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CONTAGION IN THE RECENT CRISES: DYNAMIC CONDITIONAL CORRELATION ANALYSIS

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ABSTRACT

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Contagion theory began to take place in the literature since the years 1990s, and mainly focuses on how, and through which channels the crisis that occurred in a country, or the crises caused by the global shock spread to other countries. Identifying these channels is especially important for policy makers to determine the vulnerability of countries to shocks from other countries and to implement the policies. In this study, DCC-GARCH method is applied to determine which countries are affected by the 2008 Global Financial Crisis and the European Sovereign Debt Crisis through stock markets. The European Debt Crisis are evaluated with two separate analyzes. Firstly, the contagion effect of the Greece Debt crisis to the Eurozone countries then the contagion of European Countries to the developed and developing countries are tested.

As a result, evidence of the contagion for all crisis is found. The findings show that there is no evidence of the contagion of the Global Financial Crisis in Asian countries and the contagion of the Greek Debt Crisis in the Eurozone core countries. The results indicate that the Greek Debt Crisis has infected the Euro Zone periphery group may be an indication that there may be a cascading effect and that the contagion to the Euro Zone countries may be through this periphery country group. Evidence for this effect is also seen in the analysis of the contagion of the Eurozone Sovereign Debt crisis to developed and developing countries as well.

Keywords: Financial Contagion, Global Financial Crisis (CFC), European Debt Crisis, DCC-GARCH.

ÖZ

SON KRİZLERDE BULAŞMA:
DİNAMİK KOŞULLU KORELASYON ANALİZİ

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1990'lı yıllardan itibaren literatürde yer almaya başlayan bulaşma teorisi, ağırlıklı olarak bir ülkede meydana gelen krizin veya küresel şokun neden olduğu krizlerin diğer ülkelere nasıl ve hangi kanallardan yayıldığına odaklanmaktadır. Bu kanalların tespit edilmesi özellikle politika yapıcıların ülkelerin diğer ülkelerden gelen şoklara karşı kırılganlığı tespit etme ve politikaları uygulamaları açısından önemlidir. Bu çalışmada, 2008 Küresel Finansal Krizi ve Avrupa Egemen Borç Krizi'nden hangi ülkelerin etkilendiğini hisse senedi piyasaları aracılığıyla belirlemek için DCC-GARCH yöntemi uygulanmıştır. Avrupa Borç Krizi iki ayrı analizle değerlendirilmektedir. Öncelikle Yunanistan Borç krizinin Euro Bölgesi ülkelerine bulaşma etkisi, ardından Avrupa Ülkelerinin gelişmiş ve gelişmekte olan ülkelere bulaşması test edilmiştir.

Sonuç olarak, tüm krizler için bulaşma kanıtı bulunur. Bulgular, Küresel Mali Krizin Asya ülkelerinde yayıldığına ve Yunanistan Borç Krizinin Euro Bölgesi çekirdek ülkelerinde yayıldığına dair bir kanıt bulunmadığını gösteriyor. Sonuçlar, Yunanistan Borç Krizi'nin Euro Bölgesi çevre grubunu etkilediğine işaret ediyor, bu durumun kademeli bir etki olabileceğinin ve Euro Bölgesi ülkelerine bulaşmanın bu çevre ülke grubu üzerinden olabileceğinin bir göstergesi olabilir. Bu etkinin kanıtları, Euro Bölgesi Egemen Borç krizinin gelişmiş ve gelişmekte olan ülkelere de bulaşmasının analizinde de görülmektedir.

Anahtar Kelimeler: Finansal Bulaşma, Küresel Finansal Kriz (KFK), Avrupa Borç Krizi, DCC-GARCH

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Merve KESER

İzmir, 2022

TEXT OF OATH

I declare and honestly confirm that my study, titled “Contagion in the Recent Crises: Dynamic Conditional Correlation Analysis” and presented as a Master’s Thesis, has been written without applying to any assistance inconsistent with scientific ethics and traditions. I declare, to the best of my knowledge and belief, that all content and ideas drawn directly or indirectly from external sources are indicated in the text and listed in the list of references.

Merve KESER

August 4, 2022

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ABBREVIATIONS

ARCH Autoregressive Conditional Heteroskedasticity.

GARCH Generalized Autoregressive Conditional Heteroskedasticity.

CCC Constant Conditional Correlation.

DCC Dynamic Conditional Correlation.

GFC Global Financial Crisis.

OLS Ordinary Least Squares.

US United States.

UK United Kingdom.

ADF Augmented Dickey Fuller.

JB-Stat Jarque-Bera Statistic.

PP Phillips–Perron.

LM Lagrange multiplier.

EU European Union.

ERM European Exchange Rate Mechanism.

CHAPTER 1
INTRODUCTION

In the last decade, many economies were marked by the severe financial crises since the financial liberalization period in 1980s. The 1994 Mexico, European Exchange Rate Mechanism (ERM), 1997 Asian and 1998 Russian crises led to the emergence of the view of crises could spread to other countries. This view has been called the contagion of crises in the literature, as if contaminating a disease.

Contagion theory generally examines why and how crises spread among countries. Firstly, due to the macroeconomic similarities among countries, the idea that crises spread from one country to another. Secondly, there is the view that crises spread to other countries due to international trade relations. However, by examining the transmission channels of the crises is clear that there may be many reasons for the spread of the crisis among countries. Due to the fact that countries may have a common lender and the behavior of investors, in other words, because of the financial link between countries. The fact that countries have a common lender may cause the crisis to spread to the other country through the lending country. As risk-averse investors rebalance their portfolios, these investors may cause the crisis to spread to another country. Asymmetric information and herding behavior are also other factors that can affect portfolio balancing and mispricing as well as factors that increase the likelihood of the crisis being contagious.

The determination of these transmission channels of contagion that cause the spread of crises among countries is crucial for policy makers. In order to reduce the high level of fragility and volatility in financial markets and to protect these markets from external shocks is crucial for policy makers to determine the policy tools.

After the 1997 Asian crisis, the contagiousness of crises began to take place theoretically and empirically in the literature. Although the 1992 European Currency Crisis covers developed countries, after the Asian Crisis, started in Thailand in 1997, empirical studies began to focus on the contagiousness of crises in emerging economies. This focus has been replaced by research on the contagiousness of crises

in developed countries with the 2008 Global Financial Crisis and the Eurozone Sovereign Debt Crisis. Especially with the recent developments in data and statistical methods help to to examine the channels through which the contagion of the crises occurred rather than whether the contagion occurs or not.

The purpose of this thesis is to examine 2008 Global Financial Crisis and Eurozone Sovereign Debt Crisis. Sudden and unexpected shocks are quickly reflected in the stock markets due to the position taken by the investors. For this reason, in this thesis the stock markets of the countries are preferred to test the contagion of the crises. Firstly, the contagion effect of 2008 Global Financial Crisis is analyzed among the top ten countries with the highest total value of the stocks traded in the world. The aim of choosing these countries is that they meet a large part of the total value of stocks trade in the world. The Eurozone Sovereign Debt crisis is analyzed in two phases. First of all, the contagion of the Greek Debt Crisis to Eurozone countries is tested in order to determine are core Eurozone countries affected by Greek Debt Crisis. Afterwards, the contagion of the Eurozone Sovereign Debt crisis is investigated together with developed and developing economies.

The thesis is organized as follows: after the introduction chapter, Chapter Two provides the general information about the definition, and types of financial crisis. The brief overview of 2008 Global Financial Crisis and the Eurozone Sovereign Debt Crisis is also given in this chapter while the following chapter concentrate on the contagion. The definition of contagion has varied in the literature, both theoretically and empirically. While the definition of contagion, which is defined theoretically, remains impossible to be examined empirically which causes many question marks and uncertainties. Therefore, Chapter Three defines contagion and examines its historical development theoretically. Even as the studies is examining contagion through the correlation coefficients between the returns of the stock markets of the countries in the early empirical literature, with the development of data and methods, it continued to be researched with methods such as regime switching models, copula models and network models. The first part of Chapter Four examines the evaluation of empirical literature on the empirical assessment of contagion of crises. In the second part of the chapter to assess contagion effect of 2008 Global Financial Crisis and Eurozone Sovereign Debt Crisis with Greek Debt Crisis are examining with DCC-GARCH model. Finally, the last chapter is concluding all findings from the three

analysis of crisis contagion and gives recommendations for future work in the light of the findings.

CHAPTER 2
AN OVERVIEW OF FINANCIAL CRISIS

2.1. Explaining Financial Crisis

As an economic term, crisis refers unsustainable volatility in money markets and good markets. The main function of the financial system is to ensure efficiency in resource allocation in the economy by channeling funds to efficient investment opportunities. Financial crisis is a situation that financial markets are unable to be linkage between economic agents who have excess of fund and who have shortage of fund. According to well-known definition by Mishkin (1991), financial crisis is a disruption in which adverse selection and moral hazard problems become worsen due to the asymmetric information. As can be seen in below mentioned figure, Mishkin (1991) attributes the reasons for financial crisis into three main reasons increase in uncertainty, increase in interest rates and decline in stock markets.

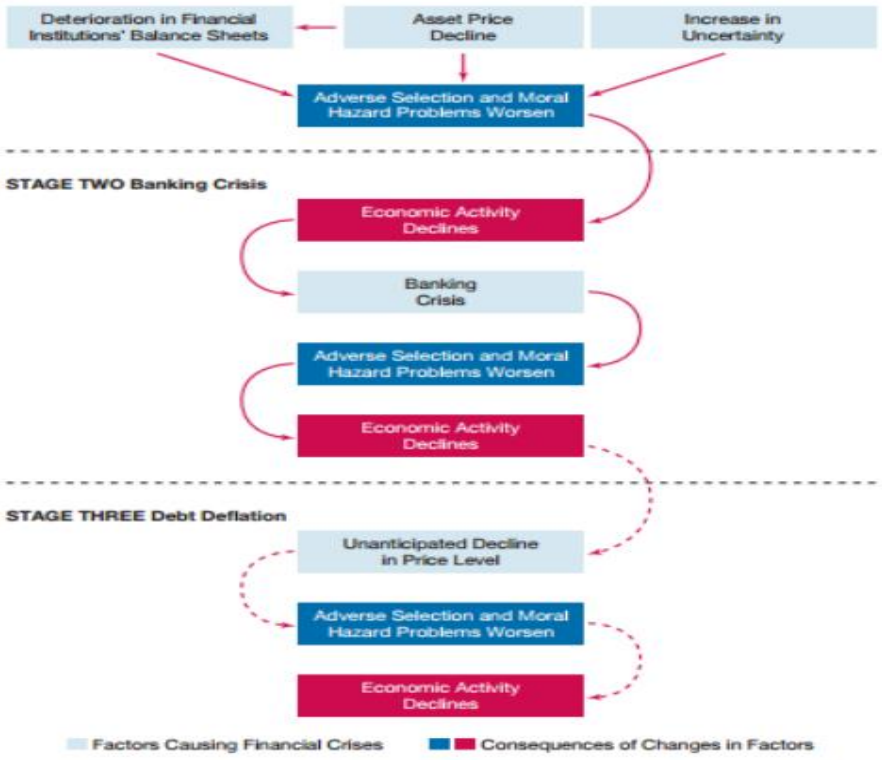


Figure1.1. Sequence of Events in Financial Crisis in Advanced Economies, Mishkin (1992).

Different than the advanced economies, extreme increase in interest rates is seen as the signal of a financial crisis in emerging market economies while the banking sector is affected at the last stage of a financial crisis. The below mentioned figure shows the sequence of events.

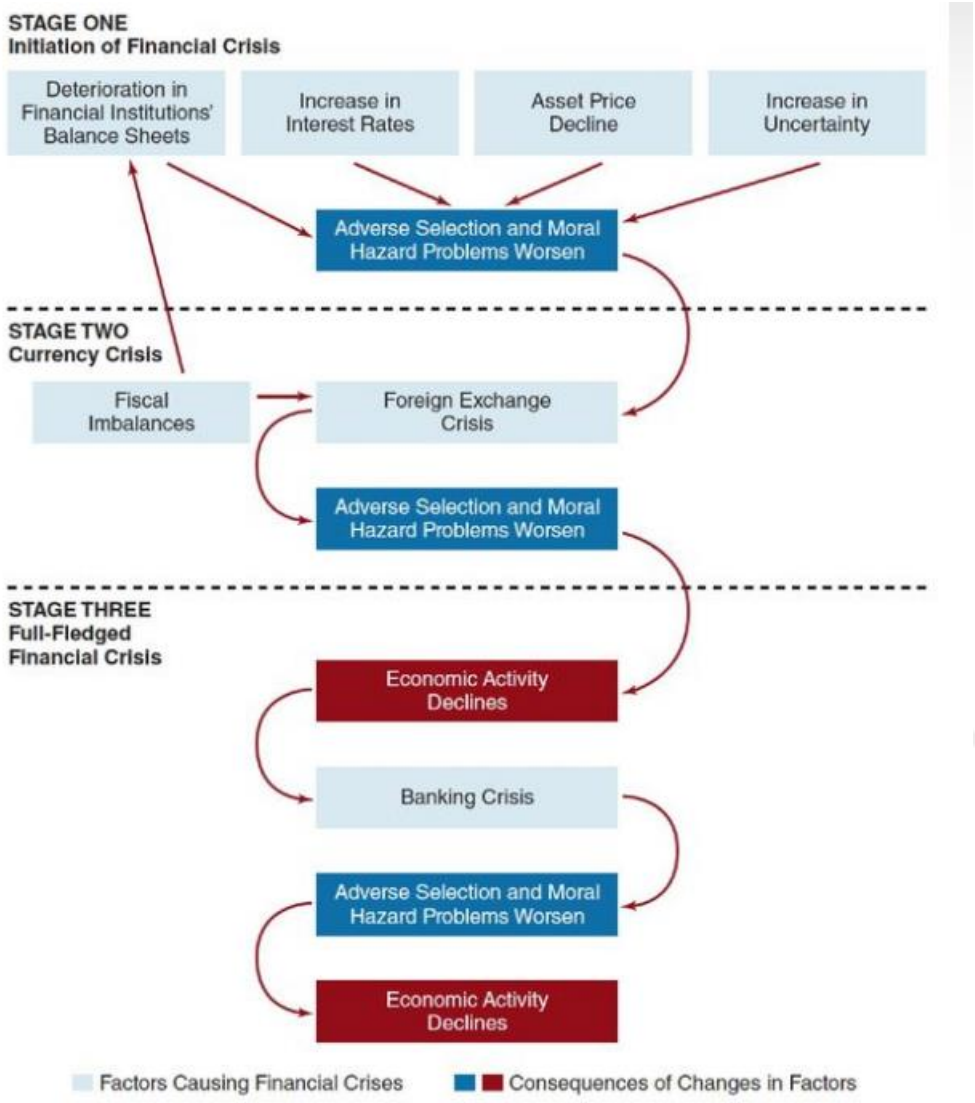


Figure.1.2. Sequence of Events in Financial Crisis in Emerging Market Economies, Mishkin (1992).

It can be said that generally financial crisis is defined as a phenomenon when uncertainty and risk factors arise in markets that lead to permanent deterioration in both macro and micro economic indicators. All these factors lead economic agents to act with extreme cautions.

2.1.1. Asset Price Booms and Bust

As in Global Financial Crisis, sharp increase and large fluctuations in asset prices called bubbles and usually followed by crashes or booms. A bubble indicates that the extreme increase in asset prices in a short period of time. Some theoretical models try to answer the question of how economic agents' rational behavior led to collective mispricing which in turn asset bubble. Others criticize this view by explaining them without distortions. These views mainly focus on the future expectations of investors. However, expectations play a crucial role in this movement. For instance, any shocks or high volatility which push the stock prices up also lead the increase in expected future return. This is the time for the stock market investors to become more risk lover until the bubble bursts. Thus, more generally the theories suggest that bubbles may appear without any uncertainty, distortion, or speculation in financial markets. (Claessens and Kose, 2013).

2.1.2. Credit Booms and Bust

Another key characteristic or common thread of this crisis is credit booms and bust. The financial literature focus on the common patterns too explain credit booms and busts cause these situations may occur due to wide range of factors including shocks, volatility, fluctuations, or structural changes in financial markets. Moreover, some of the credit booms may arise cause of high level of growth rate in a country, means linked to high productivity level. For instance, rapid increase in international fund flow or capital flow may accelerate the credit boom. It can be said that many recent crisis experiences in developing countries have faced large international fund flow before the crisis. The transmission channel is as follows: in expansionary periods, high level of interest rates may lead to increase asset prices which in turn the impact on lending activities. This mechanism goes until the interest rates decline. Empirical models explain this interaction in the light of agency problem. Another process explains the credit booms and bust with institutional weakness and lending standards in financial markets (Claessens and Kose, 2013).

2.2. Types of Financial Crisis

Financial crises are subject to dual distinctions by most of the financial economists as "old style financial crises" or "slow-moving financial crises and "new style financial

crises" or "contagion crises". Old style financial crisis begins with excessive increase in aggregate spending often resulting in excessive capital movements while new style financial crisis arises from speculative attacks mainly on exchange markets (IMF, 2002). The crisis, which started with a deterioration in the balance sheets, is followed by a currency crisis in the second stage. In the third and final stage, the currency crisis turns into a financial crisis that brings devastating effects on financial and non-financial balance sheets and the economy.

2.2.1. Banking Crisis

Banking crises refer to situations in which banks have difficulties in fulfilling their obligations and bank overflows are experienced. The intervention of the policy makers to financial markets, merging or financial support as a result of bank failure is described as a banking crisis. According to Kaminsky and Reinhart, bank panic situation, which started with significant deposit withdrawals, affects the bank's balance sheet, which is called a banking crisis (Kaminsky, 1998). The fact that each country differs in terms of financial system, institutional structure and political stability makes it difficult to draw a single framework that can explain the crises. In the literature, banking crises are based on two sources, the first of these is the view that states that banking crises are a self-feeding phenomenon independent of the developments in the real economy. The other view which explains the crisis in the sector with the changes in the real conjuncture and connects it to the increase in risk factor. This type of risk is faced by banks is credit risk. The deterioration of the credit discipline of banks plays an important role in the formation of the crisis. Credit risk can also be expressed as the default risk arising from the payment of principal and interest on the promised time.

Banking crises can be accompanied by currency crises, but they can also be seen as a result of currency crises. In such a situation, the Central Bank's loss of a significant part or all of its reserves, pressure to increase interest rates, or rapid depreciation of the national currency are the most important factors causing currency crises. The banking crisis in developed countries refers to the problems observed in bank assets such as doubtful receivables, bad loans which are high probability risk. and increase in securities volatility.

Goldstein and Turner (1996) list the factors causing the banking crisis as follows but not limited to:

- Sudden decreases in asset prices,

- Maturity and exchange rate mismatches increase the liabilities of banks,

- Decreases in credit controls due to excessive increase in credit and capital inflows,

- Lack of adequate infrastructure and legal regulations for financial liberalization, and

- The variability in macroeconomic indicators and the exchange rate regimes that are not suitable for the economic structure are seen as the most important factors.

Unlike other financial institutions, banks' liabilities with a high turnover rate, which have the characteristics of payment instruments. It is observed that some banks avoid giving loans even to companies with high solvency due to the fact that banks have to allocate high provision expenses for the loans they provide and the increasing risk environment. The impact of the banking crisis is high due to both the contraction in production and the high restructuring costs of the sector.

According to the view emphasizing that the basis of the crises in the banking system is the balance sheet problem, the balance sheet risk arises from public or private credit risk or the distrust in foreign exchange rates. With the effect of capital flows, these two problems drag the economy into a high instability. Despite the high liquidity of its current liabilities, the low liquidity of its assets increases the risk level. This accelerating factor of instability in the structure of the financial system may cause a bank to lose its solvency, may lead to a bank crisis, or it may spread to the whole sector rapidly and even result in an economic crisis. For this reason, it would be more accurate to describe banking crises as financial crises today.

2.2.2. Currency Crisis

Liquidity risk is the type of risk arising from the difference in maturity periods of interest-bearing instruments in assets and liabilities. Funding risk, which refers to the inability to renew or extend bank deposits, is also a type of liquidity risk. Currency crises are subject to a dual distinction as currency crises and balance of payments crises. Currency crises in the fixed exchange rate regime are characterized as balance of payments crisis and the focus is on the decrease in international reserves. The currency crisis seen in the flexible exchange rate regime is characterized as a currency crisis and attention is drawn to exchange rate changes. Therefore, in order to evaluate the interest rate risk and liquidity risk together, and to control the interest rate risk, it

is necessary to consider the maturity periods. In case of liquidity risk, banks' choosing to borrow with higher costs or to obtain liquidity by selling their assets at a loss may cause the bank to lose its solvency.

Risks arising from foreign exchange assets in liquidity crises are called liquidity risk. Currency risk can also be expressed as the bank's foreign currency liabilities exceeding its foreign currency assets. In exchange rate fluctuations, banks that take a high foreign exchange risk face a short FX position by decreasing their solvency. During the crisis, with the depreciation of the national currency, it causes position deficits in banks whose assets and liabilities are in different currencies, resulting in serious imbalances in the balance sheets. In particular, the rise in short-term interest rates increases the risk profiles of banks with short positions. In case of short position, the increase in the value of the foreign currency may cause the banks to lose their solvency by making a loss.

Any exchange rate intervention and disrupts the structure between relative prices poses a serious financial risk. A sudden rise in the exchange rates manifests itself through two channels. According to the first effect, the decrease in the investments of the firms creates difficulty in paying the debts to the financial sector and causes a decrease in the national income. The second channel is the decrease in national income brought about by the decrease in investments and the increase in the rates of non-performing loans due to foreign capital outflows. Theoretically, any reversal in capital flows could result in a currency crisis due to the withdrawal of foreign capital from the country (Inan, 2009).

In case the Central Bank does not have sufficient foreign currency reserves lead to increase in interest rates and public sector borrowing requirements, and especially in countries with short-term debt or high foreign currency debt burden, the financial structures of banks deteriorate and then followed by the crisis.

2.2.3. Twin Crisis

Twin crisis or systemic crisis includes liquidity crisis and banking crisis, in other words those crises are seen together. Another basic function of the financial system is to provide the liquidity needs of the economic decision units. The increase in uncertainty in the financial markets and the sudden extreme volatility or collapse of the stock markets, together with the banks' liquidity problems lead twin crisis. Theoretically, a

reversal in capital mobility causes currency crises or a reduction in current account deficits. The most important cause of capital account crises is high capital inflows, which are dominated by short-term loans. These two components can cause a twin crisis by bringing along currency crises and banking crises. The sudden increase in exchange rates and interest rates after the financial crisis decreases the value of financial assets and decreases the real value of private sector savings. As all debt mechanisms are affected by the decrease in exchange rates, it is inevitable to experience a debt crisis that spreads throughout the system (Mishkin, 2001). 1994 Mexico Tequila Crisis, 1997 Asian Crisis and the currency crises are well-known examples for systemic crises.

2.2.4. Debt Crises

The theories of debt crises are closely associated with the explaining of international lending. These models imply that inability to pay back the foreign debt, default, may result from the different factors. For instance, opportunity cost of borrowing may be low when the terms of trade are not good enough due to the country' borrowing capacity. However, countries do not always default when they are unwillingness to pay back the debt. Debt default, during the high level of inflation in countries, usually followed by the currency crises. Moreover, financial repression is also another form of debt default. Currency crises that have been faced by the many developing countries after the year 1980s are examples of this process. As well-known foreign currency denominated debt, FDI-foreign direct investment, capital inflow are the main fund sources for developing countries. Thus, it can be said that financial integration, institutional framework and political economy have also crucial impact on debt crisis as well as unwillingness to pay back (Claessens and Kose, 2013).

CHAPTER 3
CONTAGION THEORY

3.1. What is Contagion?

Simply, the spread of a crisis that started in one country to another country is defined as contagion. Particularly in the 1990s, with a series of crises in developing countries, the theoretical approaches of contagion, which started to take shape, diversified in the theory and empirical analysis. The most common definition is that co-movement between economies increases in times of crisis compared to periods of calm. But there is another term which causes confusion here, is "interconnectedness". The high correlation between the financial markets of the two countries is not only a sign of contagion. As a consequence of the significant economic linkages between the two countries, the correlation might be high even after the shock, and can be already markets have high correlation during stability period. This demonstrates the interdependence of the markets. Thus, contagion is defined as a considerable rise in the correlation between markets following a shock to one or more countries (Forbes & Rigobon, 2002).

Corsetti et al. (2005) discussion on the difference between contagion and interconnectedness is based on their theoretical and empirical investigations. According to them, in a simple model with two countries, country-specific components and common factors, interdependence is defined as the correlation that occurs when generating stock returns data. Again, if the correlation emerges in this process is very strong and cannot be explained even by the country-specific component and the common factor, so it is a contagion. In short, contagion that the connection between the markets is affected due to the changes in the international economic structure because of the crisis in the specific country.

There may be factors that facilitate transmission of crisis. Lucey et al. (2018) highlight. The authors indicate that although it is believed that financial integration has many benefits, at the end of the crises that took place in the 1990s and 2000s, economists

claim that financial integration is also a risk in this situation. This is noteworthy that regional and global financial integration can bring systematic instability with the possibility of financial contagion. But thereafter Forbes (2012) refers that financial integration is not increasing the risk of contagion.

Gagnon & Karolyi (2006) address the issue of contagion through the question "Is fluctuations in international stock markets due to news about economic fundamentals or just a result of “market contagions" in their literature survey about that the volatility and co-movement in global asset prices. According to their analysis, the weak link between economic-based news and international stock market movements compelled researchers to consider the contagion. As a result, while some of the literature focused on investigating the existence of contagion, the other portion of the literature started to form on the channels of this contagion.

It can be said that there is an important reason why some of the literature has focused on the channels of contagion. The channels through which the contagion takes place in the economic relations between countries are important for the policy makers of the countries. Because these channels actually show the economic factors that countries are weak fundamentals. Policy makers can take measures so that the shock reaching the country through these channels does not increase the possibility of crisis in the country.

To sum up, the concepts of interconnectedness between markets refers high correlation between markets or co-movements of markets during stability periods. Contagion occurs during turmoil periods, and with the shock none-existing or existing correlation between countries’ markets significantly increases.

3.2. Debates on the Definition of Contagion

There is no clear consensus among economists on what contagion is. The reason is that the perception of adaptation according to the theoretical and empirical approaches that have been going on for years in the definition of contagion.

Pericoli & Sbracia (2003) also indicate there is a lot of confusion in the literature on what constitutes contagion since no one researcher entirely agree on a theoretical or empirical definition of a contagion. There are several definitions that are often used in the literature, despite the fact that there is no general agreement on what contagion is.

Authors discussed the five most notable definitions of contagion in the literature, highlighting the importance of defining and measuring financial crisis such as currency crisis, debt crisis or banking crisis, in actually defining financial contagion. The contagion effect in order to explain the financial crisis, based on the fact that crises can be contagious to explain a series of financial crises, occurred in emerging economies in the 1990s. In this context, while trying to explain the contagion effect of crises theoretically and empirically, economists provide many definitions.

Moreover, while the issue of contagion gains importance in the literature, especially after the Asian (1997) and Russian (1998) crises, there is still no generally accepted definition among economists. But question of how crisis spread one country to other countries began to take its role in the literature. Firstly, Dornbusch et al. (2000) define financial contagion as the spread of the downward movement in one country to other countries and examine its formation in two categories. The first one arises due to financial or real relations between countries, and the other one arises due to the irrational behavior of investors despite the lack of a fundamental reasons or interconnectedness between countries. Similarly, Rigobon (2002) also drew attention to two types of contagion namely pure contagion and shift contagion while defining financial contagion. Accordingly, pure contagion is the spread of shocks between markets without main channels of transmission. Any changing effects the spread of shocks' strength is shift contagion.

Calvo & Reinhart (1996) defined the spread of crises from large economy to small open economies as "spillover" or "contagion". But further studies make the distinction between these two terms. Kaminsky et al. (2003) is such one study to eliminate the ambiguity in the definition of contagion. Authors define contagion as a situation in which following an event, a lot of nations experience severe aftereffects immediately. However, the term spillover refers appearing more slowly and gradually affects. Another point is that external shocks such as changes in oil prices and increases in global interest rates are not the subject of contagion. If these common external shocks cause excessive co-movement and volatility in the economic and financial variables of the countries, this is contagion.

Fratzscher (2003) examines the contagion and the contagion channels with the crises emerged in the developing countries in the 1990s. Author defines the contagion as the

spread of a crisis to a certain country as a result of that country's actual and financial dependency to other countries.

According to the Forbes (2012) the majority of studies agree that contagion occurs when shocks in one country spreads to another that this is not typically tied to it via traditional channels. Additionally, findings demonstrate that contagion risks are not necessarily arise by financial integration of a country with the other countries as well.

In addition to all these debates, it is also argued that there is no contagion. Morales and Andreosso-O'Callaghan (2014) is one such study who advocates that the contagion is a problem that concerns crisis in emerging economies in the literature. Authors point out that the definition of contagion is slack. Another their claim is that the evidence for financial contagion is weak in the selected literature and the term contagion as measured by correlation coefficients among stock markets is frequently used in research that examines the impact of contagion between financial markets. There are also a few studies which argue that there is no evidence for contagion.

Finally, it is seen that the contagion nature of the crises also differs due to the different characteristics of financial markets both in developed and developing countries.

3.3. Theory of Contagion

Kaminsky & Reinhart (2000) highlight while inadequate policies and high interest rates are cited as reasons for the crises experienced by emerging economies in 1980s when the possibility of crises being contagious is overlooked. Especially after the 1994 Mexica, 1997 Asia, and 1998 Russian crises, there has been an increase interest in research on financial contagion in the literature. According to Masson (1998) expectation on the occurrence of a crisis simultaneously in time may be for a variety of reasons. Firstly, the so-called "moonsonal effect", where the policies of developed countries have a combined effect on emerging economies. Secondly, other emerging economies are affected as a result of the crisis in emerging economies and the use of policy tools such as devaluation that reduce price competition of other countries and it is called spillover effect. Finally, financial contagion, that is, crises triggered in other countries that cannot be explained by their economic fundamentals.

King & Wadhwani (1990) provide their contagion model, this model is also accepted by some researchers as the first empirical analysis of financial contagion. By

examining the US, London, and Tokyo stock markets with high-frequency data. In other words, hourly data, according to authors provides the opportunity to examine the London stock market reaction of the macroeconomic data announced in the US, with the advantage of the time zone differences. According to their contagion model, it is expected that the London stock market will react due to the reaction of the US stock market, which is opened one hour after the macroeconomic data announced in the US. As a result of their analysis, the volatility of the London stock market increases one hour after the US macroeconomic data is released, that is, when the US stock market opens. What the authors find in the study is that the London stock market reacts according to the reaction of the US stock market rather than the macroeconomic announcement. In other words, volatility spreads from the US to London market.

Becker et al. (1995) criticize that the analysis is made only for the 1987 market crash period (July 1988-Februrary 1988). Authors consider the longer time analysis in their study, again with the high frequency data and choosing FTSE100 index for the UK and the S&P500 index for the US between July 1986 and December 1990, in order to also investigate the calm times. Contrary to the findings of King and Wadhwani (1990), they found that the London stock market reacted immediately to US macroeconomic news rather than lagged. As a result, the volatility of both London and US stock markets increases with the release of US macroeconomic news, and the correlation between the days of the announcements becomes stronger. These studies also provide evidence in explaining the relationship between international markets. Moreover, public information is announced, for example, announcement of inflation rate has also significant effect.

Poterba (1990) also criticizes the findings of King and Wadhwani (1990). But this critique is not an empirical counter-research like the previous one. He simply states that there are other raising questions in explaining these findings. First of all, according to the criticism, based on the fact that the London stock market is generally volatile at the opening, it may seem to support their theory of financial contagion. The volatility of the New York, London and Tokyo stock markets may have another interpretation, such as country-specific shocks or higher interest rates globally. Finally, it is indicated that a change in price movements in one market may affect another market as it affects the fundamentals of the price in the other market. For instance, as a result of a crisis in the USA, GDP shrinks, and London and Tokyo's demand for goods from the USA

decreases, and so on. Investors, who can see this situation in the long term, may be reacting to the long-term consequences of it at that moment.

In order to determine the potential of contagion, Eichengreen et al. (1996) have surveyed the theoretical and empirical literature on crises in the foreign exchange markets. Also, they presented their own empirical analysis. Authors support contagion of currency crises. Despite the fact that there aren't many empirical research since the 1990s, they also emphasis on the fact that the studies have been conducted on contagion.

Pure contagion is the transmission of shocks by contagion channels other than the fundamental-based transmission channels. Thus, this type of contagion is actually related to the channels of contagion and shock of transmission. For example, what Eichengreen et al. (1996) found is closely related to the definition of pure contagion. They examined the transmission channels of the contagion of crises and found that much of the transmission of shocks could be explained through the trade channel rather than macroeconomic similarities. This contagion study is also the first study to contribute to the pure contagion literature. But, if there is an increase in the existing transmission of shocks and the strength of that transmission, that is shift contagion. Studies that examine and compare inter-market correlation coefficients actually investigate shift contagion. Because, if there is a change and an increase in the strength of inter-market shocks in times of crisis compared to calm times, this indicates a shift (Rigobon,2002). Simply, shift contagion is defined as a shift in the transmission channel of an inter-market shock after a market shock. The source of this type of contagion may also be due to investor behavior (Pericoli & Sbracia, 2003).

Calvo and Reinhart (1996) defined the spread of crises between countries as "spillover" or "contagion". Authors examine herding behavior and the fundamental channels of contagion in the literature. They indicate that herding behavior leads to a series of events that change the foundations by causing a liquidity or currency crisis, leading to self-fulfilling crises. The emergence of herding behavior in the international market is another story, in which investors and speculators play an important role even in countries with heterogeneous fundamentals. Even in the absence of herding behavior, there are channels through which shock is transmitted from large country to small open economy. First, the highly integrated capital markets of the two countries so that the shock is transferred from the large country to the small country through

financial assets. Next, international trade and agreements between countries. Thirdly, institutional shocks might potentially be factor for shock transmission. Additionally, another reason is the spread of shocks as a result of a mechanism caused by foreign investors. Authors also underlined the effects of technology and policy instability in regional contagion, taking reference from studies on economic growth. Finally, even if the macroeconomic fundamentals of the countries are not affected by the shock from the neighboring country, it may pave the way for self-fulfilling crises through investor sentiment.

Gerlach & Smets (1995) examine the relationship between contagion and speculative attack. According to them, there are three reasons why attacks against currencies affect other currency pairs. The first is competitiveness between countries, the second is information asymmetries, and the last is self-fulfilling speculative attacks. Authors test this relationship between contagion and speculative attack with contagion in the 1992 ERM crisis and examine competitive attack. In the fixed exchange rate system, speculative attack against the currency affects competitiveness due to depreciation, and increases the speculative effect in other countries, accelerating the effect of currencies. They also point out that to avoid such contagion, countries' coordinated monetary policies are the most appropriate recommendation to protect their currencies under attack.

The role of information is also considered in contagion theory. Connolly & Wang (2003) are examined the effect of foreign markets to domestic markets in two categories, whether the foreign market effect is due to economic fundamentals or financial contagion. According to them it is not sufficient to explain that internationally co-movements of markets are due to macroeconomic fundamentals within public information. Authors suggest that this situation should be evaluated in terms of financial contagion and private information in further studies.

To sum up, mainly theoretical literature are agreed on the how contagion arises broadly explained by three main channels. Firstly, real shocks and financial links explained by the fundamental reasons, and lastly behavior of investors. Even though the difference between financial and investor behavior channels may seem subtle, the distinction here is that investor behavior between financial markets is examined according to the assumption is that they act rationally. But Dornbusch et al. (2000) state that even if investors act rationally, investors' excessive actions can cause the contagion of crises

across countries. The behavior of investors may lead to contagion of crisis. For example, Kyle & Xiong (2001) introduce continuous time model with financial contagion. In the model, three investors who noise traders, long-term investors and converge traders trading two risky assets and risk-free asset. According to them, converge traders who make short-term trades are the key to the emergence of financial contagion. When converge traders cope with a big shock and suffer losses as a result, the liquidity in the market decreases due to the position they take. This leads to the transfer of the shock to other assets. Therefore, contagion occurs due to the welfare effect of investors.

3.4. Contagion Channels

If a contagion occurred as a result of a crisis in a country, why were some countries able to protect themselves or not be affected by the shock of the contagion, while some countries suffered significant economic losses as a result of the contagion? To find the answer to this question, research focuses not only on proving the existence of financial contagion, but also on the channels of contagion. Although these channels are based on theoretical existence, which sometimes makes it difficult to examine empirically, contagion channels are generally divided into three main categories.

As mentioned before the contagion research, which has increased rapidly especially after the 1997 Asian and 1998 Russian crises, while examining the contagion, with the question of how to transfer it to other countries. These channels have been discussed both theoretically and empirically with the subject of contagion in the literature. The most transparent of these channels of contagion are trade and financial links, which can be easily examine with two simple examples. Suppose two neighboring countries with strong trade linkages, as a result of a crisis in one of these two countries. A country may be weak in meeting the demand for goods of the other country which is a trading partner.

Thus, trade between the two countries is not the only factor to be affected. The country whose demand for goods cannot be met will also be significantly affected by this situation. For the trade connection, this is easily apparent. Similarly, the exemplification of the financial link can be explained simply and clearly. Suppose two countries and one of them is the creditor of the other. A country that cannot pay its debt on time due to the crisis may put the creditor country in financial distress. This is

an example of a financial link of financial contagion (Kolb, 2011). How and which links of contagion occurs is mainly examined into two categories. First one is fundamental-based channels and other is through behavior of investors (Karolyi, 2004; Dornbusch et al., 2000).

Dornbusch et al. (2000), conceptually examine how the contagion arises from the crisis country to other countries and define the channels of contagion in two main categories. Table 3.1 summarizes the channels of contagion from their study.

Table 3.1. Channels of Contagion

<table>
<tr><td rowspan="3">Fundamental Based</td><td colspan="2">Common Shocks</td></tr>
<tr><td colspan="2">Trade Links & Competitive Devaluations</td></tr>
<tr><td colspan="2">Financial Links</td></tr>
<tr><td rowspan="4">Investors' Behaviour</td><td rowspan="2">Investors' Practices</td><td>Liquidity & Intensive Problems</td></tr>
<tr><td>Information Asymmetries & Coordination Problem</td></tr>
<tr><td colspan="2">Multiple Equilibriums</td></tr>
<tr><td colspan="2">Change in the Games' Rules</td></tr>
</table>

Rigobon (2016) analyzes the contagion theories by dividing them into three categories and states that the transmission of crises from country to country generally occurs through these three broadly defined channels. These channels are called fundamental, financial and coordination. Research paper primarily deals with the fundamental channel, which is often emphasized in the early theoretical literature. The transfer of shocks between countries occurs through the real channel. These real channels are mutual trade between countries, trade of similar goods in the common trade market, monetary policy and macroeconomic similarities of countries. The second category, the financial channel, is examined within the framework of the transmission of shock with international equity markets and banking sectors. In this channel, real channels are ignored in the analyses and the transfer of shock between countries is assumed to

occur only through financial markets. In the studies on this channel, the literature mainly focuses on the common lender theory. Finally, the coordination channel of contagion, actually this channel deals with the behavior of investors and policy makers. Shocks are transferred between countries as a result of multiple equilibrium, herding behavior, and political contagion.

Caramazza et al. (2000) state that while macroeconomic variables can be explanatory in predicting currency crises in the literature, explaining the spread of these crises remains weak. For this reason, economists have taken other factors into account to explain the transmission of currency crises. These are common shocks, trade and financial links, and investor sentiment. Crises may spread to other countries due to common shock such as global slowdown, trade links such as price competitiveness caused by depreciation, financial linkage as investors rebalance their portfolios due to increased risk, and lastly changes in investor sentiment.

Kaminsky & Reinhart (2000) examine channels of trade and financial links of crises. Their findings imply that financial links—rather than trade links—have more obvious patterns and are thus better at explaining the spread of crises. Another study commenting that financial links have a more important role in explaining of contagion is conducted by Kaminsky et al. (2003). They investigate through literature review of channels of contagion are herding behavior, trade links, financial links, and other explanations such as wake-up call. In brief literature reviews for these channels, according to their view, herding behavior and financial links have important roles in explaining of contagion in theoretical examination of contagion.

Pritsker (2001) introduces a Keynesian model with N countries, K banks, M non-bank market participants and whose economic units are real sectors, banks, financial markets, and non-financial markets. This is evaluated in the research that the Thai financial crisis is reasoned by the real shock that caused the devaluation in Thailand, which states that the crisis spread from Thailand to Southeast Asia. There can be only three reasons for this, firstly, crises occur in other countries by incidental, secondly, a common global shock hits the countries, and the other is the contagion of the crisis among countries. How such a real shock could be transmitted is evaluated through more than one way, called the "transmission pathway". A real shock would be seven transmission paths. A real shock in one country in crisis may spread to another country as a real shock. The other process of transmission is through a joint financial

institution, the other through multiple financial institutions such as banks. Others through two combinations of financial institutions and financial markets. Finally, financial market contagion through banks and non-bank financial market participants. In summary, the contagion of a real shock occurs as a result of real, financial institutions, financial markets, and their combination.

According to Fratzscher (2003), contagion occurs through three channels. The first of these channels is financial links, transmission through financial links occurs directly or indirectly. What is meant by indirect financial links is that if the crisis country has a common lender, and this lender country may refuse to give a new loan or seek a loan, so that crisis can be transmitted indirectly to other countries. Second channel is real links between countries. Contagion may spread through real links, direct trade linkages between countries and causing devaluation in the other country due to price competition in the third market. The third channel, called is Sunspots by the author, which contagion can spread with changes in the behavior of investors. Herding behavior may also be related to this channel.

3.4.1. Trade Links

Glick and Rose (1999) associated the reason for the regional spread of currency crises as the link they established from the regional nature of international trade. Currency crises could be regional if economies' macroeconomic characteristics are prone to regionalization. Trade has a significant role in the spread of currency crises. Authors found that currency crises tend to spread regionally, and they found results that support the view that the contagion of crises is due to trade links. Furthermore, their findings support the early literature about one of channel of contagion is trade link.

De Gregorio & Valdes (2001) are examined the contagion of the 1982 debt crisis, the 1994 Mexican and 1997 Asian crises and the transmission channels of these crises. The analysis of how crises spread focuses on trade links between countries, competition in third markets, neighborhood effects, and macroeconomic indicators' similarities of countries. Authors conclude that trade relations, namely regional effect, is play a role in the transmission of the financial contagion, drawing attention to the similarity of the contagion in the debt crisis and the Asian crisis, and the strong trade relations of neighboring countries during crisis periods.

3.4.2. Financial Links

Kaminsky (2000) criticizes the studies that examine the contagion through the trade channels. What these studies ignore is that countries with trade relations may also have financial relations. Trading goods and services can be based on financial arrangements between the countries. Another is that countries with trade relations may have financial relations with the only regional common creditor country, so the results suggest that the trade channel of a contagion is regional are supported by the regional common creditor probability. Another point is that in times of crisis, banks may seek credit, and during the credit search, banks may run out of credits or call from another country, causing the crisis to spread to that country. They conclude that the contagion occurs through the trade channel as well.

Evaluating the financial link channel of contagion, Kaminsky et al. (2003) support the view that contagion through a financial link can be better investigated. In fact, authors investigate that why financial contagion arises with some crisis and not others, through the financial link. To answer this question, they examine three circumstances, capital inflows to the countries, surprises, and common creditors of countries. Initially, authors define the 1994 Mexico, 1997 Thailand and 1998 Russian crises as "fast and furious" crises, while the 1999 Brazil, 2001 Turkey and 2001 Argentina crises as crises with limited results. Firstly, they indicate that the situation observed in contagious called fast and furious crisis is sudden changes in capital inflows. The change in these capital inflows is seen as a sudden stop after a crisis or as a sudden increase in capital flows that come to a standstill. Also, limited or low-volume international capital flows are generally related to financial crises which have not triggered big worldwide dominoes. Secondly, surprises, there is a relationship between "fast and furious crises" and contagion. Authors explain this as follows, no change is occurred for Mexico and Thailand’s credit ratings by the credit rating agencies until 12 months before the crisis and three changes are seen for Russia. Moreover, these crises are in their "fast and furious contagion" scenario. In contrast, the credit ratings of Brazil, Turkey and Argentina are changed two, three and five times, respectively, in the year preceding the crisis, and the crises in these countries' crises have local effects. Therefore, unanticipated crises and contagion of these crises have common factor which they are surprises. According to their study, third reason of why some countries experiences contagion of crisis other not is common creditors. The heavy loans that banks and non-

bank lenders made to crisis countries in the 1990s may have contributed to the contagion of the crisis. Foreign banks providing loans, for example, cut off the flow of credit to the Asian region as a result of the Thai currency fluctuation in 1997. Another point is the capital outflows from Thailand during the crisis, which are realized through mutual funds.

3.4.3. Investors' Behavior

Dornbusch et al. (2000) analyze one of the contagion channels is behavior of investors' According to them, investors, even if they are rational, can take extreme actions, even extremes that cannot be explained by real fundamental-based. Even if the investors behave rationally, they cause cross-country contagion through the channel called investor practices. Liquidity and incentive problems, information asymmetry and market coordination problems form are the subcategories of this channel. Financial markets are prone to many equilibrium adjustments in self-fulfilling expectations. According to this view subject to multiple equilibrium, crisis in one developing market can force another to shift or leap to a poor equilibrium. Lastly, following a primary crisis, modifications to the rules of the game or the global financial system may prompt investors to adjust their behavior.

3.4.4. Other Channels

The other channels are related to the financial links and based on investors' behavior due to the information and uncertainty. Firstly, a multi-asset model is presented to analyze the contagion in financial markets by Kodres & Pritsker (2002). This model takes liquidity and information shocks into account, also in the model a new channel for cross-market rebalancing is formed. The contagion arises with this new channel when market players experience a unique shock in one country and then spread the shock internationally by carefully adjusting investors' portfolio's exposure to macroeconomic risks through the markets of other nations. Therefore, countries with common macroeconomic factors remain defenseless to financial contagion. This study answers the question of why crises affect some countries but not others, by showing that they arise from a new channel formed due to information asymmetries, and that asymmetric information makes the country more vulnerable to external shocks. This explained channel also called portfolio rebalancing channel.

Kannan & Koehler-Geib (2011) introduce a new channel for contagion theory, the uncertainty channel. It gives information about the functioning mechanism of this channel by exemplifying at the investor and firm level. The quality of information is an element that affects the cautiousness of investors. In this direction, information about the firm affects the investor's investment amount and affects the market, driving down the prices of the firm's securities. As a result, this may lead to increase the costs of the issuing firm, making it vulnerable to external shocks. Investor behavior and vulnerability faced by the firm as a result of uncertainty about the quality of information are examples of how this channel works. Thus, an unexpected crisis, investors still have distrust of its quality, no matter how they obtain the information. In this case, investors are cautious towards the countries to invest in, causing the fund costs of the companies in those countries to increase. AT the final stage, both the firms and the economies of the countries where the firms are located become vulnerable in case of crisis and the contagion takes place through this channel.

3.5. Recent Financial Crises as Examples of Contagion

3.5.1. 2008 Global Financial Crisis

2008 Global Financial Crisis has rapidly spread other countries and require immediate policy interventions. The crisis also calls for financial regulations with international coordination. The impact of the crisis underlines contagion characteristic of a crisis. The below mentioned Figure 3.1 show the sequence of the events in 2008 Global Financial Crisis (Claessens & Kose, 2013). 2008 Global Financial Crisis gives its first signals with collapse of two investment funds of Bern Sterns in June 2007. Due to the low interest rates in the USA for many years, subprime mortgage customers mostly preferred to use variable rate loans. In the USA, about 10 percentage mortgage loan volume belongs to the loan owners with low credibility, which is called “subprime mortgage”. Due to the low interest rates for many years, variable interest rate loans are mostly preferred by the loan owners. After the FED's unexpected and rapid increase lead to increase default probability of loan owners who have low level of credibility. In this process, the increase in the transaction volume of real estate-followed by the nominal price increases which lead welfare effect and mispricing as well. As a result, the inflation in real estate prices inevitably turned into a downward trend. Later then on, mortgage loans began to be traded through the derivatives in financial markets.

The derivatives are used as the risk transfer opportunity such as hedge funds, but they became the risk factor. At the end, the Lehman Brothers which the derivative transactions mostly occurred, have faced bankruptcy. That was the beginning of the crisis. Followed by the bankruptcy of the two big mortgage providers, Fannie May and Freddie Mac, the spread of bank bankruptcies gained a global character. This crisis is one of the largest credit bubbles in the world economic history.

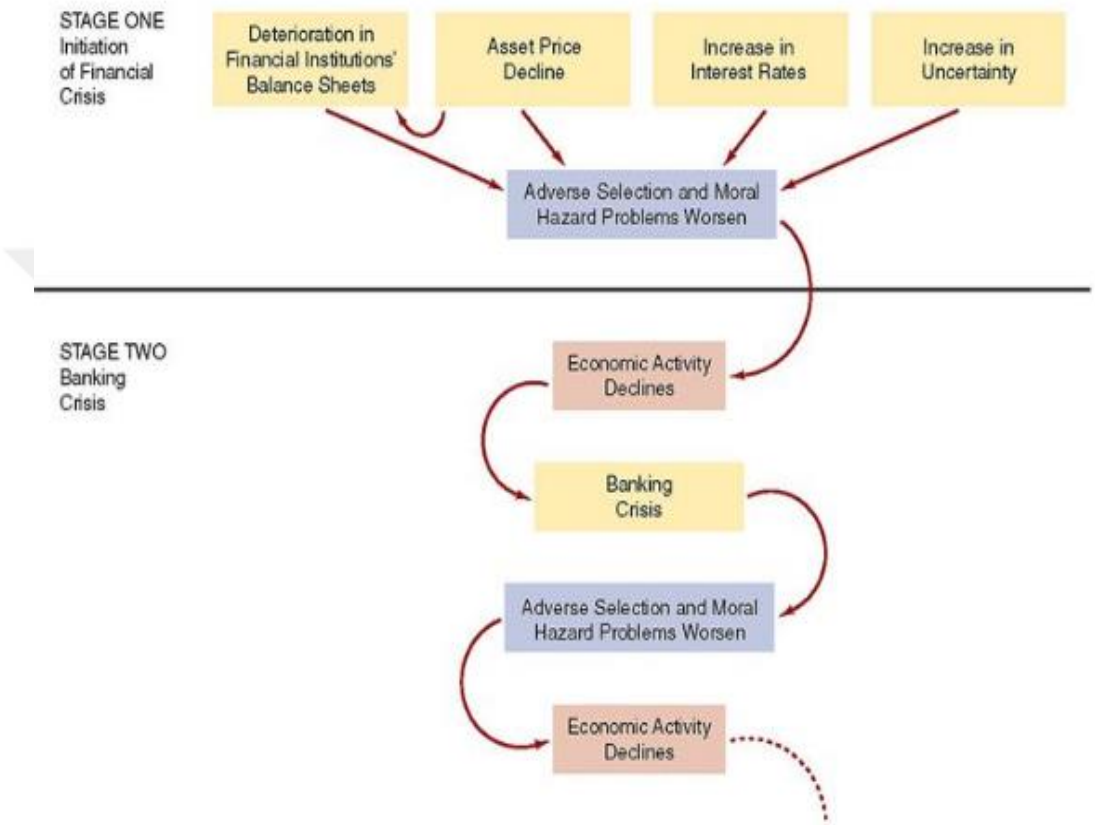


Figure 3.1. Sequence of Events in 2008 Global Financial Crisis, Mishkin & Eakens (2012).

2008 Global Financial Crisis experience shows that due to the credit expansion and high risk-taking behaviors lead extreme increase in asset prices which in turn financial fragility and crisis at the final stage.

3.5.2. Eurozone Sovereign Debt Crisis

The Euro area have faced considerable financial difficulties in 2010. The Eurozone Sovereign Debt Crisis began in Greece and then spread to the other periphery countries, Portugal, Spain, Ireland, and Italy, very rapidly. Among these crisis

countries, in Ireland the banking sector is the source of financial crisis related to the domestic housing boom financed by foreign debt.

It can be said that, since the euro adoption until the 2008 Global Financial crisis, financial and monetary stability were successful in euro area. However, following the collapse of the Lehman Brothers as the beginning of the 2008 Global Financial Crisis, severe instability emerged in Euro zone. This period is also known as the first stage dubbed “financial fragility” of the Eurozone Sovereign Debt Crisis. The second stage began with the announcement of the rescue packaged by policy makers in September 2009. Lastly, the third and the final stage is known as the “sovereign default”. During the crisis, economic policy makers focus on the default probability, and fragility in financial markets. The crisis spread very rapidly to the whole euro area.

Moreover, due to this experience, macroeconomic policy makers began to argue monetary and fiscal policies in euro area and discuss on Maastricht criteria to adopting the euro. The Eurozone Sovereign Debt Crisis experience shows that the default probability of one country heavily depend on the default risk in another country cause the risk may easily transfer to bond markets in Europe. Economists suggest that the lender of last resort tole of European Central Bank is the only way to reduce the contagion effect of the Eurozone Sovereign Debt Crisis. Because one of the main problematics in euro area that the national central banks are heavily depended to each other in Euro area. This experience also highlights the importance of integrated financial markets as a major issue in contagion.

CHAPTER 4
EMPIRICAL ANALYSIS OF CONTAGION

The calm and crisis times are determined mainly by the various asset return volatility levels in the empirical literature. The transfer movement across nations would be substantial as a result, in accordance with the degree of the shock, the crisis, which increased volatility above normal in a few markets, happened with an increase in variance brought on by a common trigger. As a result, a rise in cross-country correlations during a time of financial instability is not always proof of contagion. The co-movement pattern in asset prices must be excessively strong or weak in comparison to what may be expected on the assumption of a consistent method of global transmission for contagion to occur (Corsetti et al., 2005).

Haile & Pozo (2008) draw attention to the scarcity of empirical studies on how crises spread between countries, although different theoretical models have been developed regarding the spread of crises between countries. Despite the fact that the literature has been discussing the theoretically transmission of crises between markets since the 1990s systematic crisis, empirical studies on transmission channels or contagion channels of crises is remained limited.

4.1. Empirical Literature

Empirical examination of the spread of crises between countries and its place in the literature starts from the 1990s. During this time, the empirical study of financial contagion has evolved, with the development and diversification of data and statistical methods and the introduction of new methods. Until the end of 1990s generally empirical analysis of contagion based on correlation coefficient analysis of markets. According to some researchers the first empirical analysis is conducted by King & Wadhwani (1990) with correlation coefficient analysis. To others believe that the first empirical analysis is conducted by Forbes & Rigobon (2002). Because authors indicate that correlation coefficients analysis provides biased results because of characteristics of data. Mostly, during the crisis times the data are highly volatile, therefore there is a

possibility of heteroskedasticity. Another empirical critical view belongs to Pesaran & Pick (2007). Authors suggest that for accurate estimation of contagion, country-specific regression is needed, otherwise analysis of contagion is vulnerable to sample selection bias.

Literature survey for empirical studies on contagion and also financial contagion is plenty such as Eichengreen et al. 1996a; Eichengreen et al. 1996b; Pericoli & Sbracia 2003; Dungey et al., 2005; Dungey et al. 2011; Seth & Panda, 2018. The most widely used definitions of financial contagion in the literature are actually shaped according to the analyzed crisis and the methods used to measure, according to Pericoli & Sbracia (2003). Authors indicate that firstly the testing the probability of a crisis (see, the standard deviation above the sample mean) is used for currency crises, secondly the volatility spread based on the multivariate GARCH method to measure the contagion from one crisis country's market to the other. The analyzing of multiple-equilibria model (Markow-Switching) to measure if co-movement in inter-country asset prices cannot be explained by fundamentals. Next, if the co-movement of prices and quantities between markets increases significantly to measure it the correlation between rates of return (single-factor model) is used. Lastly, the two-factor models are used for if investigated financial contagion occurs with changes or strengthening in the international transmission mechanism. Pesaran & Pick (2007) states in the analysis results that if there are no country-specific regressions, it is unlikely to predict contagion effects because there is error interdependencies. Authors' view for correlation-based techniques often used in the early empirical literature of contagion is because the correlation-based technique necessitates the pre-specification of crisis periods, all associated contagion tests are vulnerable to sample selection bias.

In addition to the lack of consensus in the definition of financial contagion, there is no consensus on the subject of the study, which is considered to be the first to empirically examine financial contagion. According to Seth & Panda (2018), the first empirical study examining financial contagion is carried out by King & Wadhwani (1990). Authors also point out that many authors acknowledge that the first empirical study on financial contagion is carried out by Forbes & Rigobon (2002). But besides this general view, there are significant studies examining financial contagion prior to the work of Forbes and Rigobon (2002).

Early works of financial contagion is a study conducted by King & Wadhwani (1990). Authors examine the stock market crash in October 1987 using high-frequency data between July 1987 and February 1988. With the financial contagion model that they introduced by examining the London, Tokyo, and New York stock markets' volatility transmission considers the time zone differences between the trading hours of selected stock markets. Authors perform regression model and correlation coefficients of markets.

Another study on the issue is a study of Calvo and Reinhart (1996) which focus on the weekly stock market and bond returns of seven Latin American countries and six Asian countries to analyze the contagion of the Mexican crisis. Pre-crisis and post-crisis estimates are conducted with sample range between January 1993 and April 1995 by using factor analysis. Their findings show that Mexican crises have contagious effects to other countries. Authors found that the contagion may be regional rather than global, international capital movements are affected by the fluctuation in the US interest rate, and the rising US interest rate causes capital outflows from the Latin American region. Finally, changes in capital accounts of large countries have an impact on capital inflows and outflows of smaller countries.

Table 4.1. Empirical Pioner Studies

Study	Method	Investigated Crisis	Findings
Eichengreen, Rose, & Wyplosz (1996b)	Probit Model	ERM Crisis	Speculative attack from other countries increases the likelihood of a currency crisis.
Dungey & Martin (2001)	Latent Factor Model	Asian Crisis	Currency market have contagion effect on equity markets.
Forbes & Rigobon (2002)	Correlation Analysis	1987 U.S. Stock Market Crash,	Unconditional correlation coefficients show interdependencies of markets, on

		Mexican & Asian Crisis	the other and conditional coefficients shows contagion.
Favero & Giavazzi (2002)	VAR Approach	ERM	The European countries have non-linear shock effects on each other.
Bae, Karolyi, and Stulz (2003)	Multinominal Regression Model (Co-exceedances)	Mexican Crisis, Asian Crisis & Russian Crisis	Conditional volatility, the level of interest rates and changes in exchange rates in a region are the causes of regional extreme returns. While America is unaffected by shocks from Asia, Latin America's contagion is more striking than Asia's.

Table 4.1. reports pioneering empirical studies in the contagion literature. It can be said that probit model is frequently used method in the early empirical literature. Eichengreen et al. (1996b) examine the contagion of currency crises with quarterly data between 1959 and 1993 for twenty developed countries, using the probit model and the Exchange Market Pressure (EMP) index as an indicator of speculative attack. According to the results, there is an 8 perventage point rise in the likelihood of a home currency crisis following a speculative attack from other countries. The findings support the statistically and economically significant presence of a contagion effect. Eichengreen et al. (1996a) also examines the channels of contagion of currency crises. They examined the trade and macroeconomic channels in the model they built earlier, for this study. Authors estimated with weighted trade and weighted macro contagion variable. According to the results, currency crises are transmitted through both the trade channel and the macroeconomic channel. But they use the factor analysis approach to investigate which one is more dominant. Their further findings imply that international trade ties have a major role in how contagious currency crises spread between countries. On the other hand, when the various kinds of contagion measures are added simultaneously, the impact of macroeconomic similarities vanishes.

Glick and Rose (1999) are analyzed the 5 currency crises contagion for 161 countries the years between 1971 and 1998 using a multivariate probit model. Authors conclude currency crises spread regionally due to trade links.

Caramazza et al. (2000) are examined the contagion of the currency crises in the 1990s using the panel probit model with data from 61 countries. Authors focus on trade and financial channels of currency crises. Their findings indicate that spillover of currency crises through fundamentals, trade and financial linkages are important while regimes of exchange rate and controls of capital are not important for currency crises spillover. Another study performed by Haile & Pozo (2008) try to find out the financial contagion and channels using a panel probit model with quarterly data of 37 countries between 1960 and 1998. The findings of this study revealed that contagion and macroeconomic fundamentals are responsible for countries' currency crises.

Dungey & Martin (2001) introduce a latent factor model in order to investigate contagion. The underlying concept is that events that are specifically connected to the stock or currency market, as well as aspects that generally impact all equities and currencies, may be captured using unobserved factors. To test their models, authors examine the Asian crisis and its contagion impact and also their contagion effects of two markets which are equity and currency markets. The countries that they focus on are Thailand, Indonesia, Malaysia, South Korea, Australia, and the US. Firstly, while they find no evidence of contagion from the equity markets to the currency markets, they find that a shock in the currency market has a contagious effect on the equity market. As a result, authors obtain consistent evidence for the Asian crisis, which began in the currency market.

In another study, Forbes & Rigobon (2002) obtain correlation coefficients in the framework of VAR to capture this information because stock markets are in different time zones and trading hours are different, to analyze contagion in the 1987 US stock market crash, Asian and Mexican crises. Noting that the early empirical literature correlation coefficient analyzes are biased, they examine the unconditional correlation coefficients, which are free from heteroskedastic and bias problems, instead of conditional correlation coefficients in their analysis. As a result of these estimates for three crises, they find that the US stock market crash, the Mexican and Asian crises have no contagious effect, the market co-movements are only attributable to interdependence.

When examining contagion of crises, as a result of adjustments made to the correlation coefficients, such as adjustment for heteroscedasticity, so the contagion effect can no longer be captured with this analysis. Because, such as considering the omitted variable factor, the correlation coefficient analysis has many obstacles econometrically. For these reasons, correlation coefficient analysis has no longer be preferred by many researchers (Forbes, 2012). Therefore, Forbes & Rigobon (2002)'s analysis and their findings stimulate to the researchers new empirical method for investigating contagion of crises.

Another pioneer study is conducted by Favero & Giavazzi (2002). Using dummy variables, they try to capture the nonlinearity of the shocks in the VAR framework in order to investigate contagious effect European exchange rate mechanism (ERM) crisis. Authors conduct their analysis on eight countries covering the periods between 1988 and 1992 by using weekly data of three months interest rates. The result of the study suggest that the countries have non-linear shock effects on each other.

Bae et al. (2003) introduce a new method in financial contagion literature which they adapt from epidemiology, the multinomial regression model. Authors use daily stock market data from 1992 to 2000 to measure the financial contagion between Asian and Latin America countries, also within region. Since they define financial contagion as excessive returns, they focused on excessive returns and gathers by performing multi-nominal regression model. Later then, authors investigate the financial contagion within and between the region with using extreme returns, and estimate with multinomial logit regression, using interest rate, exchange rate, and conditional volatility. As a result, the contagion is more pronounced in Latin America than in Asia. In addition, changes regional conditional volatility, exchange rate and interest rates reason of regional extreme returns thereby reason of contagion.

Bekaert et al. (2003) analyzed the stock returns of 22 countries from Europe, Asia, and Latin America for the period 1980-1998 using a two-factor model. By adapting the traditional CAPM model to the two-factor model with time varying risk parameters, they estimated the model by following the GARCH process. Moreover, while there is a significant correlation between countries for the Asian crisis, there is no strong evidence of contagion as a result of the Mexican crisis.

Chiang et al. (2007) are analyzed the Asian Crisis in two periods using the dynamic GARCH method by considering the heteroscedasticity between years 1990-2003. Authors use the daily stock data of ten countries in the analysis. The study identifies two phases of the Asian crisis by indicating while contagion occurs in the first stage, the stable high correlation seen in the second stage is the result of investor behavior resulting from herd behavior. Another finding is that correlation coefficients are sensitive to structural changes. In the case of Asia, the fact that if credit rating agencies cause changes in the credit rating of that country or foreign country that is affects the stock markets.

Seth & Panda (2018) survey empirical literature of financial contagion by examining 151 research papers published between the years 1990 and 2015. About 60% of these studies are focused on the stock market, and therefore the stock market channel as a transmission of financial contagion is mainly studied in the literature. According to the literature research, mostly the Asian Crisis, the Global Crisis, and the Eurozone Sovereign Debt Crisis are examined, respectively. In addition, while the number of countries included in the study in research generally are not exceed 20, the sample range is predominantly between 1-5 years and 5-10 years. Finally, it can be said that the most used methods in these studies are correlation coefficients, especially DCC, and very few of the studies use the higher order co-movement analysis.

On the other hand, financial contagion, especially after the global financial crisis, attracted the attention of researchers for developed countries rather than developing countries. Baur (2012)’s empirical analysis under GARCH framework is the study of the contagion of the Global Financial Crisis from the financial market to the real economy across sectors, globally, across countries, and within the country.

Morales & Andreosso-O'Callaghan (2014) examined financial contagion with three different econometric methods, using daily stock data of 58 countries between January 2003 and May 2009. Authors chose the US stock market as the source of the contagion. In order to avoid sample bias, they analyzed it in two periods as crisis period and calm period. The first method that they followed Forbes & Rigobon (2002) and in the other two methods, they built models within the framework of AR (1)-GARCH (1,1). In the second model, authors alter model in order to minimize the issues related to omitting variables in the model specification by combining the residuals from the various markets allocated to each area. In the third model, model is modified to account for

shocks that influence and originate from regional markets instead of US stock market. The results of the study indicate that there is not any significant evidence, either globally or regionally, to support the idea that the US stock markets have caused contagion.

4.4.1 VAR Models

Fratzscher (2003) provides a different perspective and consider the possibility that crises may have a cascading effect in the analysis. The term "cascading effect" refers to the potential for shocks to spread from not just the nation where a crisis started but also from other countries that are subsequently affected. Examining with context of cascades provides the basis for examining contagion with network models. Fratzscher (2003) performs a non-linear Markov-switching VAR model to examine the contagion by considering three main channels, real, financial and investor behavior. The main purpose of using this model is to make a comparison between the observable real and financial channels and the unobservable investor behavior (the author calls it sunspots). Consequently, observable, or unobservable, whichever is dominant, may explain the contagion in currency crises. Evidence is found that the Latin America and Asian crises are contagious, and that the contagion is occurred through financial links. In line with these results, the most important factor in estimating the country to be affected by a crisis is the degree of real and financial interconnectedness between these countries.

Another VAR method is used by Samarakoon (2017) which the sovereign bond yield of GIPSI countries and the contagion between the stock markets of developed and emerging economies are examined with daily data. Analysis period covers between 2003-2012, and all the sample is divided into two subsamples for analysis calm times and crisis times. GIPSI countries are determined as crisis countries and their bond and stock markets as source of contagion. Contrary to the literature, the number of countries in the analysis is high, in which 25 developing and 27 developed countries markets are examined. A total of 52 country markets are presented, according to region. The contagion between developed Eurozone, emerging Eurozone, North and South America, Middle East and Africa for bond and stock market is found. While there is not much evidence of contagion from the bond market to Asian countries, there is little evidence of contagion to Asian countries in the stock market. Contagion to

frontier Eurozone countries for bond markets, there is no evidence for contagion, although there is evidence for a few frontier countries' stock markets.

4.4.2. DCC-GARCH Models

DCC-GARCH models are frequently used in financial and economic literature in order to examine highly volatile as well as high frequency data such as stock market data. Naoui et al. (2010) estimation is one such study based on the DCC-GARCH method to examine the contagion during the GFC between six developed countries and ten developing countries. Authors use daily data between January 2006 and February 2010 and found that the correlation between US stocks and developed countries stock markets increased during the crisis. The contagion effect for developing countries varies from country to country.

Syllignakis & Kouretas (2011) also perform the DCC-GARCH model to analyze the contagion between seven emerging equity markets in Central and Eastern Europe between 1997-2009. Emerging markets as well as the US, Germany and Russia are included in the analysis. As a result of the estimation is conducted by using weekly data, authors' findings indicate that the correlation between both USA and Germany, and emerging markets increased during the GFC period. However, their study does not support the evidence of contagion to selected emerging markets for the Asian and Russian crises.

Another study conducted by Celik (2012) examines the contagion of the US subprime crisis to developed and emerging countries' foreign exchange market. By using daily data, contagion is tested 9 developed and 10 emerging countries between the years 2005 and 2009. The analysis is estimated under the DCC-GARCH model. Then, subsamples of obtained DCCs which are pre-crisis and crisis periods equality compared with t-test in order to judgment of contagion. Results of the study indicate that US subprime crisis has contagion effect for all countries.

Ahmad et al. (2014) firstly uses the Markov Regime Switching method to predict the crisis period. Afterwards, authors examine the contagion from the GIPSI, and the US stock markets to the stock markets of European and non-European countries between the years 2009-2012 with the DCC-GARCH method. The results show that significant contagion occurs in both Eurozone and non-Eurozone markets from the GIPSI countries, except from Greece, from Ireland, Portugal, Spain, and Italy.

Moreover, Mollah et al. (2016) focus on a large sample of countries in their analysis when examining the contagion effect of the GFC and Eurozone crises. Authors explore sources of contagion while examining 55 countries under the DCC-GARCH framework. In this study daily stock data, the entire analysis period is from 2003 to 2013. Contrary to the literature, instead of sub-sampling the entire analysis period as calm and crisis periods, dummy variables are used in the GARCH model to indicate GFC and Eurozone crisis periods. In addition to finding evidence of contagion, authors state that the US stock market is the source of contagion in both the GFC crisis and the Eurozone Sovereign Debt Crisis. The findings suggest that while Latin American countries are affected by both crises, the emerging economies of Asia and Africa and Middle East are not equally affected by these two crises. Additionally, while Asian emerging economies partially affected by the GFC, they are not affected by the Eurozone Sovereign Debt Crisis. There is evidence to the contrary for Middle East and African countries, they are not affected by the GFC but partly affected by the Eurozone Sovereign Debt Crisis. Authors also emphasize that the interbank risk transfer is the source of contagion causing spread of crisis US to other economies.

Nguyen et al. (2022) perform the DCC-EGARCH model to test financial contagion during the GFC and Covid-19 pandemic. Authors examine the impact of contagion from the US, Japan, and China to ten developing Asian countries during the GFC and Covid-19 pandemic, via stock markets. In this study, the analysis periods for the GFC and for the Covid-19 pandemic are January 2005 and December 2009, 1 January 2013, and 6 July 2021 with daily data are selected respectively. The difference between the DCC coefficients of the two periods, determined as pre-crisis and crisis period, is tested against the contagion effect by using the t-test. The results of the GFC analysis period show that not every Asian country is affected by the US, while developing countries in Asia are affected by the Chinese stock market. However, during the Covid-19 pandemic period, the influence of the US on Asian countries is limited compared to the GFC, during this period China's stock market has contagion effect on Asian countries.

4.4.3. Copula Models

Rodriguez (2007) performs the copula model by using Markow-Switching parameters to examine financial contagion with daily stock market data from Mexico and Asian

countries. It is stated that this method considers non-linearity and asymptotic dependence, and highlights that is important for straightforward interpretation of extreme results. As a result, it reveals that the dependency structure between the stock markets of the countries has changed in times of crisis.

The study conducted by Horta et al. (2016) examine the investor induced channel and assesses the contagion of the US financial crisis to Belgium, France, Netherlands, and Portugal. Authors conduct their analysis based on maximum likelihood and Copula theory with obtained series from ARMA-GARCH model using daily bond and stock returns data between January 2005 and December 2009. The result suggest that the contagion from the US to these four European markets, and contagion firstly occurs in in national level through as investors rebalanced their portfolios with bonds rather than stocks with the intention of reducing their risk.

4.4.4. Network Models

In recent years, financial contagion is started to be examined with network models by drawing attention to the complexity of financial structures and the possibility of cascading effect of crisis. Firstly, Elliot et al. (2014) provide theoretical perspectives of contagion with network framework. Authors introduce a model that offers new perspectives on financial contagion. In order to investigate of contagion, they examine the cascades of failures across financial institutions by a network of financial interdependencies. In order to test their model and investigate contagion during end of 2011 in Europe, authors use as data consolidated foreign claims of banks from six European countries. Therefore, they build a network model of six countries' cross holdings. The results show that although Portugal is not directly affected by Greece's debt, it is indirectly the country most affected. Secondly, this influence also hits Spain, as Portugal is affected. Because Spain is impacted, this influence also extends to France and Germany. In this case, Italy is the last affected country because Italy's impact on the debts of other countries is very limited.

In another study, Ahelegbey et al. (2020) analyze the Global Financial Crisis, European sovereign debt crisis and post-crisis periods for ten developed countries between the years 2006-2015. Authors examine financial contagion and its two channels, financial markets, and bank lending channels with Network based VAR model. They found that while equity-to-equity contagion is important during the

financial crisis, lending-to-lending contagion is more dominant between countries, especially in the European Sovereign Debt crisis. In addition to finding the effect of contagion through lending and equity channels significant, they also point out to the existence of contagion between these channels. Changes in lending volume between in a country's banks can spread to other countries through financial markets channels. Similarly, vice and versa is possible financial markets can be affecting the lending's of banks, but its effect is limited.

4.4.5. Hazard Models

In recent years, researchers have tried to explain the causes and channels of contagion by using newly introduced models. According to one of thesemodel, the Cox-Proportional Hazards model, which has limited use in economics and finance, Puttachai et al. (2018) examine the spread of the US financial crisis to 182 countries and to what extent countries are affected. Authors examine the GDP of the countries to detect the regime change, by using the Markov Switching Autoregressive method to detect the crises in these countries. Additionally, they investigate the effects of the US financial crisis on 182 countries divided into five groups according to regions, levels of economic and human development, income levels and economic communities. As a result of the estimation made by using quarterly data between 1997 and 2016, it is shown that 114 countries are affected by the US financial crisis. As a region, Asia, Africa and Australia and high-development countries are not affected by the US financial crisis, as well as countries that are members of economic communities such as APEC and WTO seem likely to be affected by the US financial crisis.

Another study examining the channels of contagion by modifying the Cox proportional hazard model is carried out by Karimi & Voia (2019). In the contagion of currency crises, financial and real channels are examined with models build for 21 countries between 1970 and 1998, selecting monthly and quarterly data frequency for macroeconomic variables. The results indicate that currency crisis risk grows with highly volatile rate of unemployment, rate of inflation, contagion variables that largely operate through trade links, real effective exchange rate, the degrees of trade openness and economy size.

4.4.6. Other Models

There are also other models on the issue which are conducted to examine the contagion in the literature. Kalbaska & Gatkowski (2012) is one of these models to examine contagion by CDSs of eight European countries and the US. This study is performed by using the Exponentially Weighted Moving Average, Impulse Response analysis and Granger causality methods with daily data between August 2005 and September 2010. There is evidence of contagion between CDS markets after 2007. The results of the impulse-response analysis show that, in addition to the strong defense of the UK against shocks from other countries, the shocks of countries such as Greece, Spain and Italy have little effect on other countries, and their shock not strong enough to trigger the contagion.

Moreover, Gomez-Puig & Sosvilla-Rivero (2014) examine the contagion between Eurozone countries at the time of the Eurozone Debt Crisis with a causality test. In their analysis, they use daily 10-year bond data covering the period 1999-2012, also many breaks in the data finding. Especially these breaks are mostly found in November 2009 period. The causality test is applied as the pre-crisis and post-crisis period before and after these identified breakout periods. As a result, more causality emerges in crisis periods than in pre-crisis periods. The crisis period causality from periphery countries to Eurozone core countries is more than in the pre-crisis period. Hence, results indicate that peripheral countries threaten the sovereign debt risk of core countries.

Lastly, Ye et al. (2021) tests financial contagion for six developed countries covering periods between 2000 and 2018. The data of this study consists of financial and real variables; therefore, their frequencies is not the same. Then, the using MIDAS technique which allows estimating daily and monthly data together between, the estimate tail index regression. The findings indicate that any downside movement in the US market affect Germany and Hong Kongs' markets.

4.2. Method

The two important points in the empirical study of contagion are highlighted by the Rigobon (2016). The first is the fact that the variables are endogenous and the presence of omitted variables in the models created, which causes the estimation results to be biased. The second point is that the data used in the analysis of contagion are heteroscedastic in nature since they are volatile in times of crisis. As a result, when

these two situations are considered as a whole, if the bias of the estimation results, namely misspecification, changes with heteroscedasticity, then the bias also changes over time, namely time-varying.

The broad definition of contagion, "cross-market co-movements increases after the shock", is a definition that makes it easy to test empirically because even analyzing the correlation coefficients between two markets allows to empirically examine the presence of contagion. Another factor that facilitates the empirical analysis of contagion is that this definition ignores the transmission channels of contagion mentioned and underlined in the theoretical literature. Thus, analysis of such as correlation coefficients of markets is able to answer the hypothesis of whether there is a contagion as a result of the estimation. However, the analysis of correlation coefficients suffers from heteroscedasticity and bias due to markets data that is volatile in times of crisis (Forbes & Rigobon 2002).

As stated, this method provides an opportunity to test the hypothesis of whether there is only contagion, and this definition is used in this analysis to test the "cross-market co-movement increases after the shock from one country or group of countries" hypothesis. First, the DCC-GARCH process is estimated. The DCCs obtained thereafter are used to test the contagion hypothesis during GFC and European Sovereign Debt Crisis. DCCs to be obtained from the GARCH process are time-varying, thus giving more precise results than constant conditional coefficients (CCCs). First of all, ARCH process conditions must be met in order to predict the GARCH process.

4.2.1 ARCH and GARCH Models

In the analysis of financial time series, the process called volatility clustering is observed. In error terms, big and major shocks follow two-way such as before and after major shocks, while minor shocks follow minor shocks. This is especially true for the high-frequency financial data with a frequency such as daily or weekly. One of the best ways to analyze such a structure is to examine the historical dependency of variances of the error terms. Engle (1982), who made an important contribution to the empirical literature, introduces the Autoregressive Conditional Heteroskedasticity (ARCH) model to study this structure. Simply, in this model, the variance of the error

term at time t is dependent on the square of the error term in earlier periods (Verbeek, 2004). According to Verbeek (2004), basic ARCH(1) model is

$$\sigma_t^2 = \bar{\omega} + \alpha_1 \varepsilon_{t-1}^2, \quad (1)$$

where σ_t^2 is variance of error term which is dependent on past squared error terms. But this equation does not provide stationarity. The stationarity is,

$$\sigma^2 = \bar{\omega} \,/\, (1 - \alpha), \quad (2)$$

in order to ensure that stationary solution α must be $0 \leq \alpha < 1$.

Therefore, ARCH(p) model can be written as,

$$\sigma_t^2 = \bar{\omega} + \alpha_1 \varepsilon_{t-1}^2 + \alpha_2 \varepsilon_{t-2}^2 + \alpha_3 \varepsilon_{t-3}^2 + .. + \alpha_p \varepsilon_{t-p}^2 . \quad (3)$$

There are two important points in order to provide non-negativity of conditional variance and stationarity of ARCH(p) model. First, $\bar{\omega}$ and α_i must be positive for non-negativity of conditional variances. Second is $0 \leq \alpha < 1$ for stationarity of ARCH model.

Bollerslev (1986) introduce generalized form of ARCH model which is Generalized Autoregression Conditional Heteroskedasticity (GARCH) model. In GARCH (p, q) model, p indicates number of lags squared error term like ARCH(p) and q refers to the number of lag the conditional variances. GARCH (p, q) model is,

$$\sigma_t^2 = \bar{\omega} + \sum_{i=1}^{P} \alpha_i \varepsilon_{t-i}^2 + \sum_{i=1}^{q} \beta_i \sigma_{t-i}^2$$

where conditional variance depends on past squared errors and past conditional variances. Like ARCH(p) model, stationarity and non-negativity of conditional variances must be provided. The stationarity equation is $\sigma^2 = \bar{\omega} \,/\, (1 - \alpha - \beta)$. Thus, in order to provide non-negativity $\bar{\omega}$, α_i and β_i must be positive. Stationarity of process is required that $\alpha + \beta < 1$.

A GARCH(1,1) model has been found to frequently be adequate for estimating volatility. Since the GARCH model is not a linear model, it cannot be estimated with the OLS method. One of the most important reasons is the minimization of residual sum of squares in the OLS method. The maximum likelihood (ML) method is a suitable method for estimating both linear and nonlinear model parameters, therefore GARCH model estimation suitable with using maximum likelihood (Brooks, 2008).

4.2.2 DCC-GARCH Model and Estimation

The ability to acquire all potential pair-wise correlation coefficients for the market returns in the sample is a benefit of the multivariate DCC-GARCH model. Additionally, another benefit is observation of how they behave at times, such as times of crisis. As a result, using this method makes it possible to search for potential market-wide crises, namely contagion that might spread to other markets (Syllignakis & Kouretas, 2011).

Engle (2002) introduce to DCC-GARCH model which this multivariate model allows the investigate correlation between variables time-varying. Model is based on Bollerslev (1990) CCC's, conditional covariance matrix is

$$H_t = D_t R D_t \tag{4}$$

$D_t = diag(\sqrt{h_{i,t}})$ is diagonal matrix and $h_{i,t}$ is variances. Correlation matrix is R.

The difference between the CCC's and DCC's is in DCC model R is time-varying. Therefore, conditional covariance matrix of DCC model is,

$$H_t = D_t R_t D_t. \tag{5}$$

The specification of Engle (2002) for in order to obtain time-varying correlation matrix (R_t) is explained by the Bauwens et al. (2006),

$$R_t = diag\left(q_{11,t}^{1/2}, \cdots q_{NN,t}^{1/2}\right)^{-1} Q_t diag\left(q_{11,t}^{1/2}, \cdots q_{NN,t}^{1/2}\right)^{-1} \tag{6}$$

$Q_t = (q_{i,j,t})$ and Q_t is N x N symmetric and positive matrix.

$$Q_t = (1 - \alpha - \beta)\bar{Q} + \alpha u_{t-1} u'_{t-1} + \beta Q_{t-1} \tag{7}$$

where $\bar{Q}$ is the matrix of unconditional variance of u_t. α and β are parameters of GARCH model.

Recall GARCH(1,1) model and it's specifications. Therefore, α and β must satisfy non-negativity and stationarity which is $\alpha + \beta < 1$.

Consequently, correlation coefficients from the bivariate GARCH estimation is

$$\rho_{ij,t} = \frac{(1 - \alpha - \beta)q_{ij} + \alpha u_{i,t-1} u_{j,t-1} + \beta q_{ij,t-1}}{\left((1 - \alpha - \beta)\bar{q}_{ii} + \alpha u_{i,t-1}^2 + \beta q_{ii,t-1}\right)^{1/2} \left((1 - \alpha - \beta)\bar{q}_{jj} + \alpha u_{j,t-1}^2 + \beta q_{jj,t-1}\right)^{1/2}}$$

As indicated before that since GARCH model is non-linear estimation cannot be conducted using OLS. Best suitable model is ML estimation. Bollerslev & Wooldridge (1992) state that the ML estimation is used under normality. Authors examine QMLE when log-likelihood is maximized in dynamic models, but the normality assumption is violated. They present formulas for obtaining asymptotic standard errors using estimator of quasi-maximum likelihood. The validity of these asymptotic standard errors is true even in the presence of nonnormality.

In this analysis, with following Engle (2002) and two stage estimation of quasi-maximum likelihood method is conducted. Recall DCC model and suppose ϑ refers parameters in *D*, and ψ refers to the additional parameters in *R*. Hence,

$$L_v(\vartheta) = -\frac{1}{2}\sum_t (n\,log(2\pi) + log\,|D_t|^2 + r_t' D_t^{-2} r_t)$$

is volatility component. The correlation part is

$$L_c(\vartheta, \psi) = -\frac{1}{2}\sum_t (log\,|R_t| + u_t' R_t^{-1} u_t - u_t' u_t)$$

and summation of these two equations gives the log-likelihood,

$L(\vartheta, \psi) = L_v(\vartheta) + L_c(\vartheta, \psi)$.

Engle (2002) states that the consistency of the first step which is volatility component estimation brings consistency of second step estimation. Because second step is function of obtained parameter from volatility component part.

4.2.2. Contagion Test

Correlation coefficients between markets are compared according to calm and crisis periods and t-test is applied by Forbes & Rigobon (2002) to evaluate the contagion effect between markets. The null hypothesis is that all sample correlation coefficients are greater than the crisis period coefficients. If the null hypothesis is rejected, there is contagion. This framework is followed by Nguyen et al. (2022), also Celik (2012) uses t-test for comparison of calm and crisis periods with the null hypothesis that calm period's population mean of dynamic conditional correlations is equal crisis period's population mean of dynamic conditional correlations. If the null hypothesis is rejected, then we can say that there is contagion between the markets. In this thesis, the hypothesis of Forbes & Rigobon (2002) is followed in order to test contagion effect.

In order to test contagion effect between stock markets, two sample t-test with unknown variance or mean is applied to all sample and crisis periods for each DCC of GARCH(1,1) models. Hypothesis of test is,

$H_0: \mu_\rho^{Sample} \geq \mu_\rho^{Crisis}$

$H_1: \mu_\rho^{Sample} < \mu_\rho^{Crisis}$.

The test indicates that the null hypothesis is the population mean of all sample is greater or equal than population of crisis periods, alternative hypothesis therefore indicates contagion effect. According to test statistics, if null hypothesis is rejected, this is signaling for contagion effect.

4.3. The Analysis of Global Financial Crisis

4.3.1. Data

In order to test contagion through stock markets during Global Financial Crisis, by using the data from World Bank (2022) namely countries' total value of shares traded, the top ten countries are selected among 224 countries by annually averaging countries' the total value of traded stocks between years 2000 and 2007. These countries are Canada, China, Germany, Spain, France, United Kingdom, Italy, Japan, South Korea, and the United States.

Figure 4.1 shows selected countries' the total value of traded stocks excluding the US between 2000 and 2007. While the total traded stock values of Japan and the UK are comparatively high in the graph, the total traded stock values of China increased dramatically in 2007 compared to 2006. This change in China's value is an increase of about 444%.

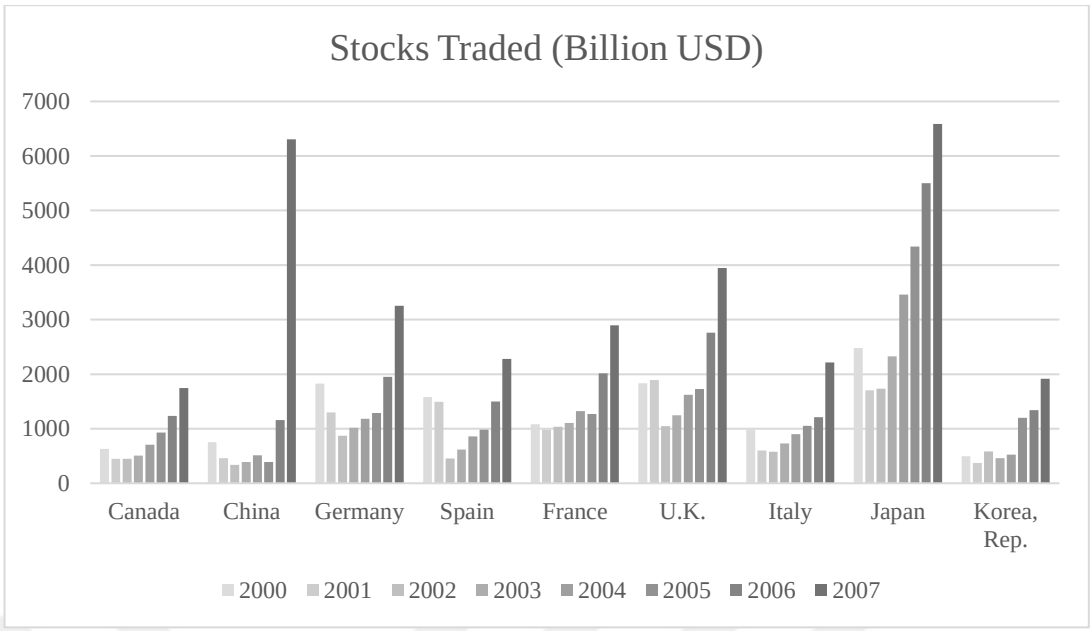


Figure 4.1. The Countries' Total Value of Stocks Traded

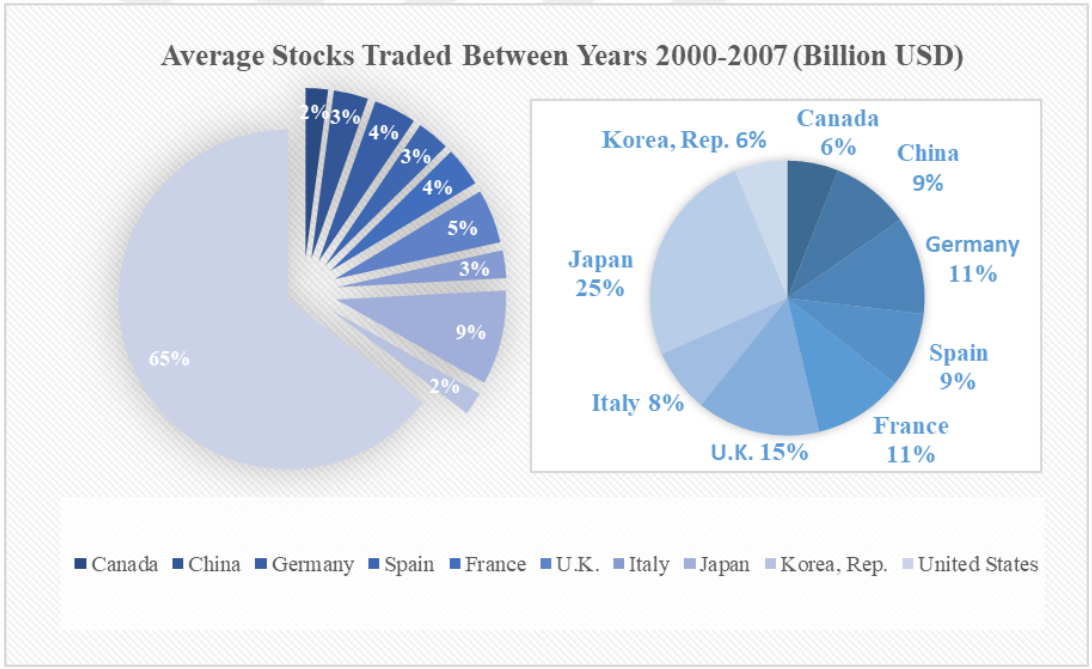


Figure 4.2. The Countries' Average Value of Stocks Traded

Figure 4.2 illustrates the countries' the average of the years between 2000 and 2007 of total value of traded stocks. The pie chart on the left side of the figure shows that the share of the US among these countries is 65 percent. When the distribution of the remaining nine countries is examined with excluding US, the chart on the right side of

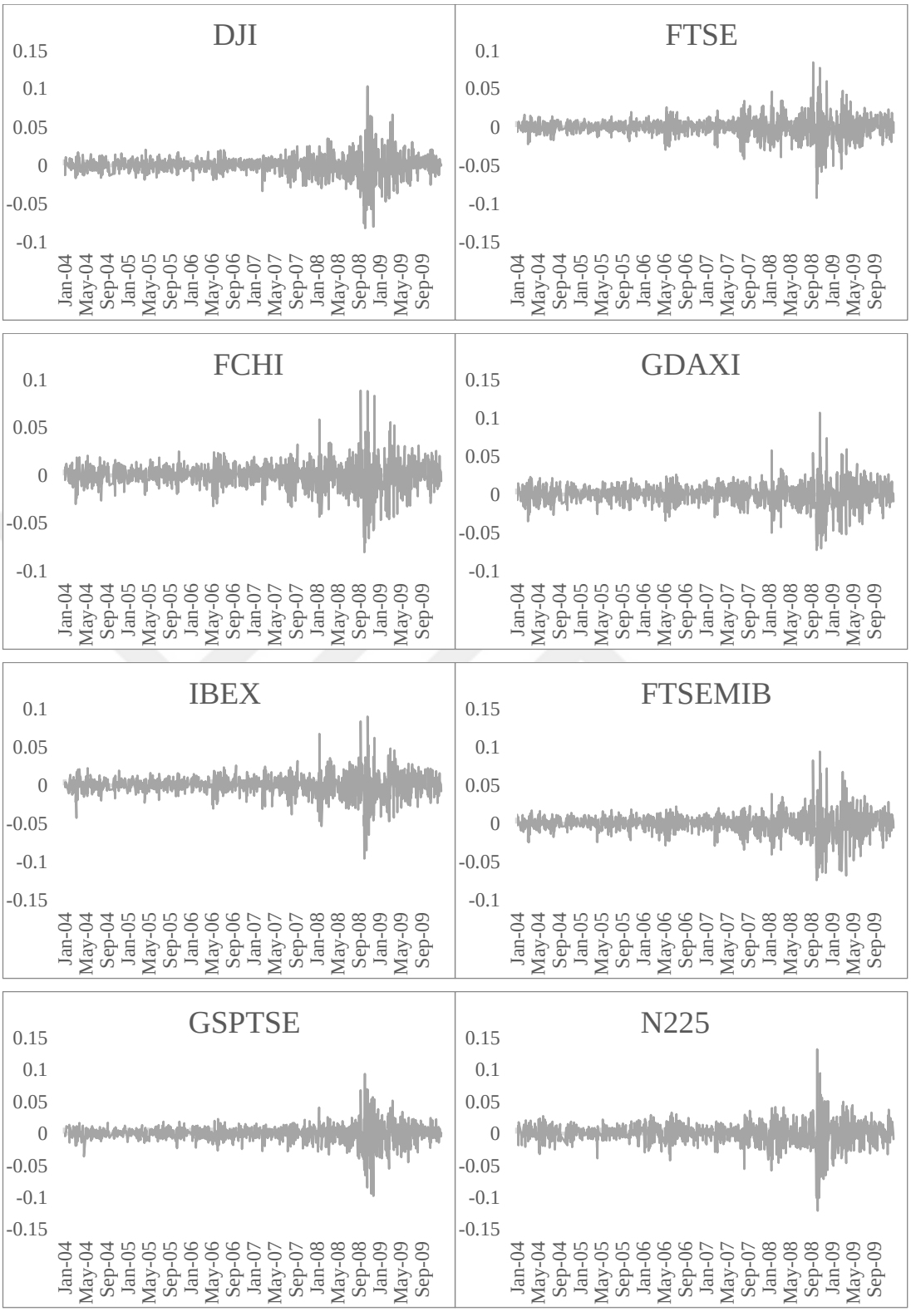
the figure shows that Japan accounts for 25 percent, the UK 15 percent, and Germany and France 11 percent.

Table 4.2. Description of Stock Markets for GFC Analysis

Country	Stock Index	Code	Data Source
U.S.	Dow Jones	DJI	Yahoo Finance
U.K.	FTSE 100	FTSE	Yahoo Finance
France	CAC 40	FCHI	Yahoo Finance
Germany	DAX	GDAXI	Yahoo Finance
Spain	IBEX 35	IBEX	Yahoo Finance
Italy	FTSE MIB	FTSEMIB.MI	Yahoo Finance
Canada	S&P/TSX	GSPTSE	Yahoo Finance
Japan	Nikkei 225	N225	Yahoo Finance
South Korea	KOSPI	KS11	Yahoo Finance
China	SSE	000001.SS	Yahoo Finance

Table 4.2 indicates description of countries' stock market indices. Firsly, to examine the contagion effect of Global Financial Crisis for the stock market of these ten selected countries, data of daily stock indexes' closing prices are collected from Yahoo Finance (2020). All stock markets' closing prices are local currency of countries. In this analysis, the sample range is between 8/1/2004 and 30/12/2009 with 1187 trading days for each stock market.

In order to obtain return series, daily log differences of closing prices are calculated. Returns of ith market are calculated according to formula that $Returns_i = LN\left(P_{i,t} \,/\, P_{i,t-1}\right)$. The data is cleared because of the days that are not match due to the stock markets of the countries that are closed different days for national holidays or other reasons.


DJI
FTSE
FCHI
GDAXI
IBEX
FTSEMIB
GSPTSE
N225
Jan-04
May-04
Sep-04
Jan-05
May-05
Sep-05
Jan-06
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Sep-08
Jan-09
May-09
Sep-09

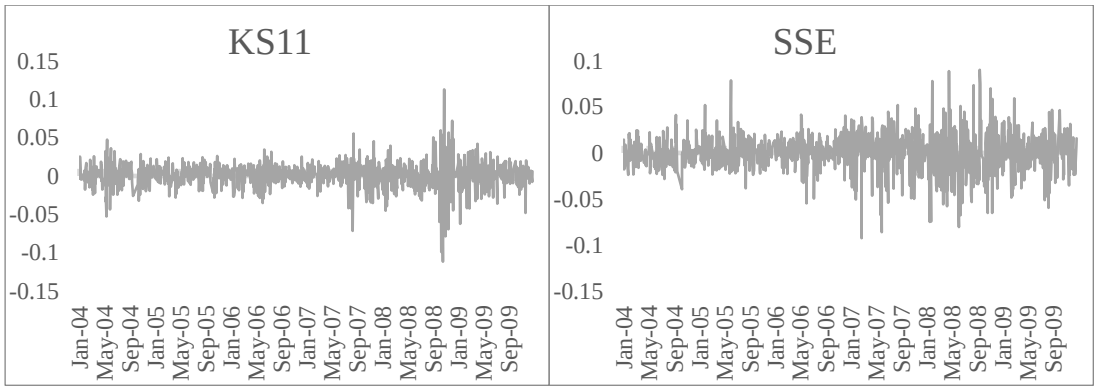


Figure 4.3. GFC Analysis' Return Series of Stock Markets

Figure 4.3 illustrates returns of stock indexes between the 4 January 2004 and 30 December 2009. US stock market index returns are highly volatile from August 2007 until the end of analysis period. Specifically, all stock markets returns extremely volatile during September 2008.

4.3.2. Identification of Crisis Period

In the analysis, two sub-samples are formed in order to examine the contagion effect of the GFC crisis. Therefore, it is crucial to identify the crisis period in order to obtain more precise results. Firstly, Greenbaum et al. (2016) in their study examining the major events of the GFC crisis states that accordingly, mostly August 2007 is considered as the beginning of the crisis, also major events such as problems in the credit market spilling over into the interbank market during August 2007. While econometric methods can be used to define the crisis period, an event can also be used to determine the crisis period in analysis.

Dungey (2008) uses an event as the onset of crisis in his analysis. In study starting date of crisis is set on July 17, 2007, when New York-based Bear Stearns informs investors about failing hedge funds. For example, studies that consider starting date of 2008 Global Financial Crisis are varying in the literature. Some studies consider starting date of crisis period when Bear Stearn informs investors (Dungey, 2008; Celik, 2012; Yalama & Celik, 2013). Other studies consider different events. For example, Wang et al. (2021) uses the date August 1, 2007, in their analysis of the GFC to separate to calm and crisis times into two distinct periods of their sample. In analysis of BenMim & BenSaida (2019), crisis period of GFC begin with first day of 2008, they consider calm times until the end of 2007. Next, Jin & An (2016) when investing contagion of

GFC between stock markets, they consider for pre and post analysis of Lehman Brothers collapse. Therefore, their crisis period beginning is identified as October 2008.

The report of BIS (2009) analyzes the GFC crisis in five stages, report indicates that the in the first stage of crisis financial stress arise with common result of subprime mortgage defaults, when this stress interrupt the interbank market then crisis begins in August 2007. Dungey & Gajurel (2014) are find the crisis is begin on 19 July 2007 with using Iterative Cumulative Sum of Squares (ICSS) approach. Horta et al. (2016) indicate the GFC crisis period is assumed begin on 1 August 2007 in their analysis. In order to avoid the Eurozone Sovereign Debt Crisis period, which is starting end of the 2009, their GFC crisis period end in December 2009. Authors' identification of crisis is also followed by Wang et al. (2021).

In the study, Dungey (2008) is followed, and crisis considered began with an event which is when Bear Stearns informs to investors. According to this date, crisis period is covering days between 18/07/2007 and 30/12/2009 with 514 trading days. The period indicating calm times, called the pre-crisis period, is between 08/01/2004 and 13/07/2007 with 673 observations for each return series.

4.3.3. Preliminary Analysis

Table 4.3. reports the descriptive statistics of all sample. For all series, their kurtosis values are high. As a result of these kurtosis values exceeding three, it can be said that the series have a leptokurtic distribution. Expectedly, Jarque-Bera statistics also indicate that series have non-normal distribution.

Table 4.3. Descriptive Statistics of GFC Analysis Data

	Mean	Median	Max.	Min.	Std. Dev.	Skewness	Kurtosis	JB-Stat
DJI	-0.0002	0.0004	0.1033	-0.0820	0.0132	-0.213	12.355	4337.79*
FCHI	-0.0002	0.0003	0.0887	-0.0805	0.0144	-0.129	9.360	2004.11*
FTSE	-0.0001	0.0005	0.0847	-0.0926	0.0131	-0.312	10.903	3108.13*
FTSEMIB	-0.0002	0.0009	0.0941	-0.0741	0.0143	-0.271	10.150	2543.10*
GDAXI	0.0001	0.0008	0.1069	-0.0727	0.0143	-0.172	9.298	1967.84*
GSPTSE	0.0001	0.0007	0.0937	-0.0979	0.0142	-0.524	11.946	4012.20*
IBEX	0.0001	0.0009	0.0900	-0.0959	0.0140	-0.354	10.269	2638.29*
KS11	0.0006	0.0017	0.1128	-0.1117	0.0163	-0.596	10.040	2521.70*
N225	0.0001	0.0004	0.1323	-0.1211	0.0174	-0.433	12.270	4287.00*
SSE	0.0005	0.0011	0.0903	-0.0926	0.0198	-0.217	5.766	387.83*
	Pre Crisis							

	Mean	Median	Max.	Min.	Std. Dev.	Skewness	Kurtosis	JB-Stat
DJI	0.0003	0.0004	0.02069	-0.0335	0.0066	-0.306	4.390	64.69*
FCHI	0.0005	0.0006	0.02505	-0.0323	0.0086	-0.335	3.940	37.35*
FTSE	0.0004	0.0008	0.02605	-0.0296	0.0070	-0.365	4.645	90.87*
FTSEMIB	0.0005	0.0011	0.02240	-0.0292	0.0074	-0.503	4.266	73.41*
GDAXI	0.0007	0.0011	0.02605	-0.0352	0.0094	-0.390	3.806	35.26*
GSPTSE	0.0005	0.0006	0.02278	-0.0358	0.0075	-0.529	4.210	72.47*
IBEX	0.0006	0.0009	0.02602	-0.0424	0.0082	-0.465	5.041	141.04*
KS11	0.0012	0.0017	0.04733	-0.0527	0.0117	-0.367	4.417	71.41*
N225	0.0008	0.0006	0.03301	-0.0423	0.0105	-0.269	3.904	31.02*
SSE	0.0008	0.0010	0.07890	-0.0926	0.0160	-0.615	7.448	597.13*
				Crisis				
	Mean	Median	Max.	Min.	Std. Dev.	Skewness	Kurtosis	JB-Stat
DJI	-0.0008	0.0002	0.1033	-0.0820	0.0186	-0.071	7.183	375.25*
FCHI	-0.0010	-0.0002	0.0887	-0.0805	0.0195	0.027	6.214	221.32*
FTSE	-0.0007	-0.0002	0.0847	-0.0926	0.0182	-0.159	6.582	276.96*
FTSEMIB	-0.0011	-0.0001	0.0941	-0.0741	0.0200	-0.076	6.037	198.03*
GDAXI	-0.0008	0.0004	0.1069	-0.0727	0.0188	-0.004	6.824	313.24*
GSPTSE	-0.0003	0.0011	0.0937	-0.0979	0.0198	-0.350	7.149	379.19*
IBEX	-0.0005	0.0010	0.0900	-0.0959	0.0192	-0.192	6.592	279.53*
KS11	-0.0002	0.0015	0.1128	-0.1117	0.0207	-0.501	8.131	585.37*
N225	-0.0007	-0.0002	0.1323	-0.1211	0.0235	-0.284	8.258	599.07*
SSE	0.0000	0.0016	0.0903	-0.0804	0.0238	-0.010	4.346	38.80*

JB-Stat refer Jarque-Bera statistic which is test statistic for normal distribution. '' is referred to rejection of null hypothesis that normal distribution, at 1% significance level.*

According to both periods, variables have non-normal distribution and kurtosis values of variables except SSE are higher in the crisis period than in the pre-crisis period.

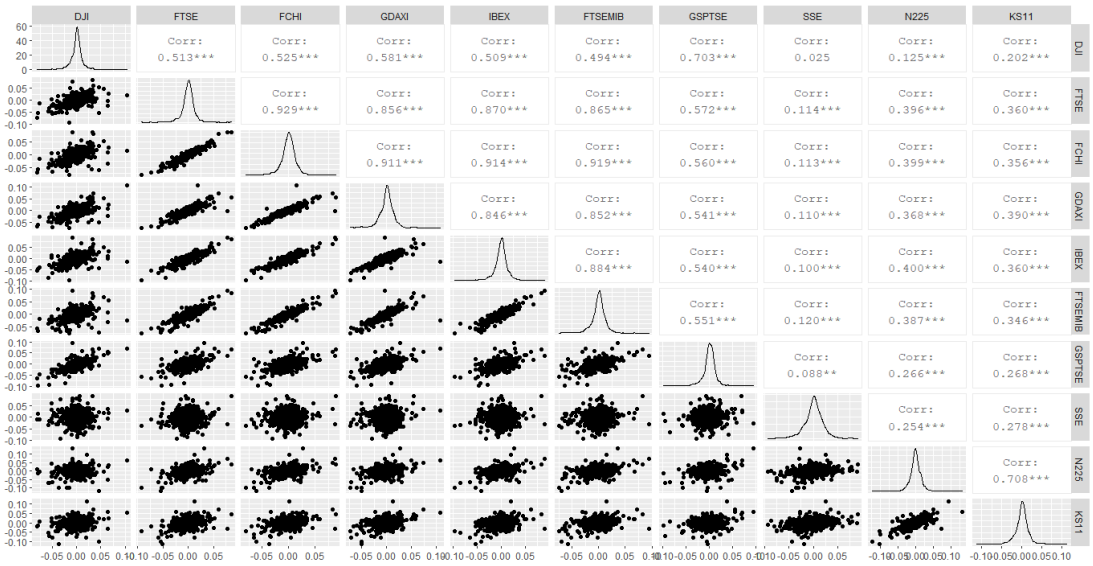


Figure 4.4. Histogram and Correlation Coefficients of GFC Analysis Data

Figure 4.4 illustrates stock markets' returns histograms and Pearson's correlation coefficients which is measure linear relationship between two variables. Variables histograms show leptokurtic distribution. The highest Pearson correlation coefficient between two stock markets' return are FCHI and FTSE with 0.93. The lowest is between SSE and DJI with 0.025 correlation coefficient. Figure also illustrates that the regional close markets have higher correlation coefficients. From Asian continent, SSE, N225 and KS11 has lower correlation coefficients with region of European and North American stock markets. Similarly, North American continent stock returns DJI and GSPTSE has low correlation coefficients with European and Asian continent stock markets. The returns of European stock markets have high correlation coefficients among themselves. In fact, the Shanghai Stock Exchange (SSE) returns correlates poorly with stock market returns even in its region.

In time series analysis, the first step is to test whether the series are stationary. As already mentioned, in ARCH/GARCH model analysis, the data must be stationary. For this reason, the ADF test, which is frequently used in the empirical analysis, and the Phillips-Perron unit root tests, which considers the autocorrelation and heteroscedasticity in the variables, are applied.

Table 4.4. Unit Root Tests of GFC Analysis Data

	ADF	Prob.	PP	Prob.
DJI	-19.3414	0.0000*	-39.9576	0.0000*
FCHI	-36.6862	0.0000*	-36.7776	0.0000*
FTSE	-36.8092	0.0000*	-37.207	0.0000*
FTSEMIB	-34.5291	0.0000*	-34.5362	0.0000*
GDAXI	-34.983	0.0000*	-34.9858	0.0000*
GSPTSE	-18.1281	0.0000*	-39.9884	0.0000*
IBEX	-34.4969	0.0000*	-34.546	0.0000*
KS11	-34.5379	0.0000*	-34.5379	0.0000*
N225	-39.56052	0.0000*	-40.04625	0.0000*

SSE	-38.34466	0.0000*	-38.34466	0.0000*

‘’ denotes rejection of null hypothesis that variable has unit root with %1 significance level.*

According to the ADF and Phillips-Perron unit root test results as shown Table 4.4, the null hypothesis of tests which is variable has unit root is rejected. Hence, one of the conditions is met that variables must be stationary in ARCH model.

Table 4.5. ARCH Effect Test of GFC Analysis Data

ARCH (1) Test

	F-stat	Prob. F	LM Stat.	Prob. Chi-Square
DJI	48.41097	0.0000*	46.58639	0.0000*
FCHI	36.20437	0.0000*	35.18867	0.0000*
FTSE	42.72328	0.0000*	41.30384	0.0000*
FTSEMIB	43.22579	0.0000*	41.77254	0.0000*
GDAXI	19.14644	0.0000*	18.87335	0.0000*
GSPTSE	179.9061	0.0000*	156.4222	0.0000*
IBEX	29.09633	0.0000*	28.44589	0.0000*
KS11	52.49288	0.0000*	50.34757	0.0000*
N225	143.7402	0.0000*	128.3839	0.0000*
SSE	16.12508	0.0001*	15.93513	0.0001*

‘’ denotes rejection of the null hypothesis that no ARCH effect with significance level at %1.*

Secondly, the ARCH effect is investigated before constructing the GARCH model . Table 4.5 reports ARCH-LM test results of variables. According to the LM statistics, the null hypothesis that no ARCH effect is rejected with 1% significance level for all variables. Therefore, variables have ARCH effect, and these variables are suitable for GARCH analysis.

4.3.4. DCC-GARCH Results

DCC-GARCH(1,1) estimation is conducted[1] for all sample period and crisis period according to described model in DCC-GARCH Model and Estimation section.

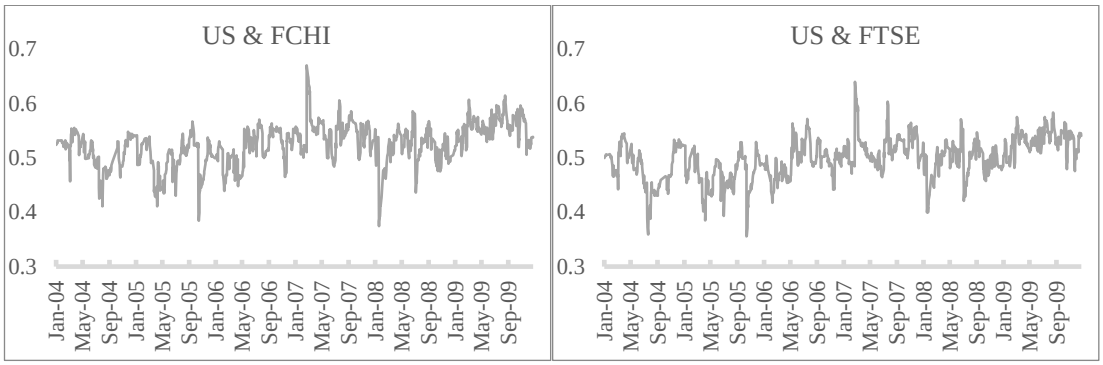
Table 4.6. GARCH Estimation Results of GFC Analysis

All Sample				
	Coefficient	Std. Error	z-Statistic	Prob.
ALPHA	0.0173	0.0023	7.5810	0.0000*
BETA	0.9179	0.0148	61.8757	0.0000*
	Log likelihood	5435.58	*AIC*	-9.1552
Crisis				
ALPHA	0.0310	0.0073	4.2550	0.0000*
BETA	0.5544	0.1690	3.2801	0.0010*
	Log likelihood	2690.2	*AIC*	-10.460

'' denotes rejection of null hypothesis that variable has unit root with %1 significance level. AIC is the Akaike Information Criteria.*

Table 4.6 shows the GARCH estimation parameters, the parameters summation for all period, pre-crisis period and crisis period satisfy the stationarity assumption which is $\alpha + \beta < 1$. Second condition is non-negativity of the parameters, this condition also is satisfied. All parameters for all samples are statistically significant at 1% significance level.

Figure 4.5 illustrates the estimation results of DCC which is conducted according to description in 4.2. Method section.



[1] Estimation conducted with Eviews 10 program and using DCC_RGARCH Package (Faldzinski, 2021)

Figure 4.5. Dynamic Conditional Correlations of GFC Analysis

The DCCs between the US stock market and UK, France, Germany, Italy, Spain, and Canada is high even before the crisis. But with the crisis, their DCC are raising. These results also indicate that, among the countries whose have the highest value of stock traded in the world, US, and Asian stock markets' DCCs are low even during calm times. On the other hand, developed countries markets who Canadian and European

stock markets' DCCs are also high during the calm period. While DCCs between US and Canadian and European stock markets increased after the crisis, Asian stock markets' DCCs are volatile.

4.3.5. The Contagion Test Results

DCC-GARCH(1,1) model is estimated for all sample, and crisis period. As mentioned before in the method section, in order to test hypothesis of contagion is,

$H_0: \mu_\rho^{Sample} \geq \mu_\rho^{Crisis}$

$H_1: \mu_\rho^{Sample} < \mu_\rho^{Crisis}$.

The test indicates that the null hypothesis is the population mean of all sample is greater than population of crisis periods, alternative hypothesis is otherwise. If null hypothesis is rejected then co-movement between markets is higher than calm times and we can say there is contagion.

Table 4.7. Contagion Test Results of GFC Analysis

	Mean	Variance	t-stat	Result
US & FCHI	0.5240	0.0015	-30.553*	Contagion
US & FCHI *Crisis*	0.5750	0.0008		
US & FTSE	0.4388	0.0010	-38.923*	Contagion
US & FTSE *Crisis*	0.5605	0.0007		
US & FTSEMIB	0.5072	0.0014	-22.863*	Contagion
US & FTSEMIB *Crisis*	0.5461	0.0009		
US & GDAXI	0.5431	0.0015	25.903*	Contagion
US & GDAXI *Crisis*	0.5875	0.0009		
US & GSPTSE	0.6118	0.0015	-47.867*	Contagion
US & GSPTSE *Crisis*	0.6824	0.0005		
US & IBEX	0.5031	0.0014	-21.648*	Contagion

US & IBEX *Crisis*	0.5396	0.0009		
US & KS11	0.1454	0.0015	-61.919*	Contagion
US & KS11 *Crisis*	0.1603	0.0012		
US & N225	0.1027	0.0012	-1.4496^{φ}	No Contagion
US & N225 *Crisis*	0.1052	0.0011		
US & SSE	0.0259	0.0024	14.134	No Contagion
US & SSE *Crisis*	-0.0029	0.0011		

'' is referred to rejection of null hypothesis at 1% and significance level. 'φ' is refers rejection of null hypothesis at 10% significance level.*

Table 4.7 shows the results of contagion test with mean and variances of all and crisis periods' series. According to the t-test results, except Japanese stock market (N225) and Chinese stock market (SSE), US stock market and other stock markets co-movement increases during crisis period with 1% significance level. Thus, findings point out that the contagion from US stock market to other stock markets during the 2007-2009 GFC.

4.3.6. Conclusion

The DCCs between US and European countries indicates that there is a strong relation of stock markets. This relation is increasing during crisis period, and this led to contagion evidence for US and European stock markets. In contrast DCCs of between US and Asian countries is very low relatively to other countries in the analysis. This finding is similar to the Naoui et al. (2010) conclusion which indicates that the US stock market and developed stock markets correlation is increasing during the GFC. Authors also find that the dynamic conditional correlation between the US and South Korea and China is weak during GFC.

Contagion test results point out the contagion of GFC crisis to European countries stock markets, Canadian and South Korean stock market is found. In contrast two Asian countries results is not supporting to contagion of GFC.

4.4. The Analysis of Greek Debt Crisis

Eurozone Sovereign Debt Crisis analyses are conducted into two phases, first is that to examine the contagion effect from Greece stock market to Eurozone countries, and then the contagion effect from European Stock to developed and developing markets.

4.4.1. Data

All stock market data are obtained from the Yahoo Finance (2022). Table 4.8 shows description of countries' daily stock market indices, codes, and their sources.

Table 4.8. Description of Stock Markets for Greek Debt Crisis Analysis

Country	Stock Index	Code	Data Source
Greece	FTSE/ATHEX20	FTSE.AT	Yahoo Finance
Netherland	AEX Index	AEX	Yahoo Finance
Austria	ATX	ATX	Yahoo Finance
Belgium	BEL 20	BFX	Yahoo Finance
France	CAC 40	FCHI	Yahoo Finance
Italy	FTSE MIB	FTSEMIB.MI	Yahoo Finance
Germany	DAX	GDAXI	Yahoo Finance
Spain	IBEX 35	IBEX	Yahoo Finance
Ireland	ISEQ All Share	ISEQ	Yahoo Finance

Following to the study of Gomez-Puig & Sosvilla-Rivero (2014), Austria, Netherland, Belgium, France, and Germany are identified as core Eurozone countries in this analysis. Others are peripheral countries.

Stock index value prices are local currencies since countries are in Eurozone, stock prices are Euro. Daily returns of ith market are calculated according to $Returns_i = LN\left(P_{i,t} \,/\, P_{i,t-1}\right)$. The data is cleared from stocks market closed days such as holidays. Return series of stock market is illustrated in Figure 4.6.

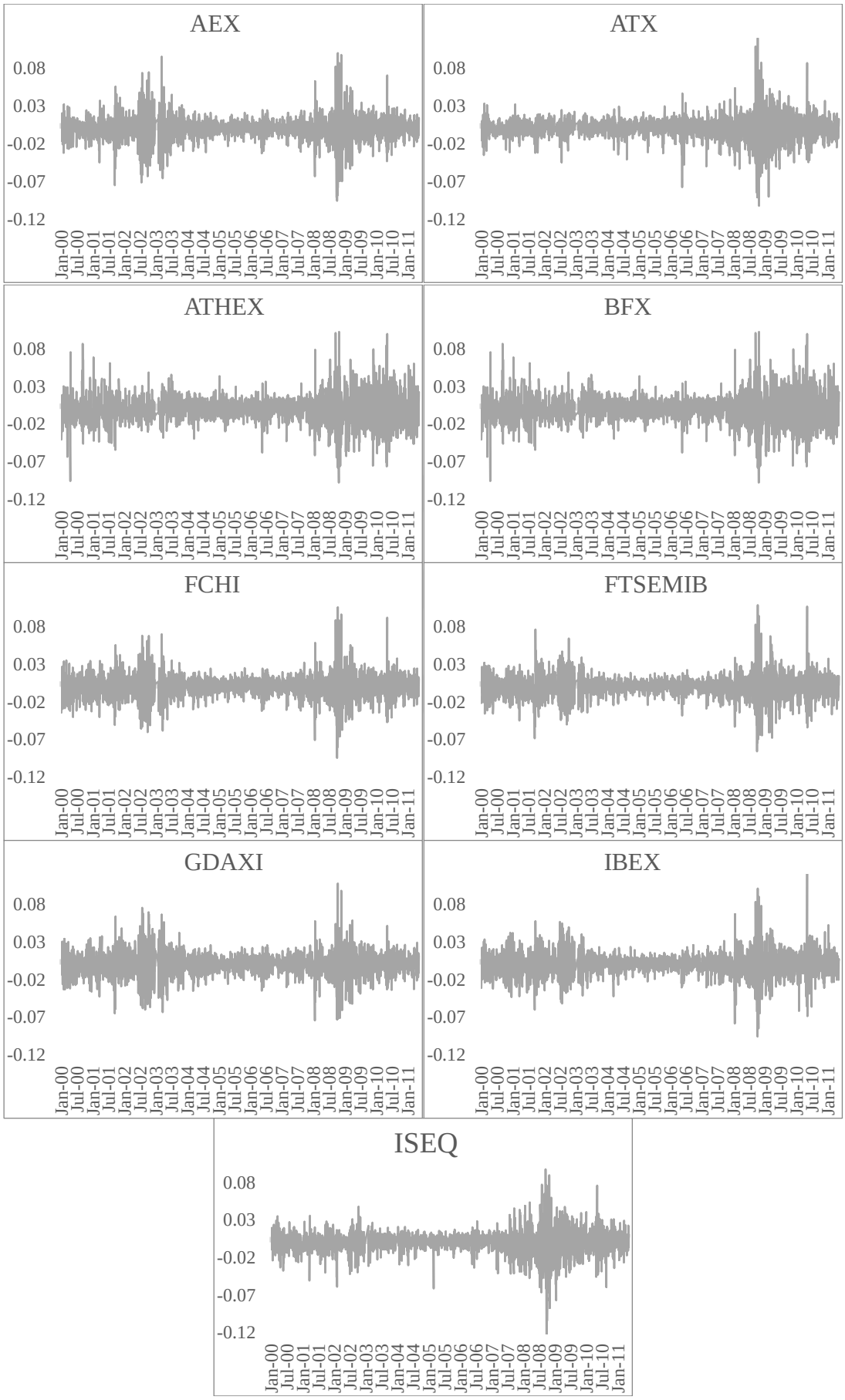


Figure 4.6. Greek Debt Crisis Analysis' Return Series of Stock Markets

Return series of markets are highly volatility from mid-August 2017 to until the end of analysis period. This period clearly indicates that the GFC effect on stock market returns. Eurozone countries stocks' returns also when excluding the GFC effect, relatively high during the May 2010.

4.4.2. Identification of Crisis Period

The newly elected government on October 20, 2009, is announced the Greece's government debt. This announcement is bringing the concerns because the government debt reported by the previous government has tripled for 2009, thus as a consequently this situation is created distrust in the international public and financial agents against Greece's data (Featherstone, 2011). In literature there is studies that authors define the beginning of Greek Crisis period is 20 October 2009 (Andenmatten & Brill, 2011; Pragidis et al.,2015). Also, according to their statistical tests the date October 19, 2011, is identified as Eurozone Sovereign Debt Crisis beginning by (Ahmad et al. 2013; Ahmad et al. 2014). Authors consider the Eurozone Sovereign Debt Crisis beginning is announcement of Greek Debt. Therefore, beginning of crisis period is identified as 21 October 2009 in this analysis according to after one day as before mentioned event and following the studies' selected period in the literature.

4.4.3. Preliminary Analysis

The data of all sample covers the periods between 05/01/2000 and 11/05/2011 with 2572 observation. Due to the GFC crisis just arose before the Greek Crisis, the GFC beginning date of sample is determined as an earlier time when compared to GFC and Eurozone Sovereign Debt Analysis. The pre-crisis period is between the 05/01/2000 – 20/10/2009 with 2200 observations. The beginning and the ending days of crisis period is determined following to literature, thus periods covers dates between 21/10/2009 and 11/05/2011 with 372 observations. To better understanding of data characteristic and comparison of all sample, pre-crisis and crisis periods descriptive statistics of stock markets data presented in Table 4.9. Jarque-Bera statistics of returns indicate stock market returns have non-normal distribution. Their kurtosis statistic values are high, and this indicates leptokurtic distribution of stock markets. Another point is that FTSEMIB and IBEX's crisis period kurtosis values higher than all sample

and pre-crisis periods. Also, BFX's crisis kurtosis value is higher than pre-crisis period value.

Table 4.9. Descriptive Statistics of Greek Debt Crisis Analysis

	Mean	Median	Max.	Min.	Std. Dev.	Skewness	Kurtosis	JB-Stat
All Sample								
AEX	-0.00026	0.0003	0.100	-0.096	0.016	-0.045	9.104	3993.52*
ATHEX	-0.00058	-0.0002	0.103	-0.098	0.018	0.036	6.797	1545.58*
ATX	0.00013	0.0007	0.120	-0.103	0.015	-0.289	11.555	7879.04*
BFX	-0.00010	0.0002	0.093	-0.083	0.014	0.118	9.579	4643.99*
FCHI	-0.00021	0.0000	0.106	-0.095	0.016	0.085	8.000	2682.18*
FTSEMIB	-0.00025	0.0006	0.109	-0.086	0.015	0.046	9.153	4058.10*
GDAXI	-0.00012	0.0007	0.108	-0.074	0.016	-0.035	6.949	1671.35*
IBEX	-0.00005	0.0008	0.135	-0.096	0.015	0.169	9.153	4070.18*
ISEQ	-0.00032	0.0005	0.097	-0.140	0.015	-0.590	10.625	6379.39*
	Pre-Crisis Period							
	Mean	Median	Max.	Min.	Std. Dev.	Skewness	Kurtosis	JB-Stat
AEX	-0.00047	0.0002	0.100	-0.096	0.017	-0.041	8.979	3127.53*
ATHEX	-0.00048	-0.0001	0.103	-0.098	0.017	-0.078	8.206	2372.61*
ATX	0.00001	0.0007	0.120	-0.103	0.015	-0.389	13.145	9053.81*
BFX	-0.00028	0.0002	0.093	-0.083	0.014	0.066	9.566	3771.60*
FCHI	-0.00036	-0.0001	0.106	-0.095	0.016	0.070	7.993	2182.04*
FTSEMIB	-0.00036	0.0004	0.109	-0.086	0.015	-0.017	9.275	3444.17*
GDAXI	-0.00033	0.0005	0.108	-0.074	0.017	-0.009	6.874	1312.83*
IBEX	-0.00015	0.0007	0.101	-0.096	0.015	-0.008	7.803	2017.19*
ISEQ	-0.00050	0.0004	0.097	-0.140	0.015	-0.692	11.929	7140.69*
	Crisis Period							
	Mean	Median	Max.	Min.	Std. Dev.	Skewness	Kurtosis	JB-Stat
AEX	0.00033	0.0003	0.071	-0.043	0.012	0.232	6.570	200.88*
ATHEX	-0.00175	-0.0022	0.100	-0.076	0.025	0.341	3.921	20.34*
ATX	0.00015	-0.0002	0.087	-0.045	0.014	0.195	6.377	179.15*
BFX	0.00027	0.0006	0.090	-0.044	0.012	0.663	10.594	921.08*
FCHI	0.00018	0.0004	0.092	-0.047	0.014	0.352	8.267	437.67*
FTSEMIB	-0.00013	0.0009	0.107	-0.054	0.015	0.486	9.888	749.94*
GDAXI	0.00072	0.0010	0.052	-0.034	0.012	-0.091	4.320	27.52*
IBEX	-0.00006	0.0006	0.135	-0.069	0.017	0.961	14.359	2057.09*
ISEQ	0.00005	0.0003	0.076	-0.060	0.015	-0.026	5.349	85.54*

JB-Stat refer Jarque-Bera statistic which is test statistic for normal distribution. '' is referred to rejection of null hypothesis that normal distribution, at 1% significance level.*

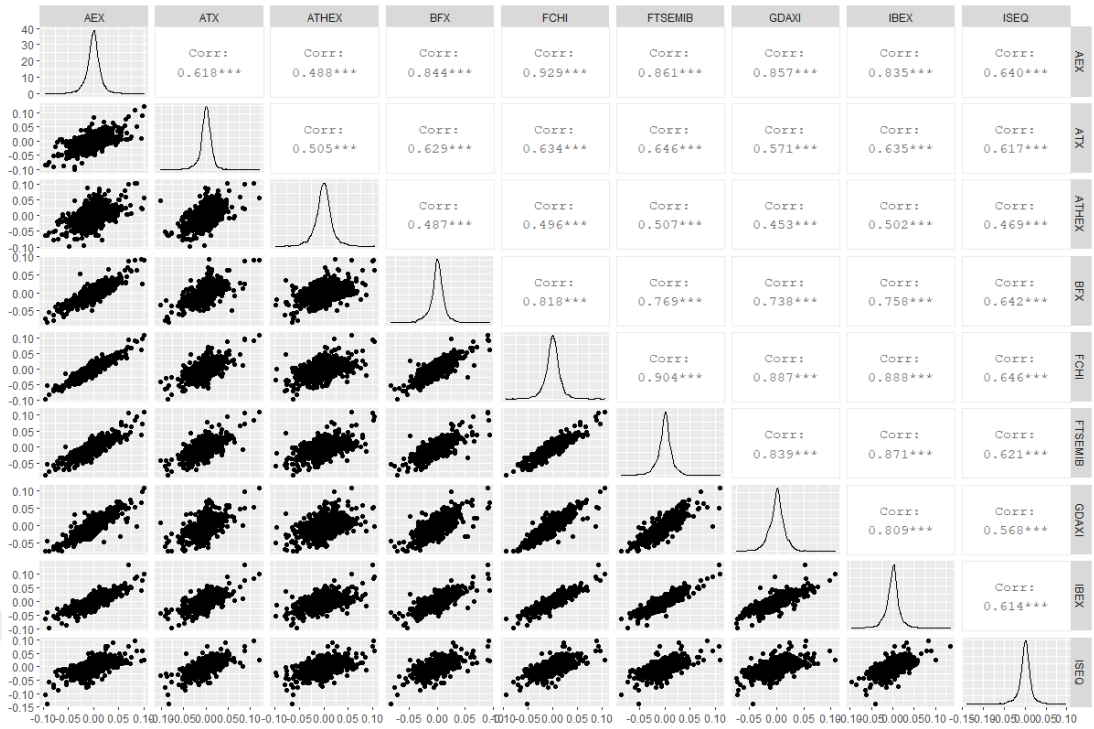


Figure 4.7. Histogram and Correlation Coefficients of Greek Debt Crisis Analysis Data

Figure 4.7 illustrates stock market returns' correlations and histograms. Leptokurtic distribution is shown in the histogram.

Table 4.10 shows Augmented Dicke Fuller (ADF) and Phillips-Perron (PP) unit root rest results of stock market returns. Statistics is rejecting the null hypothesis that variables have unit root. Therefore, stock market return variables are stationary at their level.

Table 4.10. Unit Root Tests of Greek Debt Crisis Analysis Data

	ADF	Prob.	PP	Prob.
AEX	-32.3709	0.0000*	-51.5804	0.0001*
ATHEX	-36.9633	0.0000*	-47.0038	0.0001*
ATX	-48.4264	0.0001*	-48.4264	0.0001*
BFX	-47.2624	0.0001*	-47.2624	0.0001*
FCHI	-32.9571	0.0000*	-53.4073	0.0001*
FTSEMIB	-51.1855	0.0001*	-51.2106	0.0001*
GDAXI	-51.9185	0.0001*	-51.9922	0.0001*
IBEX	-52.247	0.0001*	-52.5358	0.0001*
ISEQ	-48.843	0.0001*	-48.8162	0.0001*

'' denotes rejection of the null hypothesis with significance level at %1.*

In order to conduct GARCH estimation, it is expected that variables have ARCH effect. For that reason, ARCH-LM test is applied to stock market returns. Table 4.11

shows ARCH-LM test results that rejection of null hypothesis which is no ARCH effect. As a result, all variables have ARCH effect.

Table 4.11. ARCH Effect Test of Greek Debt Crisis Analysis Data

	ARCH (1)			
	F-stat	Prob. F	LM Stat	Prob. Chi-Square
AEX	142.0307	0.0000*	134.6918	0.0000*
ATHEX	79.31733	0.0000*	77.00079	0.0000*
ATX	340.4295	0.0000*	300.8166	0.0000*
BFX	253.8278	0.0000*	231.1755	0.0000*
FCHI	119.8419	0.0000*	114.5877	0.0000*
FTSEMIB	106.6239	0.0000*	102.453	0.0000*
GDAXI	129.5797	0.0000*	123.4514	0.0000*
IBEX	98.75153	0.0000*	95.16876	0.0000*
ISEQ	168.5337	0.0000*	158.2775	0.0000*

'' denotes rejection of the null hypothesis that no ARCH effect with significance level at %1.*

4.4.4. DCC-GARCH Results

DCC-GARCH(1,1) estimation is conducted[2] according to all crisis period and crisis period. Table 4.12 demonstrates GARCH(1,1) estimation output and for two sample coefficients are statistically significant at 1% significance level. Another important point is the summation of coefficients are less than 1 and coefficients met requirement that non-negativity. This indicate that GARCH(1,1) estimation is valid.

Table 4.12. GARCH Estimation Results of Greek Debt Analysis

All Sample				
	Coefficient	Std. Error	z-Statistic	Prob.
ALPHA	0.0154	0.0010	15.5366	0.0000*
BETA	0.9778	0.0017	586.1786	0.0000*
	Log likelihood	12619.69	*AIC*	-9.812
Crisis				
ALPHA	0.0168	0.0037	4.4842	0.0000*
BETA	0.9378	0.0162	58.0340	0.0000*
	Log likelihood	2339.44	*AIC*	-12.567

'' denotes %1 significance level. AIC refers the Akaike Information Criteria.*

[2] Estimation conducted with Eviews 10 program and using DCC_RGARCH Package (Faldzinski, 2021)

The first step of analyses highlighted that GARCH estimation is statistically significant, and therefore DCCs are obtained. Figure 4.8 demonstrates DCCs between Greece stock market and Eurozone countries' stock markets.

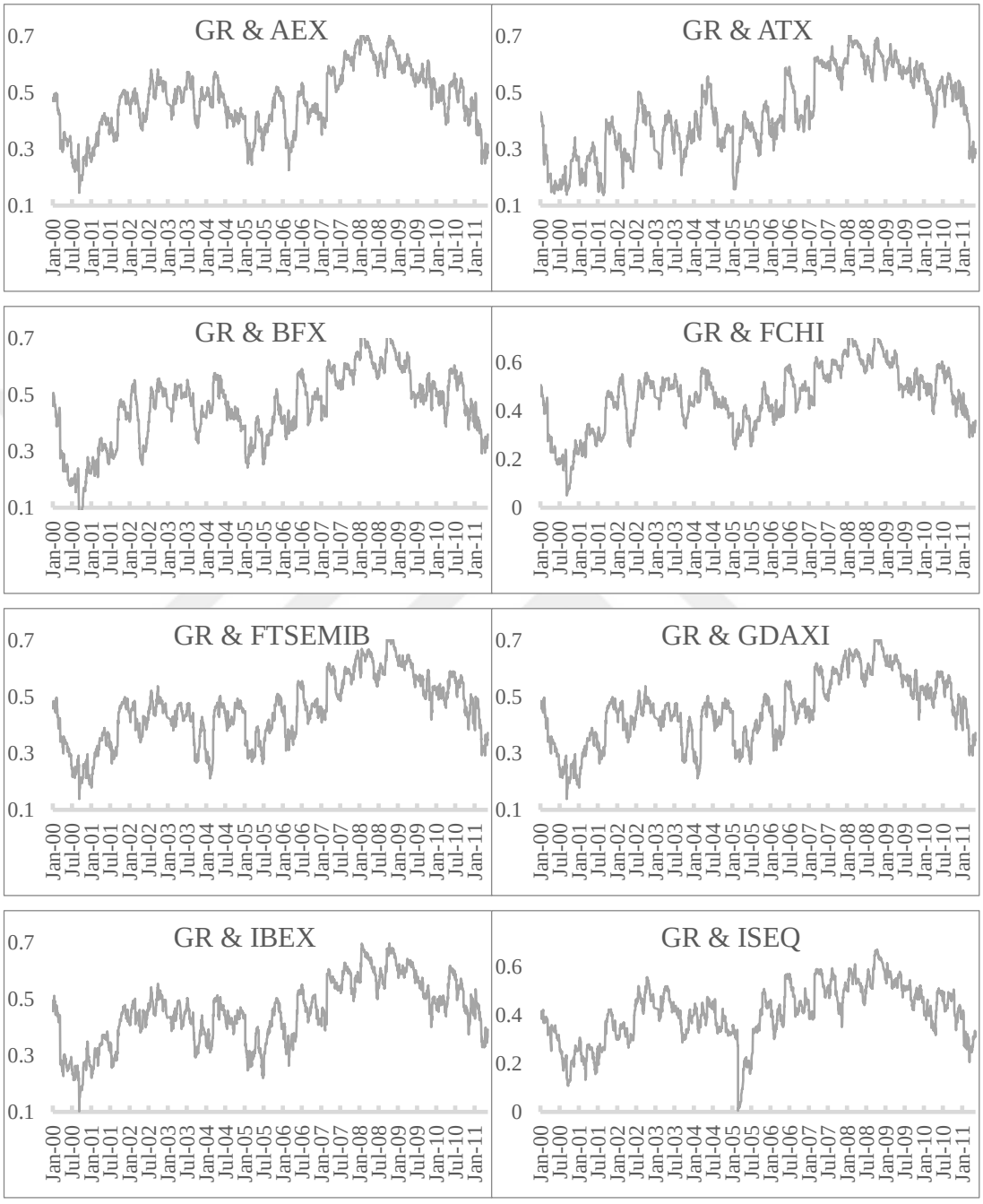


Figure 4.8. Dynamic Conditional Correlations of Greek Debt Crisis Analysis

DCCs between Greece' stock market and other Eurozone countries, excluding the Ireland stock market (ISEQ), are at their lowest during September 2000. Especially after the GFC, DCCs between Greece stock market and other countries are having

increasing trend. This trend began to shift opposite way during the October 2009 and mid-2010 again turns rising trend with fluctuations until the January 2011.

4.4.5. Contagion Test Results

DCC-GARCH(1,1) model is estimated for all sample and crisis period. As mentioned before in the method section, in order to test hypothesis of contagion is,

$H_0: \mu_\rho^{Sample} \geq \mu_\rho^{Crisis}$

$H_1: \mu_\rho^{Sample} < \mu_\rho^{Crisis}$.

Table 4.13. Contagion Test Results of Greek Debt Crisis Analysis

	Mean	Variance	t-stat	Results
GR - Netherland (AEX)	0.47019	0.012	15.375	No Contagion
Crisis Period	0.41779	0.003		
GR - Austria (ATX)	0.42708	0.021	-11.235*	Contagion
Crisis Period	0.46986	0.002		
GR - Belgium (BFX)	0.45794	0.016	-2.4853*	Contagion
Crisis Period	0.46668	0.002		
GR - France (FCHI)	0.47374	0.014	7.6211	No Contagion
Crisis Period	0.44576	0.003		
GR - Italy (FTSEMIB)	0.45664	0.014	-7.0595*	Contagion
Crisis Period	0.48010	0.002		
GR - Germany (GDAXI)	0.45159	0.012	13.669	No Contagion
Crisis Period	0.40394	0.003		
GR - Spain (IBEX)	0.45455	0.013	-9.8865*	Contagion
Crisis Period	0.48658	0.002		
GR - Ireland (ISEQ)	0.40860	0.014	2.0086	No Contagion
Crisis Period	0.40192	0.002		

'' is referred to rejection of null hypothesis at 1% and significance level.*

According to the contagion test results for Greek Crisis (Table 4.13), co-movements between stock markets during crisis period increases for between Greece & Austria, Greece & Belgium, Greece & Italy, Greece & Spain. This means that contagion effect valid at 1% significance level for these countries' stock markets. In contrast, co-movement between stock markets of Greece & Netherland, Greece & France, Greece & Germany, Greece & Ireland during the crisis period is not increasing contrast to pre-crisis period. There is contagion for these countries' stock markets.

4.4.6. Conclusion

The findings point out that the results consistent with the literature. When the results of the Greek Crisis analysis are compared with the literature, similar results are obtained. Firstly, Gomez-Puig & Sosvilla-Rivero (2014) examine the contagion by performing the causality tests, while no causality is found from Greece to Austria, Belgium, and France in the pre-crisis period, causality is found during the crisis period. No causality found for Germany and the Netherlands both before and during the crisis. Finally, while causality is not found for Italy and Spain in the pre-crisis period, during crisis period evidence for contagion is found. Moreover, Elliot et al. (2014) suggest that the cascading effect between Eurozone countries' debt. Authors also indicate that in the case of Greece's failure, the periphery countries Spain and Portugal are affected before the core Eurozone countries, and their failure caused the failure of the core countries.

In this study, which examines the contagion of the Greek Debt Crisis in the Eurozone countries in the stock market, since the cascading effects are ignored, there may be no evidence showing the contagion to the core countries. Another point is that since the GFC was just before the Greek Debt Crises, more advanced econometric methods may be preferred for the decomposition of GFC effect from analysis and obtain more clear results.

4.5. The Analysis of Eurozone Sovereign Debt Crisis

The analysis of Eurozone Sovereign Debt Crisis contagiousness firstly examined in Eurozone countries from Greece Debt Crisis. The findings reveal that Greece's Debt Crisis have not contagion effect to core Eurozone countries through stock markets, but evidence is found that European peripheral countries are affected Greece's crisis. Second part of the analysis is investigating contagion from European stock market to developed and developing countries' stock markets.

4.5.1. Data

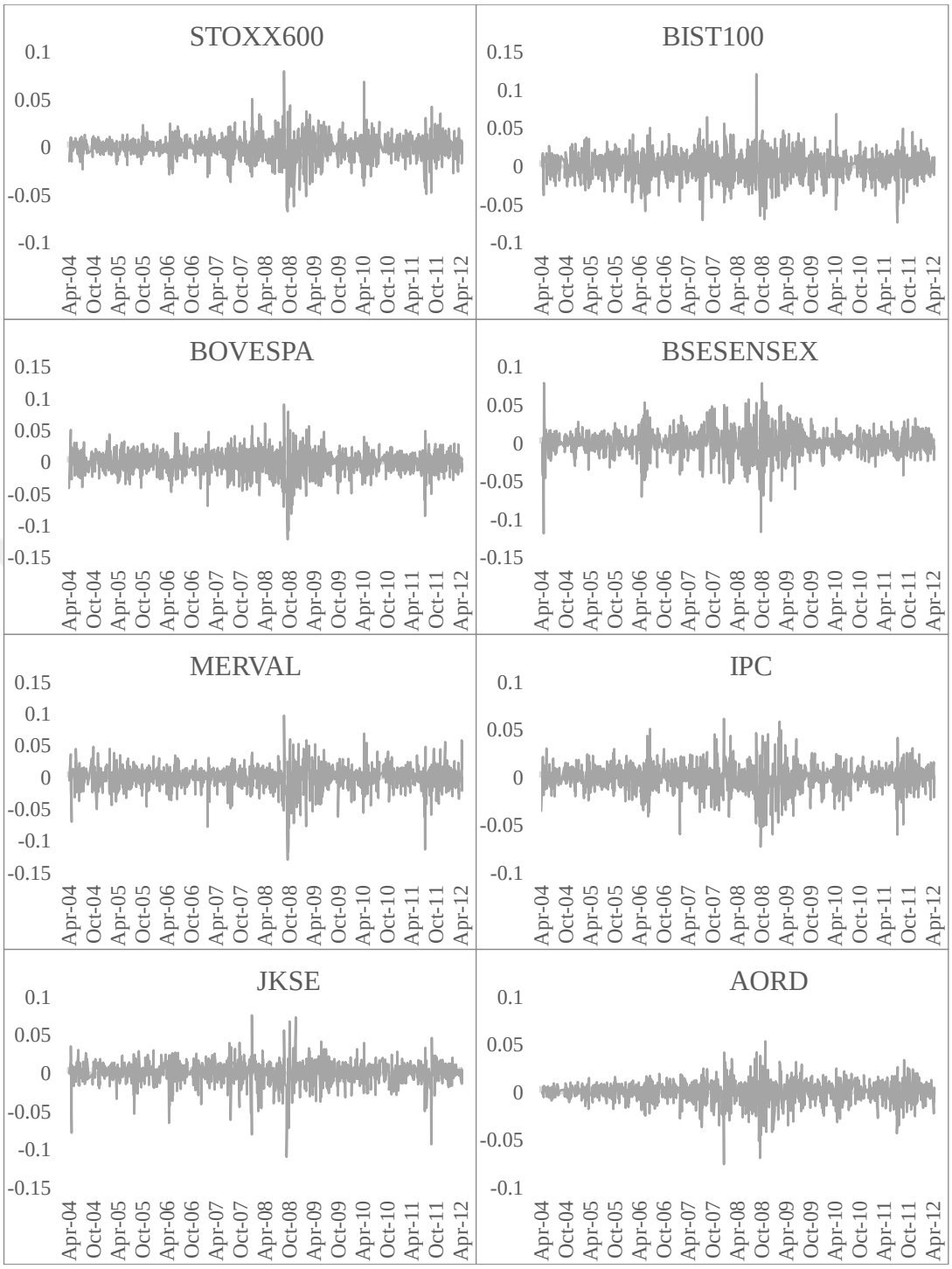
Table 4.14 shows description of Eurozone, developed and developing countries' daily stock market indices, codes. The daily data of stock markets' closed prices are obtained from Yahoo Finance (2022). The closing prices of the stock index value obtained are in the country's local currency. The STOXX 600 index, which represents the European

region, is included as the source of contagion in the analysis. Because STOXX 600 consist of UK companies stocks, UK is not included to analysis.

Table 4.14. Description of Stock Markets for Eurozone Sovereign Debt Crisis Analysis

Country	Stock Index	Code	Data Source
Europe	STOXX Europe 600	STOXX600	Yahoo Finance
Australia	AORD	AORD	Yahoo Finance
Turkey	BIST100	BIST100	Yahoo Finance
Brazil	BOVESPA	BOVESPA	Yahoo Finance
India	S&P BSE SENSEX	BSESENSEX	Yahoo Finance
U.S.	Dow Jones	DJI	Yahoo Finance
Canada	S&P/TSX	GSPTSE	Yahoo Finance
Mexico	IPC Mexico	IPC	Yahoo Finance
Indonesia	Jakarta Composite Index	JKSE	Yahoo Finance
South Korea	KOSPI	KS11	Yahoo Finance
Argentina	S&P Merval Index	MERVAL	Yahoo Finance
Japan	Nikkei 225	N225	Yahoo Finance

The ith stock market's daily returns are computed using following formula, $Returns_i = LN\left(P_{i,t} \,/\, P_{i,t-1}\right)$. The data is cleared from days when the stock market is closed, such holidays. Figure 4.9 shows return series of the stock markets.


STOXX600
BIST100
BOVESPA
BSESENSEX
MERVAL
IPC
JKSE
AORD
Apr-04
Oct-04
Apr-05
Oct-05
Apr-06
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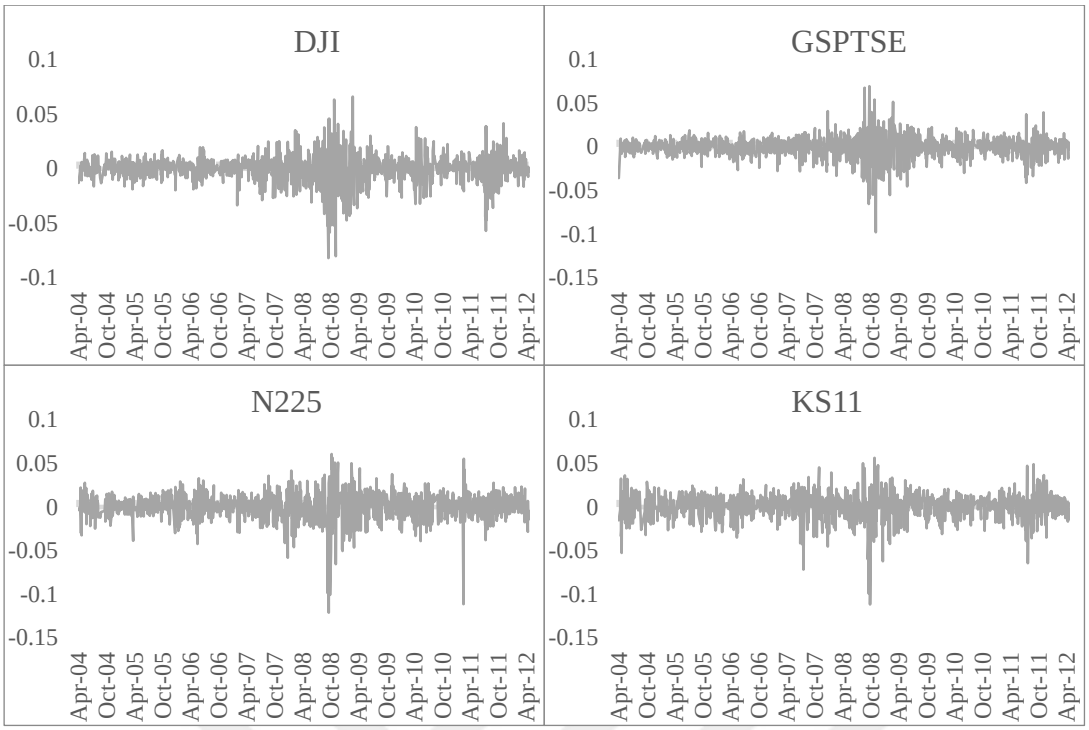


Figure 4.9. Eurozone Sovereign Debt Crisis Analysis' Return Series of Stock Markets

STOXX, BIST, MERVAL and DJI extremely volatile in September 2008, May 2010, and August 2011. The periods with the highest BOVESPA return difference are September 2008 and August 2011. BSESENSEX is highly volatile in May 2004, June 2006 and 2008. IPC is also volatile during June 2006, and from last four months of 2008 until the mid-2019. JKSE is highly volatile beginning of 2008, September 2008, and September 2011. The AORD's high volatile periods are early 2008 and September 2008. GSPTSE and KS11's returns volatile during the October 2008 and August 2011. Lastly, N225's extremely volatile in the October 2008 and March 2011.

4.5.2. Identification of Crisis Period

Kalbaska & Gatkowski (2012) defines the beginning of crisis as 14 November 2007 for impulse response analysis. Another study is also use statistical technique to identification of when crisis start is conducted by Ahmad et al. (2014). Authors examine GIPSI countries to obtain the accurate start date of the spread of the Eurozone crisis using the Markov Regime Switching method and analyzing news and reports of government agencies. Their findings indicate that while the start date of the crisis is 19 October 2009, the crisis period ends on 31 January 2012.

Horta et al. (2016) indicate when Fitch rating agency cut the extremely Greek debt rating is considered beginning of the Eurozone Sovereign Debt Crisis on 8 December 2009. Another study conducted by Samarakoon (2017) identifies crisis beginning November 2009 and ending of crisis period July 2012. In this analysis, beginning of crisis is taken as the first trading day of November 2009.

4.5.3. Preliminary Analysis

The data all sample covers periods between 28/04/2004 and 11/05/2012 with 1239 observation. The beginning of all sample period is determined according to availability of the data. The beginning day of the Eurozone Sovereign Debt Crisis period is determined following to literature Thus, crisis period is between 04/11/2009 and 11/05/2012 with 399 observations. Therefore, pre-crisis period is between 4/28/2004 and 30/10/2009 with 840 observations. Table 4.15 reports all sample, and periods pre-crisis and crisis periods' descriptive statistics for comparison purposes.

Table 4.15. Descriptive Statistics of Eurozone Sovereign Debt Crisis Analysis

	Mean	Median	Max.	Min.	Std. Dev.	Skewness	Kurtosis	JB-Stat
All Sample								
STOXX600	-0.00037	0.00029	0.080	-0.067	0.013	-0.323	7.852	1236.97*
AORD	0.00001	0.00097	0.054	-0.075	0.011	-0.632	7.446	1103.02*
BIST100	0.00060	0.00113	0.121	-0.073	0.018	-0.049	5.645	361.58*
BOVESPA	-0.00033	0.00051	0.091	-0.121	0.018	-0.546	7.092	925.97*
BSE SENSEX	0.00012	0.00089	0.079	-0.118	0.017	-0.619	8.484	1631.94*
DJI	-0.00028	0.00044	0.066	-0.082	0.013	-0.646	9.082	1995.47*
GSPTSE	-0.00034	0.00054	0.070	-0.098	0.012	-0.691	10.113	2710.31*
IPC	-0.00005	0.00082	0.062	-0.073	0.014	-0.408	6.112	534.23*
JKSE	0.00057	0.00165	0.076	-0.110	0.015	-0.980	9.746	2547.52*
KS11	0.00015	0.00117	0.056	-0.112	0.015	-1.072	9.362	2326.37*
MERVAL	-0.00056	0.00056	0.097	-0.130	0.019	-0.919	9.092	2090.43*
N225	-0.00020	0.00032	0.061	-0.121	0.015	-1.186	11.711	4207.95*
Pre Crisis								
	Mean	Median	Max.	Min.	Std. Dev.	Skewness	Kurtosis	JB-Stat
STOXX600	-0.0005	0.0004	0.080	-0.067	0.013	-0.454	8.409	1052.97*
AORD	0.0002	0.0011	0.054	-0.075	0.012	-0.726	8.119	991.06*
BIST100	0.0008	0.0013	0.121	-0.070	0.019	0.036	5.478	215.02*
BOVESPA	-0.0002	0.0007	0.091	-0.121	0.020	-0.530	6.637	502.16*
BSE SENSEX	0.0004	0.0014	0.079	-0.118	0.019	-0.678	7.652	821.86*
DJI	-0.0004	0.0004	0.066	-0.082	0.013	-0.695	9.672	1625.61*
GSPTSE	-0.0004	0.0006	0.070	-0.098	0.013	-0.746	10.048	1816.37*

IPC	-0.0001	0.0010	0.062	-0.073	0.015	-0.350	5.639	260.88*
JKSE	0.0005	0.0016	0.076	-0.110	0.016	-0.863	8.816	1288.24*
KS11	0.0001	0.0012	0.056	-0.112	0.016	-1.213	9.701	1777.48*
MERVAL	-0.0008	0.0008	0.097	-0.130	0.020	-1.054	9.222	1510.63*
N225	-0.0002	0.0004	0.061	-0.121	0.016	-1.177	10.916	2387.09*

Crisis

	Mean	Median	Max.	Min.	Std. Dev.	Skewness	Kurtosis	JB-Stat
STOXX600	-0.00009	0.00011	0.069	-0.049	0.013	-0.031	6.559	210.67*
AORD	-0.00031	0.00054	0.034	-0.043	0.010	-0.333	4.240	32.92*
BIST100	0.00015	0.00055	0.069	-0.073	0.016	-0.391	5.603	122.80*
BOVESPA	-0.00072	0.00022	0.050	-0.084	0.014	-0.613	6.522	231.18*
BSE SENSEX	-0.00039	-0.00094	0.033	-0.042	0.011	0.119	3.457	4.42
DJI	-0.00009	0.00051	0.042	-0.057	0.012	-0.472	6.550	224.31*
GSPTSE	-0.00028	0.00045	0.039	-0.041	0.010	-0.265	5.209	85.83*
IPC	0.00004	0.00033	0.042	-0.060	0.011	-0.636	6.393	218.31*
JKSE	0.00076	0.00180	0.046	-0.093	0.012	-1.391	12.105	1506.97*
KS11	0.00026	0.00085	0.049	-0.064	0.013	-0.417	5.730	135.54*
MERVAL	-0.00006	0.00028	0.069	-0.114	0.018	-0.515	8.352	493.78*
N225	-0.00026	0.00009	0.055	-0.112	0.014	-1.177	13.747	2012.31*

JB-Stat refer Jarque-Bera statistic which is test statistic for normal distribution. '' is referred to rejection of null hypothesis that normal distribution, at 1% significance level.*

Jarque-Bera statistics of variables indicate that all variables' distribution are non-normally for all sample and pre-crisis periods. In crisis period except BSE SENSEX index all variables have non-normal distribution. All variables' kurtosis values are high for all periods; therefore, variables have leptokurtic distribution. Indexes of IPC, JKSE and N225' kurtosis values higher during the crisis period than pre-crisis and all sample periods. KS11 and N225 have negative skewness value, the left-skewed distribution of variables also shown in Figure 4.10.

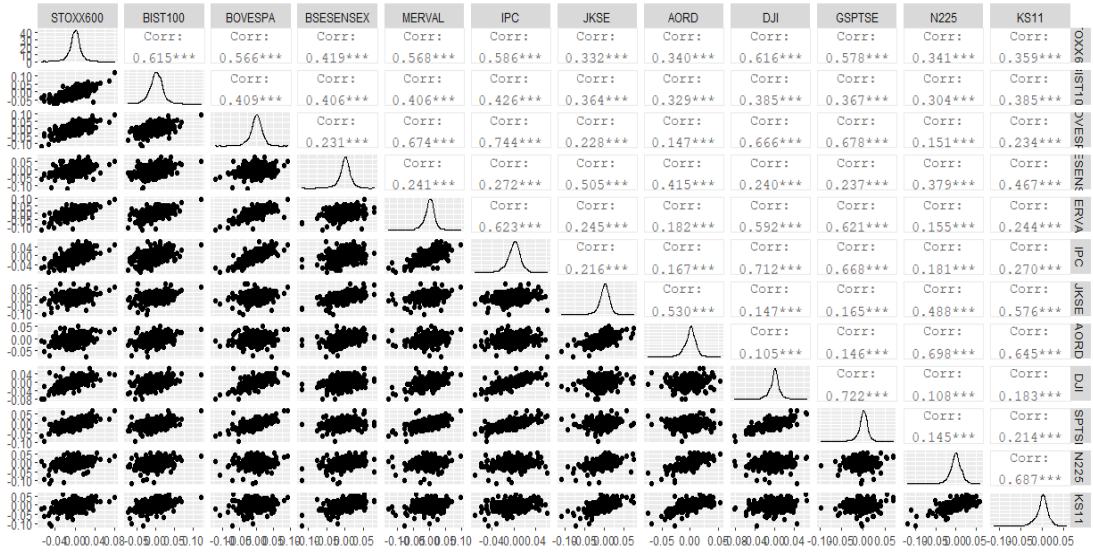


Figure 4.10. Histogram and Correlation Coefficients of Eurozone Sovereign Debt Crisis Analysis Data

Figure 4.10 illustrates correlation coefficients between the stock markets and histograms of variables for all sample. STOXX highest correlation is between DJI, BIST100 and GSPTSE with correlation coefficients 0.616, 0.615, and 0.578, respectively. Hence, STOXX highest stock market correlation is between US, Turkey, and Canada's stock markets. Highest correlation coefficients between variables is between stock market index of Mexico (IPC) and stock market index of Argentina (BOVESPA) with 0.72 correlation coefficient.

The null hypothesis of ADF and PP unit root test is variable has unit root. According to the Table 4.16, statistics indicate that the null hypothesis is rejected, and stock index returns are stationary at their level.

Table 4.16. Unit Root Tests of Eurozone Sovereign Debt Crisis Analysis Data

	ADF	Prob.	PP	Prob.
STOXX600	-27.6181	0.0000*	-35.2611	0.0000*
AORD	-34.9517	0.0000*	-35.0443	0.0000*
BIST100	-35.0871	0.0000*	-35.0965	0.0000*
BOVESPA	-36.8125	0.0000*	-36.8356	0.0000*
BSESENSEX	-36.8607	0.0000*	-36.8686	0.0000*
DJI	-40.4616	0.0000*	-40.3945	0.0000*
GSPTSE	-37.8058	0.0000*	-38.0022	0.0000*
IPC	-34.7745	0.0000*	-34.7998	0.0000*
JKSE	-32.9731	0.0000*	-32.9146	0.0000*
KS11	-34.39	0.0000*	-34.4724	0.0000*
MERVAL	-34.2306	0.0000*	-34.2204	0.0000*
N225	-36.9566	0.0000*	-36.975	0.0000*

'' denotes rejection of the null hypothesis with significance level at %1.*

The ARCH-LM test is applied to investigate whether the variables has an ARCH effect. Table 4.17 shows ARCH-LM test results which report that variables have ARCH effect.

Table 4.17. ARCH Effect Test of Eurozone Sovereign Debt Crisis Analysis Data

	ARCH (1)			
	F-stat	Prob. F	LM Stat	Prob. Chi-Square
STOXX600	78.38762	0.0000*	73.82854	0.0000*
AORD	47.86614	0.0000*	46.15479	0.0000*
BIST100	18.82457	0.0000*	18.57197	0.0000*
BOVESPA	12.56884	0.0004*	12.46236	0.0004*
BSESENSEX	205.6746	0.0000*	176.5975	0.0000*
DJI	59.59726	0.0000*	56.94575	0.0000*
GSPTSE	36.47759	0.0000*	35.48846	0.0000*
IPC	51.48935	0.0000*	49.50863	0.0000*
JKSE	39.17748	0.0000*	38.03438	0.0000*
KS11	70.06885	0.0000*	66.41425	0.0000*
MERVAL	30.78189	0.0000*	30.08196	0.0000*
N225	28.72478	0.0000*	28.11732	0.0000*

'' denotes rejection of the null hypothesis with significance level at %1.*

4.5.3. DCC-GARCH Results

According to the model as mentioned in the Method section, DCC-GARCH(1,1) model is estimated[3] for all sample and crisis period.

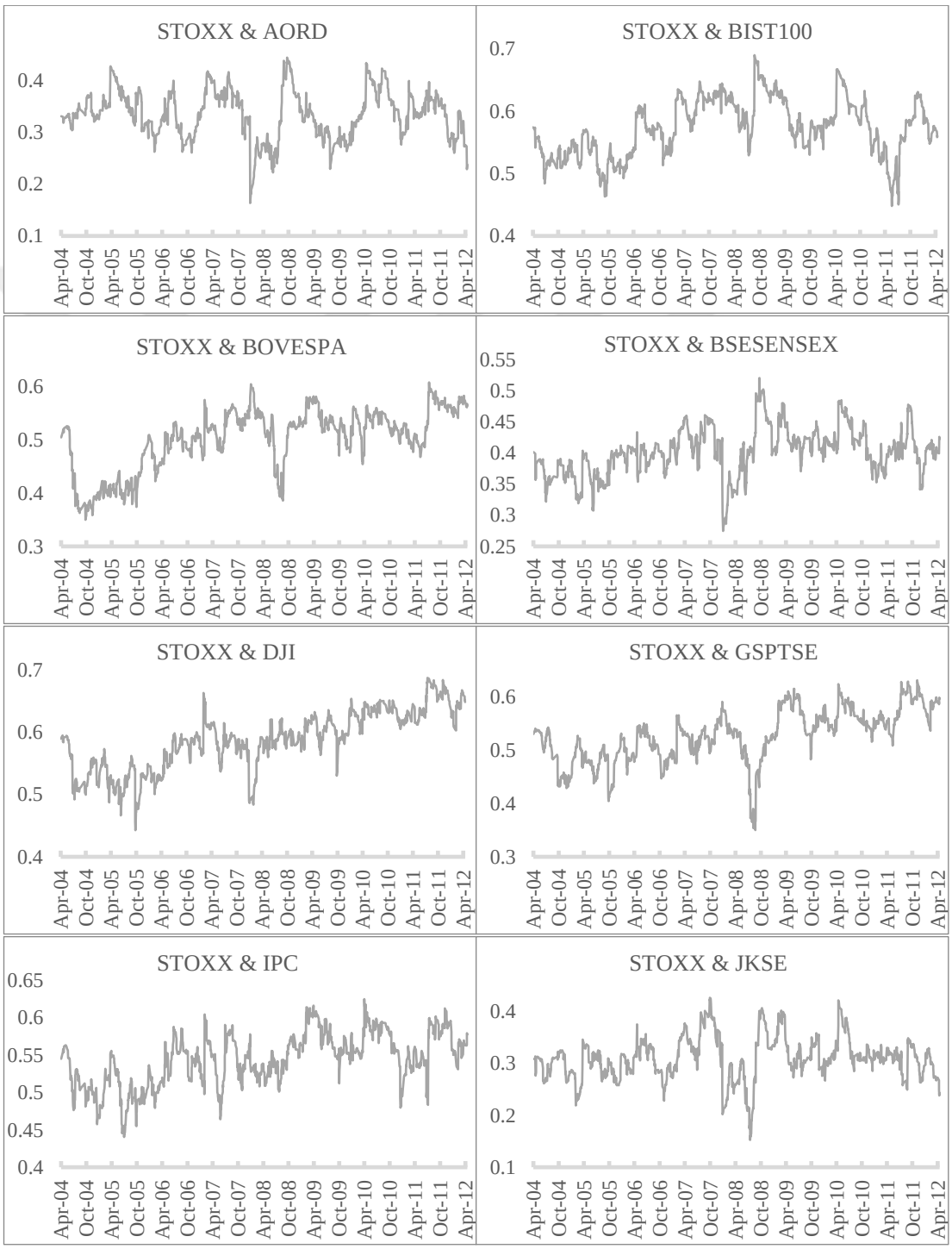
Table 4.18. GARCH Estimation Results of Eurozone Sovereign Debt Crisis Analysis

All Sample				
	Coefficient	Std. Error	z-Statistic	Prob.
ALPHA	0.0110	0.0012	9.0680	0.0000*
BETA	0.9627	0.0051	190.2402	0.0000*
	Log likelihood	3982.95	*AIC*	-6.426
Crisis				
ALPHA	0.0094	0.0033	2.8880	0.0039*
BETA	0.9220	0.0341	27.0098	0.0000*
	Log likelihood	1487.11	*AIC*	-7.444

'' denotes %1 significance level. AIC refers the Akaike Information Criteria.*

[3] Estimation conducted with Eviews 10 program and using DCC_RGARCH Package (Faldzinski, 2021)

Table 4.18 reports the GARCH(1,1) coefficients of all sample and crisis period. The conditions for GARCH (1,1) validity have been satisfied with following results. The parameters are positive, and their summation is less than one. Alpha and Beta coefficients are statistically significant with %1 significant level.



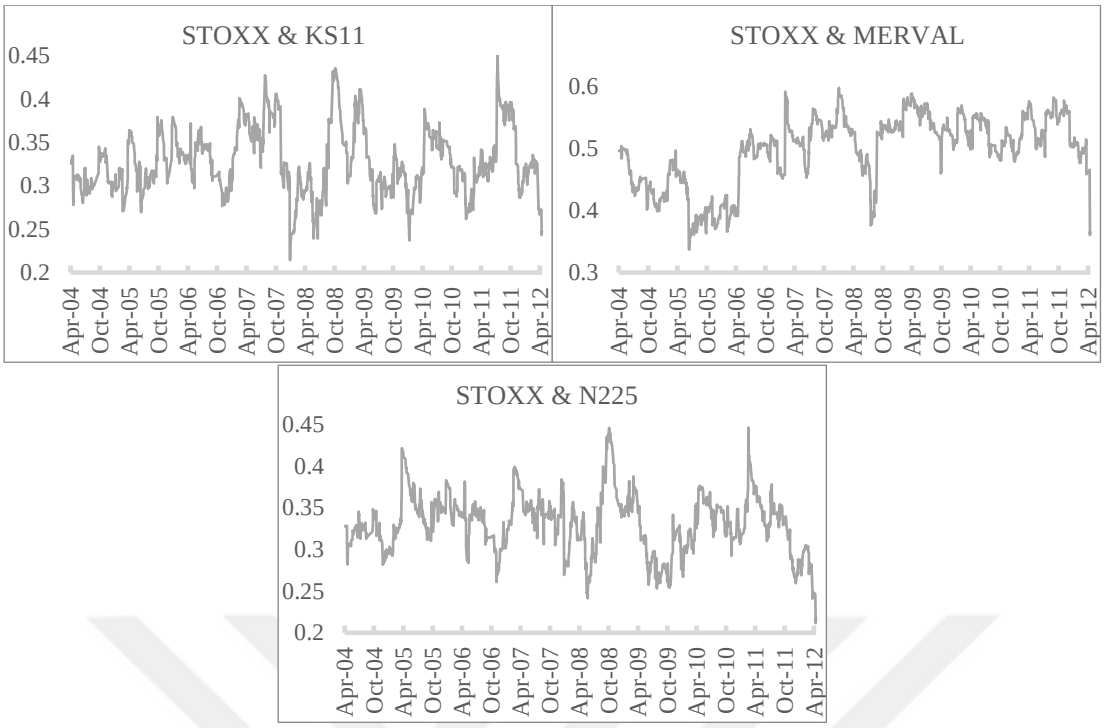


Figure 4.11. Dynamic Conditional Correlations of Eurozone Sovereign Debt Crisis Analysis

Figure 11 illustrates STOXX and other stock market index's DCCs. STOXX and US stock market DJI DCCs have increasing trend after mid-2008. The same effect as seen for the Canada stock market GSPTSE with fluctuations. Between the STOXX with Australia and Asian countries' stock markets DCCs are low when comparing to other stock markets in the analysis.

There are points where DCCs are highest between STOXX and other countries' stock markets, which draw attention in the Figure 11. Firstly, GFC effect clearly can be seen during the mid-2008 for STOXX & AORD, STOXX & BIST100, STOXX & BSESENSEX, STOXX & JKSE, STOXX & KS11, STOXX & N225.

At the beginning of May 2010, DCCs between STOXX and AORD, BIST100, BSESENSEX, GSPTSE, JKSE is high. On May 6, 2010, the stock markets of US suddenly faced strong stock sales. Due to this situation, which went down in history as "Flash Crash", the DJI index experienced a daily decline of 9% (Demirer et al., 2019) .

DCCs between STOXX & BOVESPA and STOXX & KS11 is high during the beginning of August 2011. A significant decline in the condition of the financial markets globally during the end of July and the beginning of August prompted the

European Central Bank (ECB) to unveil a series of unconventional monetary policy measures on 4 August 2010. Also, the credit rating agency S&P downgrade the US credit rating on 5 August 2010. At the same date, 10-year government bond spreads in the majority of the euro area nations hit record highs, this led to increasing CDS of European Countries (European Central Bank, 2011).

Lastly, STOXX & N225's one of highest DCC at mid-March 2011. As a result of the 2011 Major Japan earthquake during mid-March, the shock spread from the Japanese stock market to other countries through the stock markets (Kahraman & Keser, 2022).

4.5.5. Contagion Test and Results

DCC-GARCH(1,1) model is estimated for all sample, and crisis period. As mentioned before in the method section, the obtained DCCs from estimation is used in order to test hypothesis of contagion is,

$H_0: \mu_\rho^{Sample} \geq \mu_\rho^{Crisis}$

$H_1: \mu_\rho^{Sample} < \mu_\rho^{Crisis}$.

Table 4.19 reports contagion test results with mean, variance, and t-statistics.

Table 4.19. Contagion Test Results of Eurozone Sovereign Debt Crisis Analysis

	Mean	Variance	t-stat	Results
EU & Australia (AORD)	0.3330	0.0021	-0.703	No Contagion
Crisis	0.3342	0.0005		
EU & Turkey (BIST100)	0.5732	0.0021	-4.009*	Contagion
Crisis	0.5802	0.0006		
EU & Brazil (BOVESPA)	0.5013	0.0032	-67.264*	Contagion
Crisis	0.6228	0.0003		
EU & India (BSESENSEX)	0.4008	0.0014	-30.851*	Contagion
Crisis	0.4471	0.0004		
EU & US (DJI)	0.5871	0.0022	-118.790*	Contagion
Crisis	0.7551	0.0001		
EU & Canada (GSPTSE)	0.5278	0.0025	-97.951*	Contagion
Crisis	0.6790	0.0002		
EU & Mexico (IPC)	0.5437	0.0013	-61.919*	Contagion
Crisis	0.6215	0.0002		
EU & Indonesia (JKSE)	0.3099	0.0017	-0.696	No Contagion
Crisis	0.3110	0.0005		
EU & South Korea (KS11)	0.3270	0.0015	13.530	No Contagion
Crisis	0.3058	0.0005		
EU & Argentina (MERVAL)	0.4978	0.0032	-36.686*	Contagion

Crisis	0.5670	0.0004		
EU & Japan (N225)	0.3300	0.0013	21.969	No Contagion
Crisis	0.2991	0.0004		

There is no evidence for contagion from European stock market to Australia, Indonesia, South Korea, and Japan' stock markets. Contagion test results imply that the correlations between European stock market and Turkey, Brazil, India, Mexico, Argentina's stock markets increases during crisis period in contrast to before the crisis.

4.5.6. Conclusion

As a result of the analysis, the co-movement between European stock market and developing markets except Indonesia and South Korea's stock market is increases during the crisis. The increasing coefficients indicate there is evidence for contagion between the Europe and Turkey, Brazil, India, Mexico, and Argentina. For advanced economies' markets, evidence is found between Europe and US, and Canada. In contrast, for Australia and Japan there is no European Sovereign Debt Crisis contagion effect.

The findings show that during the Eurozone Sovereign Debt Crisis, other global events caused an increase in DCCs between European stock market and other stock markets. The most striking of these is that the 2010 Flash Crash in the US caused a high correlation between the EU stock market and the markets of developing and developing economies. Another point that can be drawn from this result is that the shock in the stock market may have been from the USA to the developing and developing economies with the EU stock market. According to DCCs' Brazil and South Korea, they are the most affected developing countries, even there is no contagion from EU to South Korea according to contagion test, during reason of series of events in early August 2011. These events are the downgrade of the US credit rating and the reaction of the sovereign bond spreads in European countries to this event. The ongoing debt crisis may have caused concern in global markets with the serious increase in bond spreads. Another point is that as Chiang et al. (2007) indicate that stock markets are vulnerable to such structural changes when credit rating agencies change the credit ratings of countries, even a change in the credit rating of a foreign country. In the light of this information, the EU stock market, already vulnerable due to the ongoing debt crisis, may have been affected by the change in US credit rating, and passing this shock to other countries.

CHAPTER 5
CONCLUSIONS AND FUTURE RESEARCH

Before the financial liberalization period in developing countries after the year 1980s, the pervasive effect of the crises was relatively limited. Nowadays, the structure of the financial system lead crises to spread easily to rest of the world and gain a global character. In case of financial contagion, financial markets begin to fail to fulfill their function of efficient fund flow into the real economy. At this point, balance of payment deteriorates, and the government seek the new fund sources such as money supply, foreign/public debt or reduction in public expenditures or tax income. Developing countries generally prefer to apply foreign debt instead of income-increasing and expense-reducing regulations. So that hot money inflow with high interest rate and low-level exchange rate policies are highly seen in developing countries. On the other hand, developed countries are able to have a long-term debt structure due to the string domestic currency.

Even there is no consensus on the definition of the contagion, which examines why and how crises spread between countries, according to the theoretical framework, the spread channels of crises can be grouped under three main headings. These are trade relations, financial links, and the behavior of investors. To examine the contagion with stock markets is one of the most preferred markets in the literature, as well as facilitating both access to data and testing contagion. This also makes possible to examine the channel of investor behavior, as investors' herding behavior and rebalancing the portfolios to avoid risk which is also reflected in the stock market as well.

In this thesis study, the stock markets of the countries are tested for contagion by comparing the Dynamic Conditional Correlation coefficients obtained from the GARCH estimation for the all period and during the crisis period’s samples. First of all, the 2008 Global Financial crisis is examined among the top ten countries with the highest total value of stocks traded in the world. The results show that there is a strong relationship between the stock market of the crisis source country, the US, and

European countries, even in the pre-crisis period. It is determined that the stock market correlation increased during the crisis period. There is evidence of the contagion between US and European stock markets as a result of the applied contagion test. The US and Asian countries' stock markets shows the weak links in the pre-crisis and crisis periods. The contagion test result indicates that there is no contagion from the US to China and Japan, except for South Korea.

The contagion of the Greek debt crisis is tested with core and periphery Eurozone countries. This analysis form is the first part of the analysis of the European Sovereign Debt Crisis. Due to the 2008 Global Financial Crisis just before the Greek debt crisis, the all sample range is kept wide in order to avoid the high correlation between the markets that could be caused by the 2008 Global Financial Crisis. The findings show a result consistent and parallel with the empirical literature. While there is no evidence of spread from Greece to core Eurozone countries, there is contagion to peripheral countries. Hence, Greek crisis does not have a direct impact on the core Eurozone countries through stock markets. This effect can be examined in future studies by focusing on also other markets or channels. At this point, it should be considered that the Greek debt crisis may have spread through other peripheral countries to the core countries where there may be a cascading effect between the stock markets.

The results of the analysis present important findings in the analysis of the Eurozone Sovereign Debt Crisis. According to results, evidence for the contagion from Europe to some developed and developing countries is found, but not for some others. Events that increase the dynamic correlation between the European stock market and the markets of other countries have been identified. The sudden shock in the US stock market and the decrease in the credit rating of the US country caused the correlation between the European stock market and the markets of other countries to increase, even to become one of the highest points for some countries. This indicates that the external shocks or the shock may have been transmitted through the markets of other countries. This should be investigated in future studies for clearer and more specific results.

In financial economics, countries may suffer from the effects of the crisis through another country transmitting the shock. Due to the today's economic openness and international financial flow, not suffering from the crisis even volatility or shocks seem almost impossible. So that, the contagion and its' channels play a crucial role in

transmission of risk and crisis, thus in contagion as well as policy makers. Among financial markets stock market is the most-riskiest one. Because as one of the main characteristics, stock markets have random walk and not effected by the past information, called “Random Walk Theory” (Malkiel, 1973). Moreover, there are many investors who have different risk perceptions and buy-hold behaviors, so high volatility is possible without any additional risk, even in normal times. In crisis periods, because of the high-risk level in financial markets, speculative bubble can be seen and investors respond any change very rapidly by rebuilding their portfolio or by pricing behavior. So that, policy makers should determine the policy implications to reduce risk level and volatility against any contagion. Policy timing is also must to get the expected reaction of the decision makers. Moreover, monitoring and forecasting are the other two key tools. First, macroeconomic policy makers should determine the contagion channels. Secondly, they should perform forecasting techniques mainly for the value of domestic currency, exchange rates and O/N to determine the policy intervention measure. Thirdly, Central Bank may intervene the O/N to affect the money supply which directly effects not only to financial markets but also real sector; considering investment companies, multinational corporations, international trade companies etc. Lastly, legislations and regulations might be other necessary actions against the fund flow. No doubt, world economies will continue to face crisis, thus effective and on time policies may reduce the degree of contagion.

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