and uncertainty in world economy. Thus, the FSI of Turkey can be specified as an indicator that shows periods of significant financial crisis related with Turkey.
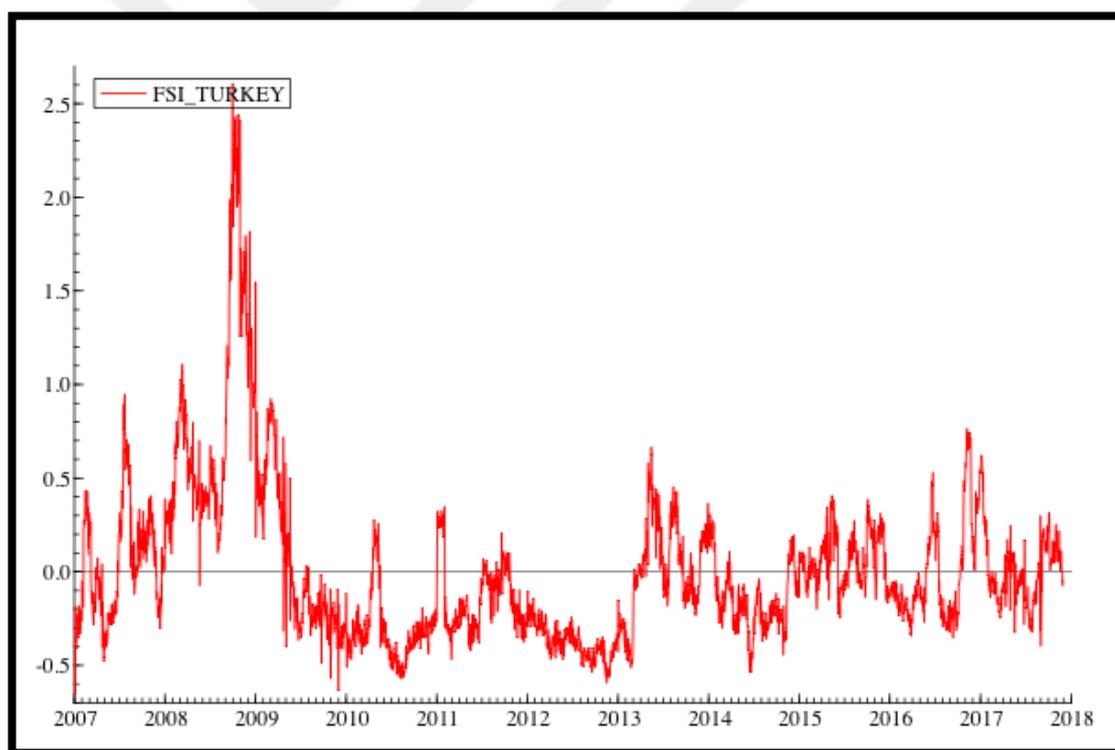

Figure 5.1: Financial stress index of Turkey plot.

The figure 5.2 illustrates that components of Financial Stress Indexes of Turkey separately. Their standardized residuals are also demonstrated in Figure 5.3. After 2008, there are peaks for every individual FSI because of World financial crisis. The second important rise of them is in 2013 after tapering decision of FED.

17

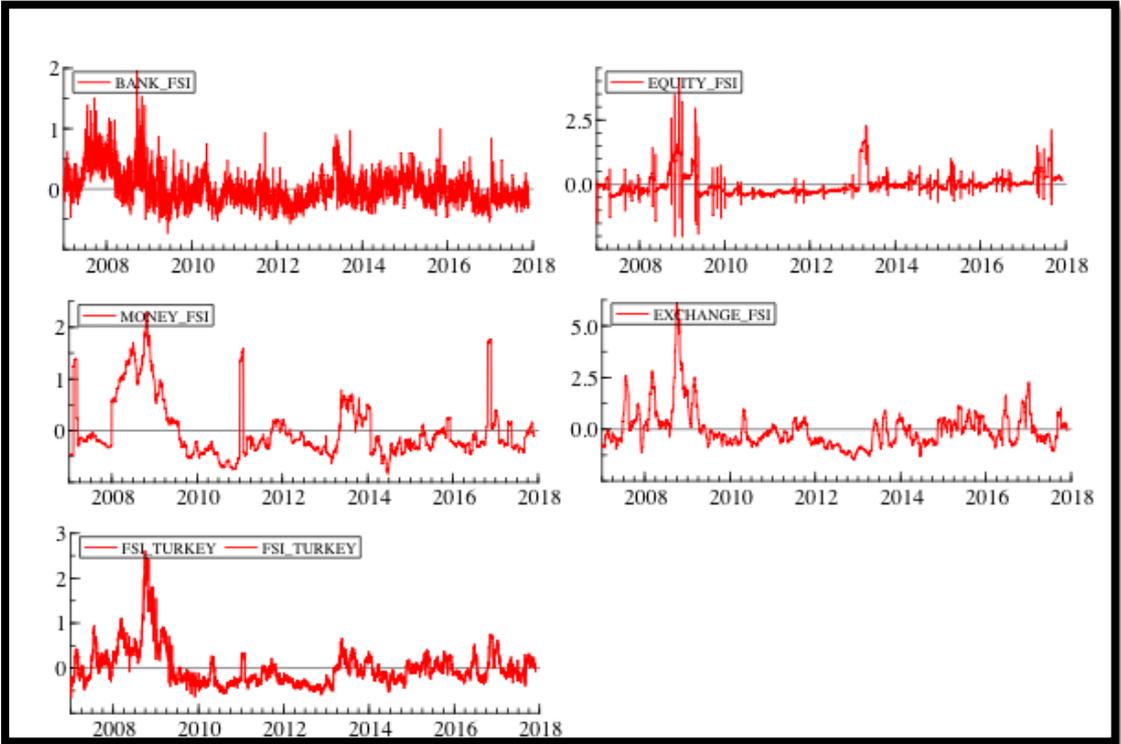The last common increase from the Figure 5.3 can be interpreted the effect of coup effect in Turkey in 2016.

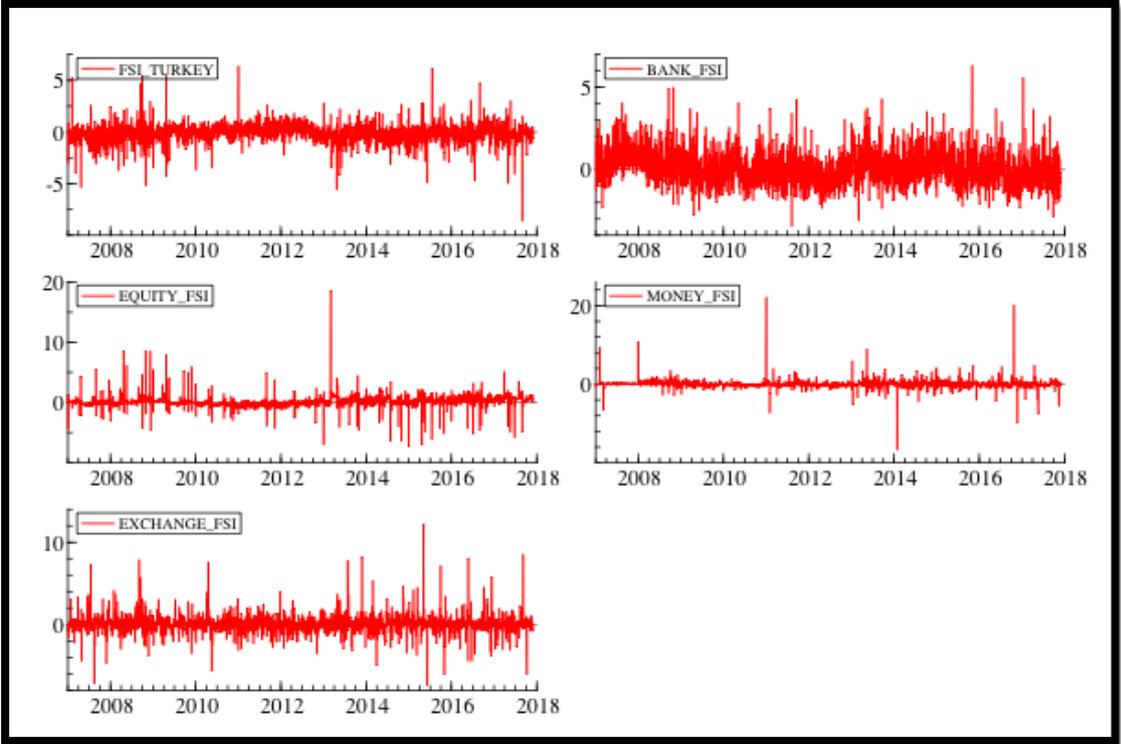**Figure 5.2:** Time series plots of the components of FSI of Turkey.

Figure 5.3: Standardized residuals of components of FSI of Turkey.

The results of DCC GARCH model for FSI of Turkey and markets between 2007 and 2017 are shown in Table 5.1, where ρ means the correlation coefficient, α is ARCH term, β is GARCH term and ν shows the degrees of freedom for t distribution. The DCC GARCH coefficient between the FSI of banking sector and the FSI of Equity market is the highest. The correlation between the FSI of money market and exchange market follows it as the second highest value.

Most of the correlation coefficients are statistically significant except $\rho_{Banking-Exchange}$, $\rho_{Equity-Money}$, and $\rho_{Equity-Exchange}$. The dynamic conditional correlations are obtained from DCC GARCH model and are presented in Figure 5.4. The correlation between FSI of equity and exchange market is very low that is close to zero. Moreover, the dynamic conditional correlation among the FSI of money market and exchange market is getting higher after 2016. The FSI of Turkey is mostly correlated with the FSI of banking sector and equity market. The correlations between FSI of Turkey and FSI of Banking sector and between FSI of Turkey and FSI of equity market are over 0.6 which is very high. This result is proved by the DCC GARCH correlation coefficient which are statistically significant suggesting higher integration between them. These finding shows that there is less diversification opportunity among them.

Moreover, the correlation between FSI of Turkey and FSI of money market, FSI of Turkey and FSI of exchange market and FSI of banking sector and FSI of equity market are less than 0.5 and higher than 0. Their correlation coefficients are also statistically significant which is obtained from DCC GARCH model. Lastly, the other correlations do not seem very important.

Table 5.1: DCC GARCH coefficients of FSI's.

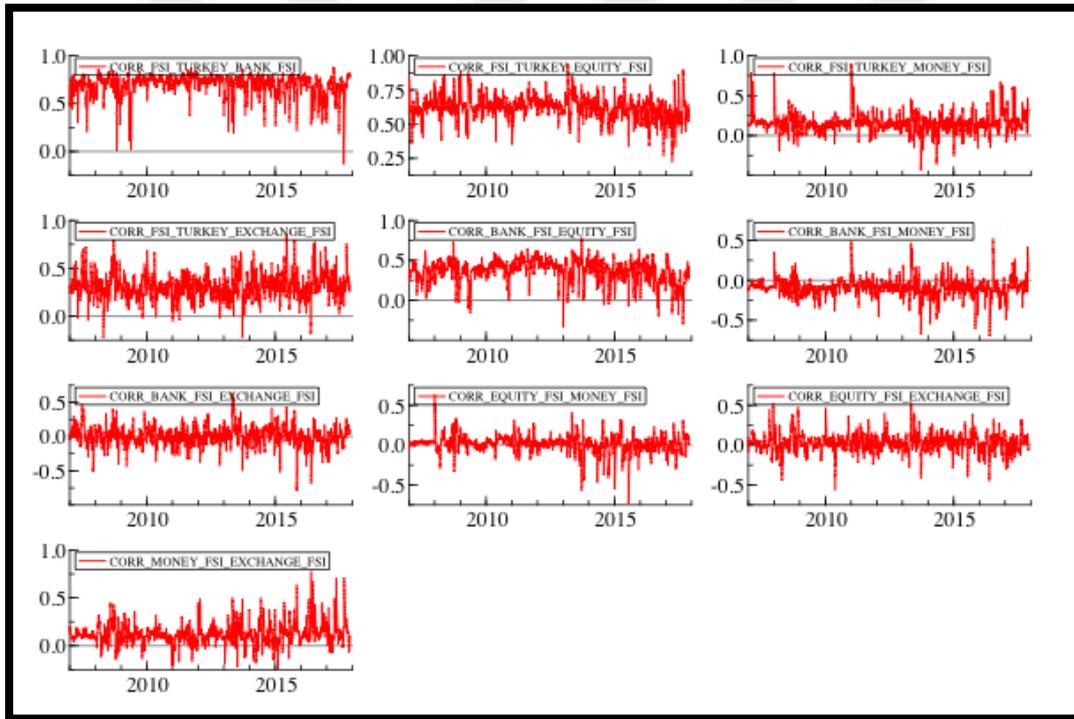| Coefficient	Value	Prob
ρFSI-Banking	0.7005	0.0000
ρFSI-Equity	0.6189	0.0000
ρFSI-Money	0.1708	0.0000
ρFSI-Exchange	0.2976	0.0000
ρBanking-Equity	0.3724	0.0000
ρBanking-Money	-0.0908	0.0000
ρBanking-Exchange	-0.0015	0.9410
ρEquity-Money	0.0368	0.4934
ρEquity-Exchange	0.0275	0.2778
ρMoney-Exchange	0.1151	0.0009
α	0.0879	0.0000
β	0.7878	0.0000
ν	3.2221	0.0000
Loglikelihood	16214.5	

Figure 5.4: Conditional correlations plots.

Additionally, the conditional covariances and variances of FSI of Turkey, FSI of banking sector, FSI of equity market, FSI of money market and FSI of exchange market are illustrated in Figure 5.5 and Figure 5.6, respectively.
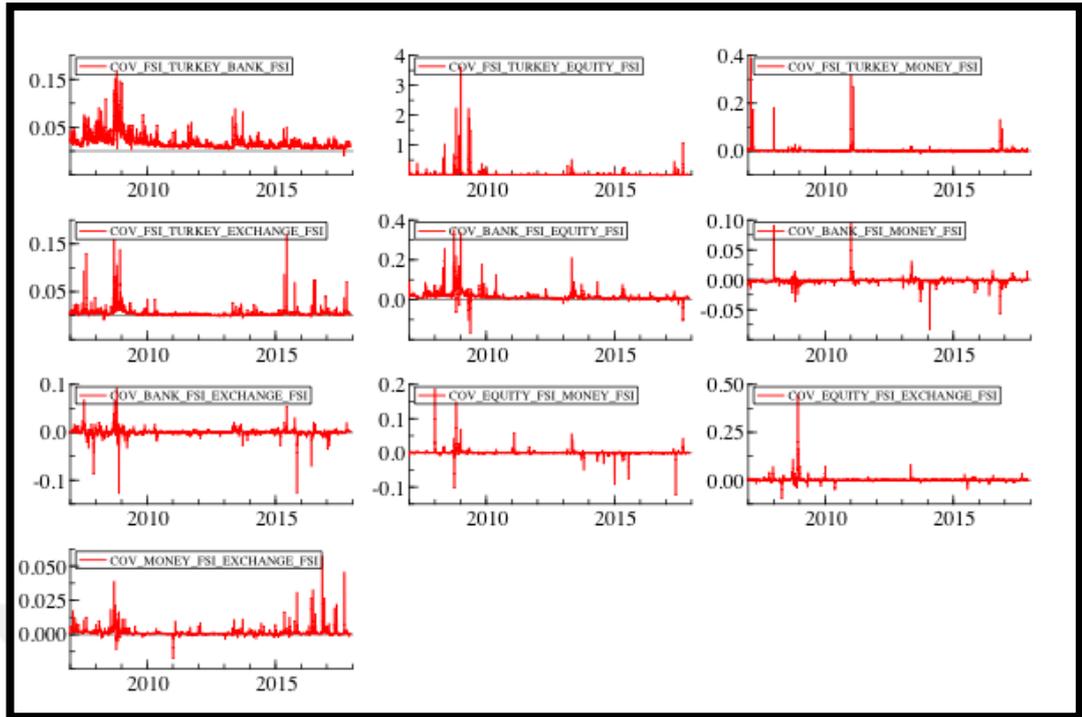
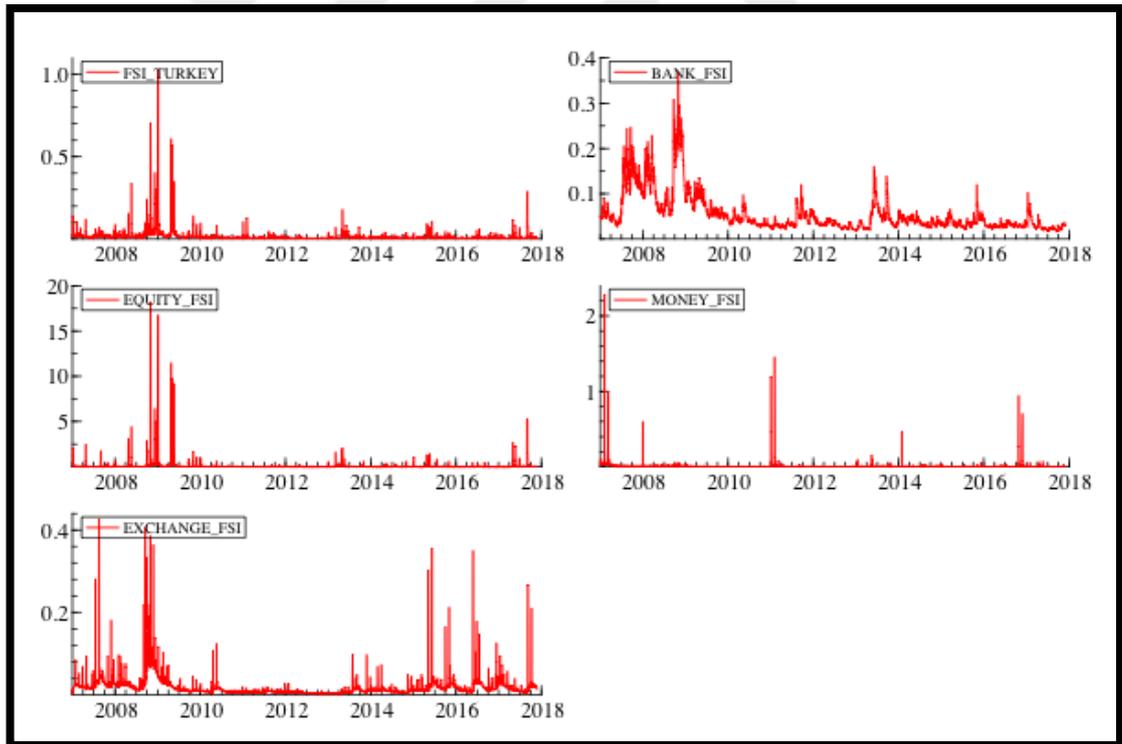**Figure 5.5:** Conditional covariances plots.

Figure 5.6: Conditional variances plots.

According to the Table 5.2, the null hypothesis of Jarque-Bera test is rejected which shows that none of the series are not normally distributed that is why t-distribution is used for DCC GARCH model.

Table 5.2: Test statistics for distribution of FSI of each sector.

		Statistic	Prob
FSI of Turkey	Skewness	-0.3582	$5.8769e^{-15}$
	Excess Kurtosis	9.5576	0.0000
	Jarque-Bera	10897	0.0000
FSI of Banking Sector	Skewness	0.6686	$4.3032e^{-63}$
	Excess Kurtosis	1.5347	$8.0019e^{-63}$
	Jarque-Bera	491.47	$1.8994e^{-107}$
FSI of Equity Market	Skewness	2.1215	0.0000
	Excess Kurtosis	55.721	0.0000
	Jarque-Bera	$3.7045e^{15}$	0.0000
FSI of Money Market	Skewness	4.7071	0.0000
	Excess Kurtosis	158.85	0.0000
	Jarque-Bera	$3.0040e^{6}$	0.0000
FSI of Exchange Market	Skewness	1.3499	$3.0539e^{-19}$
	Excess Kurtosis	19.697	0.0000
	Jarque-Bera	46886	0.0000

Table 5.3 shows the Ljung Box Q-statistics on squared standardized residuals. For the second order Q-statistics, the null hypothesis is not rejected which means that residuals are not autocorrelated. There is no remaining GARCH effect.

Table 5.3: Q-statistics on squared standardized residuals of FSI's.

	$Q^2(5)$	$Q^2(10)$	$Q^2(20)$	$Q^2(50)$
FSI of Turkey	3.47747	6.18570	8.58451	54.7399
	[0.6268]	[0.7994]	[0.9872]	[0.2994]
FSI of Banking Sector	3.72739	6.83495	16.5215	50.1091
	[0.5892]	[0.7409]	[0.6837]	[0.4690]
FSI of Equity Market	0.97760	1.34387	8.03196	42.7211
	[0.9643]	[0.9993]	[0.9916]	[0.7577]
FSI of Money Market	0.06903	0.210921	0.459967	51.5319
	[0.9999]	[0.9999]	[1.0000]	[0.4136]
FSI of Exchange Market	2.12601	5.12805	9.87787	292.059
	[0.8314]	[0.8824]	[0.9703]	[0.0000]

The credit default swaps can be count as effective tools for risk management in finance. The figure 5.7 shows CDS of Turkey and FSI of Turkey's trends in the same frame. According to this figure, it can be seen that both of indicators move together for the most of periods. This means that the financial stress index is meaningful to show the crisis periods in Turkey.
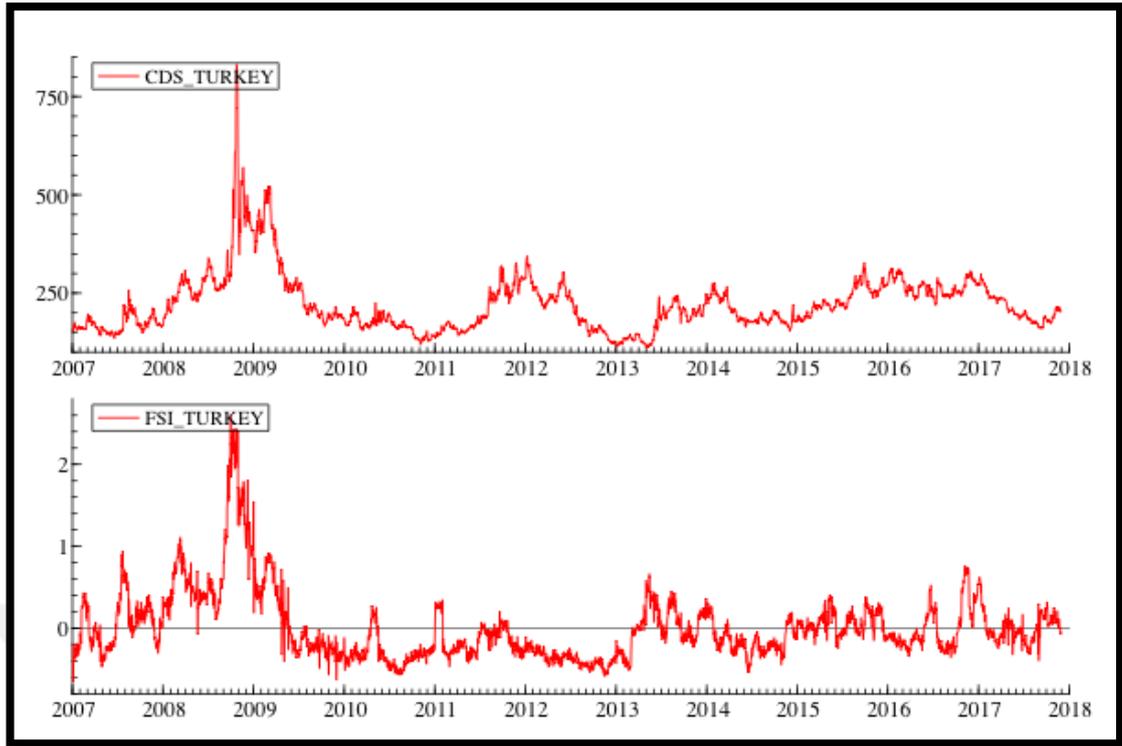
Figure 5.7**: CDS of Turkey and FSI of Turkey.**

5.1 Conclusion

There are increasing efforts to develop early warning systems to understand the financial events which affect negatively the economies. In this context, financial stress indexes have been generated by some researchers recently. These indexes are the combination of complex variables that can be combined with various methods to make them more simple and understandable. In this way, the financial stress index which is depending on a variable rather than many variables illustrates the financial stress in the simple format.

The first goal of this study is to construct a financial stress index for Turkey and to examine whether it reflects the crisis periods or not. For each sector, related variables are selected to generate the financial stress indexes of them with variance-equal aggregation method. Secondly, the DCC GARCH model is applied to estimate conditional correlations between FSI of each sector which are used to construct FSI of Turkey.

It is known that 2007-2008 global financial crisis was the one of the biggest crisis for a great deal of economies. The peak of the crisis was the announcement of Lehman Brothers' collapse. The financial stress index of Turkey has a peak after this crisis as effect of it.

Federal Reserve System (the FED) started to take some precautions in 2013. These precautions are named tapering which refers to tightening monetary policy, so the central bank of US does not give money to financial market and attracts money from market. Thus, the interest rate of US was increased, most of investors in Turkey took money from that market and invested in US market. This effect also can be seen in the FSI of Turkey as an increase.

As mentioned before, the growing uncertainty in world economic markets after the US presidential elections and coup attempt in Turkey has big impact in our economy. Furthermore, FSI of Turkey is similar to CDS of Turkey, so this index can be used in practice.

In the light of the information above, the rise of FSI of Turkey in that period can be explained.

As a consequence, the financial stress index of Turkey created in this study reflects the important economic activities. As the other many countries do, this index can be used to take some precautions by policymakers.

On the other hand, this work can be expanded with the same variables using a dynamic weighting method for creating FSI of Turkey. It may help to get better result for different time intervals.

REFERENCES

Baillie, R. T., & Bollerslev, T. (1992). Prediction In Dynamic Models With Time-Dependent Conditional Variances. *Journal of Econometrics*, 91-113.

Bollerslev, T. (1986). Generalized Autoregressive Conditional Heteroskedasticity. *Journal of Econometrics*, 307-327.

Cambón, M. I., & Estévez, L. (2016). A Spanish Financial Market Stress Index (FMSI). *The Spanish Review of Financial Economics, 14*, 23-41.

Çevik, E. İ., Dibooglu, S., & Kenc, T. (2012). Measuring Financial Stress in Turkey. *Journal of Policy Modeling*, 370-383.

Ekinci, A. (2013). Financial Stress Index for Turkey. *Doğuş Üniversitesi Dergisi*, 213-229.

Engle, R. F. (1982). Autogressive Conditional Heteroscedasticity with Estimates of the Variance of United Kingdom Inflation. *Econometrica*, 987-1008.

Engle, R. F. (2002). Dynamic conditional correlation: A Simple Class of Multivariate Garch Models. *Journal of Business & Economic Statistics, 20*, 339-350.

Hakkio, C. S., & Keeton, W. R. (2009). Financial Stress: What Is It, How Can It Be Measured, and Why Does It Matter? *Economic Review for Federal Reserve Bank of Kansas City*, 5-50.

Holló, D., Kremer, M., & Duca, M. L. (2012, March). CISS-A Composite Indicator Of Systemic Stress In The Financial System. *European Central Park Working Paper Series*, 3-51.

Illing, M., & Ying, L. (2003). An Index of Financial Stress for Canada. *Bank of Canada Working Paper 2003-14*, 1-50.

Kaya, E., & Kılınç, A. (2016). Measuring Financial Stress Index for Turkey and The Relationship of Financial Stress Index with Real Economic Activities. *Int. Journal of Management Economics and Business*, 402-413.

MacDonald, R., Sogiakas, V., & Tsopanakis, A. (2017). Volatility Co-movements and Spillover Effects Within The Eurozone Economies: A Multivariate GARCH Approach Using The Financial Stress Index. *Journal of International Financial Markets, Institutions & Money, 52*, 17-36.

Nagy, Á., Dezsi-Benyovszki, A., & Szekely, I. (2016). *Measuring Financial Systemic Stress In Romania: A Composite Indicator Approach.* Romania: Financial Studies.

Park, C. Y., & Mercado, R. V. (2013). Determinants of Financial Stress in Emerging Market Economies. *ADB Economics Working Paper Series*, 1-37.

Sandahl, J. F., Holmfeldt, M., Rydén, A., & Strömqvist, M. (2011). An Index of Financial Stress for Sweden. *Sveriges Riksbank Economic Review*, 50-69.

CURRICULUM VITAE

Name Surname	**:** Pınar Şenol
Place and Date of Birth	**:** Fatih - December 24, 1988
E-mail	**:** pinaroney@hotmail.com

EDUCATION

- **B.Sc.** : 2012, Istanbul Technical University, Faculty of Arts and Sciences, Mathematical Engineering
- **M.A.** : 2018, Istanbul Technical University, Faculty of Social Sciences, Economics