THE VOLATILITY SPILLOVER AMONG A COUNTRY'S FOREIGN EXCHANGE, BOND, AND STOCK MARKETS: A MULTIVARIATE GARCH ANALYSIS

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ABSTRACT

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The purpose of this study is to examine the volatility spillover among a country's foreign exchange, bond and stock markets and the volatility transmission from the global bond, stock and commodity markets to these local financial markets. The sample for the study includes data from both emerging and developed economies in the time period between 2004 and 2011. A multivariate GARCH methodology with the BEKK representation is applied for the local financial markets and global variables are included as exogenous variables into the model. The volatility integration of the financial markets of the emerging economies is stronger compared to the integration of the developed economies. Global variables have a spillover effect on the developed markets only after the global financial crisis, whereas they significantly affect the volatility in emerging markets for both the pre- and post-crisis period. North American countries in the sample, U.S. and Mexico, have low local volatility integration in the pre-crisis era and the integration rises in the post-crisis period. Moreover, they are more open to the internal and global short-term shocks in the post-crisis period. Germany and Turkey are the representatives of the EMEA (Europe, Middle East and Africa) region and they have high local market integration and are open to global shocks for both sub-periods. Far Eastern markets, Japan and Korea, also have high local market integration and their vulnerability to the global effects is large and getting larger for the post-crisis period. The most important limitation of this thesis is the difficulty of reaching sharp generalizations due to the small number of countries analyzed. This limitation can be addressed by the inclusion of a larger number of geographically dispersed countries. The most noteworthy originality of this study is the addition of the exogenous global variables for modeling volatility spillovers. Furthermore, comparison of results for emerging versus developed markets and the pre- versus post-crisis periods is another contribution of this study to the existing literature. The findings of this study can be used by investors interested in assessing the risks of investing internationally.

Keywords: Volatility Spillover, Multivariate GARCH, Financial Markets, Emerging vs. Developed Markets, Global Financial Crisis

ÖZ

ÜLKELERİN DÖVİZ, TAHVİL VE HİSSE SENEDİ PİYASALARI ARASINDAKİ OYNAKLIK YAYILIMLARI:
ÇOK DEĞİŞKENLİ GARCH ANALİZİ

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Bu çalışma, bir ülkenin döviz, tahvil ve hisse senetleri piyasaları arasındaki oynaklık yayılımlarını; ve küresel tahvil, hisse senedi ve emtia piyasalarından bu yerel piyasalara olan oynaklık aktarımlarını incelemeyi amaçlamaktadır. Bu çalışmanin örneklemi, 2004-2011 yılları arasında hem gelişmekte olan hem de gelişmiş ekonomilerin verilerini içermektedir. Ülke içi finansal piyasalar için BEKK gösterimli çok değişkenli GARCH modeli uygulanmış olup, küresel değişkenler modele dışsal değişkenler olarak katılmıştır. Gelişmekte olan ekonomilerin finansal piyasalarının oynaklık entegrasyonu gelişmiş ekonomilerin piyasalarının oynaklık entegrasyonuna kıyasla daha güçlüdür. Küresel değişkenlerin yayılım etkisi gelişmiş piyasalar için yalnızca küresel finansal kriz sonrası dönemde bulunurken, bu değişkenler gelişmekte olan piyasaların oynaklıklarını hem kriz öncesi hem de kriz sonrası dönemde anlamlı bir şekilde etkilemektedir. Örneklemdeki Kuzey Amerika ülkeleri olan ABD ve Meksika'da kriz öncesi dönemde düşük düzeyde yerel finansal piyasalar oynaklık entegrasyonu bulunmakta olup, bu entegrasyon kriz sonrası dönemde artmaktadır. Ayrıca bu ülkeler iç ve küresel kısa süreli şoklara, kriz sonrası dönemde daha açık durumdadırlar. Avrupa, Orta Doğu ve Afrika bölgesini temsil eden Almanya ve Türkiye, yüksek düzeyde ülke içi piyasalar arası oynaklık entegrasyonuna sahip olup, yerel piyasalarının küresel şoklara kriz öncesi ve sonrası dönemde açıklığı bulunmaktadır. Uzak Doğu piyasaları olan Japonya ve Kore de yüksek yerel finansal piyasalar oynaklık entegrasyonuna sahiptirler. Bu ülkelerin iç piyasalarının küresel etkilere hassaslığı yüksek olup, küresel finansal krizle bu hassaslık daha da artmıştır. Bu çalışmanın en önemli kısıtı incelenen ülke sayısının azlığından dolayı kesin genellemelerde bulunulamamasıdır. Bu kısıt coğrafi olarak dağılmış daha çok sayıda ülkenin analiz edilmesi yoluyla giderilebilir. Bu tezin en dikkat çekici özgünlüğü ise oynaklık yayılımlarının modellenmesine küresel değişkenlerin dışsal olarak eklenmesidir. Ayrıca, sonuçların gelişmekte olan ve gelişmiş piyasalar; kriz öncesi ve kriz sonrası arasında karşılaştırılması, bu çalışmanın mevcut literatüre yaptığı bir diğer katkıdır. Bu çalışmanın bulguları, yatırımcılar tarafından uluslararası yatırımın risklerinin değerlendirilmesi amacıyla kullanılabilir.

Anahtar Kelimeler: Oynaklık Yayılımı, Çok Değişkenli GARCH, Finansal Piyasalar, Gelişmekte ve Gelişmiş Piyasalar, Küresel Finansal Kriz

To my family, and especially my mother

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CHAPTER 1

INTRODUCTION

Volatility has become one of the main discussions of the financial literature in recent years. Advances in the computation of the second moment of return distributions and capability of applying these models by the assistance of software packages make volatility spillovers as the focal point for many studies. Increasing globalization and integration of the world markets require the examination of volatility transmissions in order to objectively determine the risk taken by agencies investing internationally. Since the existence of volatility spillovers increases the level of systemic risk and thus limits the level of international diversification, the structure and transmission of volatility should be analyzed, modeled and forecasted.

The Literature Survey section of the thesis summarizes the recent studies about volatility. Studies analyzing spillover for the same type of markets and different markets are reviewed separately.

Following the literature survey, the Data and Methodology chapter is presented. In the Data part, the intuition behind the selection of local variables, foreign exchange rate, bond and stock returns are explained. The global variables, global bond, global stock and global commodity indices that are included in this study make the model of this study distinctive among the similar academic studies. The data section also explains the rationale behind the choice of sample countries, namely the U.S., Mexico, Germany, Turkey, Japan and Korea, is described with reference to the regional and market development level groupings. The sample period from January 2, 2004 to December 30, 2011, is rationalized by the arguments of data availability and the continuous growth rate period observed in countries just prior to the global financial crisis in 2008. At the end of the data section, descriptive statistics, correlation results and stationarity test findings are presented.

In the Methodology section data transformations, diagnostic tests and volatility models are described. After demonstrating the insufficiency of the VAR model, an alternative GARCH modeling is proposed. The BEKK representation, whose variance-covariance matrix is displayed below, is selected for the multivariate GARCH model.

$$\Sigma_t = C'C + B'\Sigma_{t-1}B + A'\mathcal{E}_{t-1}\mathcal{E}'_{t-1}A + D'DX_{1t-1}{}^2 + E'EX_{2t-1}{}^2 + F'FX_{3t-1}{}^2 \qquad (1.1)$$

Although it has some drawbacks such as the difficulty of computation when the number of variables is high, the BEKK representation enables the positive definiteness of variance series by adding the ARCH and GARCH terms in multiplicative form, which is invaluable for obtaining credible results. In order to preserve the positive definiteness, the exogenous variables (global securities indices) are included in squared form. Each country's foreign exchange, bond and stock market volatilities are modeled by their own multivariate GARCH (long-run parameter) and ARCH (short-run parameter) terms as well as the ARCH coefficients of the global securities indices. As a result, it is possible to see the long- and short-run effects of each country's own foreign exchange, bond and stock market variances and the short- run shocks of the global bond, stock and commodity markets. Robust standard errors, which remove the requirement of normal distribution of error terms, are used.

In the Results and Analyses chapter, all models and diagnostic test results are presented. The findings are provided for the entire sample period as well as the pre-crisis and post-crisis periods on a comparative basis. The sample period is divided into two sub periods by taking the beginning of speculations in September 2008 related to the bankruptcy of the Lehman Brothers and acquisition of Merrill Lynch by the Bank of America as a reference and the same methodology is applied separately in order to the existence of a structural break in the volatility series. Diagnostic test results of all these models are summarized in tables in order to see the advantages of using a VAR-GARCH model instead of a basic VAR model and subsampling instead of a whole sample analysis. The Conclusion chapter presents some generalized findingsfor each geographical location. Finally the shortcomings of the model are discussed and some likely future studies are recommended.

CHAPTER 2

LITERATURE REVIEW

The structure of the relationship and transmission among the stock, foreign exchange and bond returns has been examined by the regression and causality methods for a very long time. However, analyzing the relationships of the second moments of these variables is relatively new and uncompleted. Past studies mostly consisted of the univariate examination of volatilities, which ignored the transmission mechanism between the different markets. The introduction of the multivariate GARCH models and their improved representations haverendered the inspection of these transmission mechanisms possible. A chronological order will be pursued in the similar variable clusters in order to review the previous studies,. The spillovers between the volatility of the returns have first been analyzed among the same kind of markets but in different locations such as New York and London stock exchanges. Volatility spillovers among the different types of markets have followed these studies and included stock, foreign exchange and bond markets. There are also some studies that include macroeconomic variables to model the volatility series.

2.1. Volatility Spillovers among the Same Type of Markets

The earliest volatility spillover analyses were conducted among the different stock market returns. Hamao [27] has one of the earliest works and tries to measure the volatility transmission among the returns of the New York, London and Tokyo stock exchanges by the GARCH-M model between April 1985 and March 1988. They conclude that S&P 500 and FTSE 100 index volatilities significantly affect the volatility of the Nikkei 225 index. Another study by Karolyi [34] indicates the unidirectional spillover from the S&P 500 index to TSE 300 (Toronto Stock Exchange) between April 1981 and December 1989 by using multivariate GARCH with the BEKK and CCC representations. Booth et al. [10] apply the EGARCH methodology for the 4 Scandinavian stock markets between 1988 and 1994. They find that there are bidirectional spillovers between Danish-Finnish and Finnish-Swedish and unidirectional spillover between Swedish- Norwegian stock market pairs. Kanas [32] studies the volatility transmission in the major European stock exchanges (London, Paris and Frankfurt) between 1984 and 1993 by multivariate EGARCH. His findings show the bidirectional spillover among these stock exchanges, which means the high integration of European equity markets. Ng [47] examines the volatility spillovers to the Asian countries from the Tokyo and New York stock exchanges representing the regional and global effects respectively. His study examines the period between

1975 and 1996 and concludes that the regional and global effects are quite small (global one is relatively larger) on Asian stock markets but get larger after the financial liberalization and openness of these markets. Another study by Miyakoshi [43] analyzes the same Asian countries with a shorter but newer period between 1998 and 2000. Contrary to the previous work, effect of Japanese stock market is found to be larger than the U.S. stock market in a period following the Asian crisis. Worthington and Higgs [58] make a research for the same geography in the period of 1988-2000 by using the GARCH BEKK methodology. They find that the volatility transmission is larger for the developed markets such as Hong-Kong, Singapore and Japan. The main argument for this clear difference is proposed as the stronger ties of the developed markets to the global markets with respect to the emerging ones such as Indonesia and Thailand. Baele [5] conducts a survey on 13 European equity markets between January, 1980 and August, 2001. The regime switching GARCH model used in this work clearly shows the increasing effects of the volatility spillover inside the Europe and the United States. Li and Majerowska [38] apply the GARCH approach on Warsaw and Budapest stock exchanges in the period of 1998-2005. They conclude that there are unidirectional transmissions from the DAX and S&P 500 indices to both of the Eastern European stock exchanges. Furthermore, Warsaw and Budapest stock markets have bidirectional effects on each other. In a recent study by Sok-Gee and Karim [55], EGARCH is used for the determination of volatility transmission from the Asian local, Japanese and American markets to the Asian local markets. Their findings are rather different than the previous study of Miyakoshi [43] for this region, since they support the stronger effects of the U.S. markets instead of Japanese markets. Among the local Asian markets, the Philippines Stock Exchange is the most affected from other markets. These studies generally show that stock exchanges in the developed countries have serious volatility spillovers due to their higher financial integration. Emerging markets are also affected by the global spillovers, whereas other markets in the same region are not affected with equal significance.

Though it is not as widespread as the studies on transmission between the stock market volatilities, there are also works on the foreign exchange market spillovers. Hong [28] examines the volatility relationship between DM/$ and Yen/$ rates in the period of 1976-1995. The unidirectional spillover from DM/$ to Yen/$ is identified as a conclusion of this research. Another study conducted by Black and McMillan [6] apply the CGARCH method for a number of widespread circulated currencies between 1974 and 1998. They have concluded that Japanese Yen and Italian Lira transmit their volatility to Canadian Dollar and British Pound respectively. Moreover, Japanese Yen is affected by DM, lira and pound, while French Franc is affected by all the currencies in the study except for lira.

The volatility spillover researches among the interest rates or bond returns are also uncommon. Edwards [19] conducts a survey on the volatility spillover of the short term deposit interest rates in Mexico, Chile and Argentina for the period between January, 1992 and June, 1998. The results of the GARCH method indicate a transmission from the Mexico to Argentina. Another study completed by Skintzi and Refenes [53] analyzes the bond market volatility among the bonds of 12 European countries, aggregate European bond index and U.S. bond index by bivariate EGARCH for the 1991-2002 period. Aggregate European bond index volatility has a unidirectional influence on the bond volatility of the Austrian, Spanish and Swedish individual bond markets. Belgium, Denmark, U.K., France, Germany and Italy have bidirectional volatility transmission with the aggregate European index. Dutch and Norwegian indices have a one-way effect on aggregate European index. U.S. bond index is also significantly transmits its volatility to the individual European bond markets.

2.2. Volatility Spillovers among Different Type of Markets

Following the studies investigating the spillover between the same types of markets, analyses inquiring the transmission between different financial markets began. Most of these studies are about the volatility spillover between stock and foreign exchange markets. Kanas [33] researches on these transmission effects for the markets of the G-7 countries in 1986-1998. His findings indicate that volatility from stock markets affect all the foreign exchange rates with an exception of DM/$ rate. These effects are positive and non-asymmetric, which means that an increase in the volatility of the stock market will trigger the volatility of the mentioned foreign exchange rates and there is no stronger effects of volatility declines. On the other hand, foreign exchange volatilities are ineffective to move the stock market volatilities in all countries. His conclusion is the unidirectional volatility transmission from stock market to foreign exchange markets for the developed economies. Apergis and Rezitis [4] examine the spillover between the DJIA and FTSE indices to identify whether the opening and closing price volatilities affect the each other. Bivariate GARCH methodology is applied for the data between January, 1992 and August, 1999. The results show that there is only long-run volatility persistence from stock market to foreign exchange market, whereas news effects are lacking. On the other hand, news shocks or meteor effects are dominant from the foreign exchange market to stock market instead of volatility persistence. Caporale et al. [12] analyze the East Asian markets. GARCH BEKK methodology is used for the period of 1987-2000. They have concluded that stock market volatility does not affect the foreign exchange volatility, but this effect gets more significant for the period just behind the Asian Crisis. There is also lacking spillover from foreign exchange to stock markets for the Indonesia and Thailand before the crisis. However, after the crisis, spillover from foreign exchange volatility to stock markets gets certainly significant for all 4 countries. Fang and Miller [24] apply a similar analyses on the Korean Stock Exchange and Won/$ rate for the period of

1997-2000, just after the Asian flu. The results show that there is bidirectional and positive spillover between these two separate markets. Yang and Doong [59] conducts a study for the G-7 markets by using multivariate EGARCH CCC model in a period of 1979-1999. Their findings support the lack of spillover from foreign exchange to stock volatility claimed first by Kanas [33]. On the other hand, stock market volatility affects the foreign exchange one in France, Italy, Japan and U.S. with a significant asymmetry term. The foreign exchange volatilities of these markets are affected more by negative shocks relative to positive ones. The next study in this area is completed by Dark et al. [17] for the Australian financial markets. GARCH BEKK methodology is used for the data from January, 1995 to December, 2004. Even though Australia is in the group of developed countries, their results do not support the expectation of spillover from stock market to foreign exchange market. In addition, they have indicated the significant volatility transmission from foreign exchange market to stock market, which is unusual for the developed economies. Qayyum et al. [50] make a similar volatility transmission study for the Pakistan between 1998 and 2006 by using EGARCH model. Their findings show that there is volatility spillover from foreign exchange to stock market and this spillover is asymmetric, meaning that gets larger for the negative shocks. Spillover from stock returns volatility to foreign exchange is absent for positive shocks; however, negative shocks are significantly effective. Aloui [3] examines the transmission of volatilities in Italian, German, Spanish, Belgian and French financial markets by the EGARCH methodology for the time between 1995 and 2005. It is concluded that while there are some volatility transmissions from French, Belgian and Italian stock markets to their foreign exchange markets, there are no spillovers in the opposite direction for the period before the accession of euro. In the post-euro era, some spillover effects from Belgian, French and German foreign markets to their stock markets become significant. In the same period, spillover from Italian stock market to foreign exchange market gets insignificant, while German and Spanish volatility spillovers form stock to foreign exchange markets become statistically significant. The same EGARCH procedure is completed by Mishra Kumar [42] for Indian financial markets for the time between 1993 and 2003. Their study examines the industry specific indices in the Indian stock exchanges and for almost all indices, bidirectional spillovers are found to be significant. A relatively new study on the G-7 countries for the volatility spillover between 1996 and 2006 is completed by Morales [44]. Morales's results have confirmed the previous studies conducted for the same region by the findings which express the existence of unidirectional volatility transmission from stock to foreign exchange market. Another study completed by Morales [45] for the Latin American countries for the time between 1998 and 2006 indicates the relatively weaker spillover from foreign exchange to stock volatility with respect to the opposite direction. In Brazil, Mexico and Chile, there is unidirectional transmission of the volatility from their stock markets to foreign exchange markets, whereas the opposite direction is significant merely for the Mexican Peso/$ to Argentina stock exchange. Choi et al. [14] make a specific research for the case of New Zealand for the period of 1990-2004. They have indicated the existence of the spillover from stock market to NZD/AUD, NZD/USD and trade weighted exchange rates. On contrary, the sole transmission of volatility for the opposite situation is from NZD/AUD rate to stock market. The joint study of O'Donnell and Morales [48] aims to identify the existence of the volatility spillover for the Eastern European countries. Their results acquired by EGARCH for the time between 1999 and 2006 show that there is no any spillover effect from stock market to foreign exchange market except for Czech Republic after the accession of euro. There are similar outcomes for the opposite direction with an exception of Poland for pre-euro and Hungary for post-euro era. The asymmetric coefficients which are defined as the positive shocks are mostly significant, which means that positive shocks are more effective than negative ones. Wei [57] looks for the existence and direction of the spillover among U.S., Dutch, Japanese, Chinese stock exchanges and $/RMB, $/Yen rates in a period of July, 2005-May, 2007. His findings computed by symmetric component GARCH indicate that there are volatility spillovers from $/RMB rate to DJIA and from $/RMB, $/Yen rates to Shanghai and Shenzhen stock exchange indices. Rahman et al. [51] make inquiries the volatility transmission for the Mexican financial markets for the period between 1992 and 2008, just after being signed the NAFTA. They could not find any results supporting existence of volatility spillover. Fedorova and Saleem[25] conduct a study on the Russia, Hungary, Poland and Czech Republic. The findings from GARCH BEKK model for the 1995-2008 period are the bidirectional spillovers for Russia-Hungary and Poland-Hungary pairs. There are also unidirectional transmissions from Russia to Poland and Czech Republic; from Hungary and Poland to Czech Republic stock market volatilities. Furthermore, all the exchange rates have a spillover effect on the same countries' stock exchange volatilities. Lee [37] examines the volatility transmission from Yen/$, Euro/$, S&P 500 and Nikkei 225 to 5 Asian and 5 Latin American currencies by EGARCH-M methodology between September, 2001 and August, 2008. It is concluded that global variables, Yen/$, Euro/$, S&P 500 and Nikkei 225, are statistically significant and the exchange rates' effects are stronger with respect to American and Japanese stock indices for the second moment of the returns. Li and Majerowska [38] question the existence of volatility spillover among two Eastern European countries; Poland and Hungary for the period between 1998 and 2005. The outcomes of the GARCH BEKK model with asymmetric terms confirm the bidirectional spillover between Warsaw and Budapest Stock Exchanges. Moreover, as a global factor S&P 500 and regional factor DAX transmit their volatility on both Warsaw and Budapest Stock Exchanges. The last example for the spillover effects between stock and foreign exchange markets is conducted by Saha and Chakrabarti [52] by GARCH diagonal VECH methodology in the 2006-2010 period. This study focuses on the volatility transmission from stock market indices to some foreign exchange rates. There are spillovers from DJIA, Sensex (Indian Stock Index), Nikkei 225 indices to Rupee/$, Rupee/Pound and Rupee/Yen exchange rates respectively for the period before the global financial crisis. In the crisis era, the existing spillovers are from DJIA, FTSE and Sensex to Rupee/$, Rupee/Pound and Rupee/Yen exchange rates respectively. For the time defined as post-crisis, spillovers from DJIA to Rupee/$, from FTSE to Rupee/Pound and from Nikkei 225 to Rupee/Yen rates exist.

There are also few studies on the volatility spillover between the bond markets and foreign exchange markets. One of the prominent researches is completed by So [54], which includes the trade weighted U.S. Dollar exchange rate, 3-month t-bill and 10-year government bond yields. EGARCH model has been used for handling the data between 1973 and 1998. The findings indicate that long term and short term bond yields both transmit their volatility to the value of dollar and negative shocks are more effective. There is also spillover in the opposite direction, but the positive and negative shocks do not differ since the asymmetric coefficient is insignificant. Chow and Kim [15] inquire the transmission mechanism of the volatilities to interest rates for some East Asian countries by GARCH CCC model in 1993-2002. The exogenous variables are U.S. Fed Funds interest rates, $/Yen rate and local exchange rates to dollar. In the pre-Asian crisis period, the spillover is significant and negative for Indonesia and Korea. For the post-crisis period, there is negative spillover for the Philippines interest rates. On the other hand, there is positive spillover for Thailand in both of the periods.

Some of the studies have emphasized the volatility transmission mechanism between bond and stock markets. Zafar et al. [60] complete their work on this issue for the case of Pakistan for the time between 2002 and 2006. According to their findings, interest rate volatility has a negative but significant effect on stock market volatility. Christiansen [16] makes a survey on this spillover within a larger region, for the European bond and stock markets in 1988-2003. Aggregate European bond index and U.S. bond index significantly affect the individual stock market volatilities of Belgium, Denmark, France, Germany, Italy, the Netherlands, Spain, U.K. and Sweden. In contrast, similar effects from the aggregate European stock index and U.S. stock index to individual bond index of the countries are negligible. However, U.S. and European aggregate stock indices transmit their volatility to the local stock markets in Europe for the post-euro era.

There are also some scientific works to identify the volatility spillovers by using more than two different markets types, which are foreign exchange, bond and stock market volatilities altogether. Bodart and Reding [7] make a research on the volatility of these 3 markets for some European countries between 1989 and 1994. The outcomes of the GARCH model indicate that there is a bidirectional volatility spillover between bond and foreign exchange markets. On the other hand, stock market does not transmit its volatility to any of those markets. Another study completed by Vardar et al. [56] aim to identify the volatility spillover effects among the three financial markets for the case of Turkey in a time between April, 2001 and July, 2008. Their synthetically formed multivariate model shows that foreign exchange volatility affects the stock market volatility except for technology index with positively and significantly. Furthermore, interest rate transmits its volatility to financial and composite indices negatively and to technology index positively. Cicek [13] also inquires the volatility transmission among three markets in Turkey for the period of 2004-2008. The outcomes of the EGARCH model indicate that there are significant volatility spillovers in Turkish financial markets and their directions and signs indicate transmissions from the stock market to both bond and foreign exchange markets negatively, and from the foreign exchange market to stock and bond markets positively.

2.3. Volatility Spillovers from Macroeconomic Variables to Financial Markets

In addition to these studies, some works including other macroeconomic variables also exist. Morelli [46] looks for finding any spillover from retail sales, money supply, inflation rate, foreign exchange rate and industrial production level to London stock market volatility for the time between 1967 and 1995. However, his synthetically produced multivariate GARCH model does not identify any spillovers from these markets to London Stock Exchange. Erdem et al. [23] realize a similar study by using EGARCH for Istanbul Stock Exchange from 1991 to 2004. Their industry specific outcomes show that there are volatility spillovers from inflation and interest rates to all stock indices used in the study. Moreover, foreign exchange rate transmits its volatility to composite and industrial indices, whereas money supply transmits to merely financial index as expected. Adjasi et al. [1] apply EGARCH process by using some macroeconomic variables for the case of Ghana between 1995 and 2005. They have found that trade weighted foreign exchange rate volatility has a negative impact on stock market volatility. In addition, the levels of the inflation rate and the t-bill yield also affect the stock market volatility.

All the studies mentioned so far analyze different parts of the world in different time intervals and use similar methodologies with some minor modifications. Although some of the results are conflicting, it is still possible to make some generalizations. First, there is a positive relationship with the existence of the spillovers and financial integration. Therefore, volatilities of the markets in the developed economies affect each other more. Second, the global financial instruments such as U.S. bonds; dollar, euro, pound and yen currencies and stocks traded on the New York, London and Tokyo stock exchanges have mostly significant effects on the volatilities of emerging financial markets. Lastly, these volatility spillovers usually become more significant and larger for the time periods after the structural breaks occurred due to the financial crisis and the accession of euro.

CHAPTER 3

DATA AND METHODOLOGY

3.1. Data

This study analyzes the within-country relationship between the return volatilities observed in each sample country's stock, bond and foreign exchange markets and the effects of short term shocks on these volatilities. The volatilities of these financial markets are examined within a multi-step GARCH context. The following subsections describe the collection and calculation of the variables used in the analysis.

3.1.1. Selection of Local Variables and Their Proxies

The financial markets under analysis are represented by the help of certain indices. First, since the United States Dollar is the prominent currency for international trade, international financial investments and reserves of the national central banks, the value of one dollar in terms of the local currencies are used for all countries as a proxy for the exchange rate. The only exception for this selection is the use of a trade-weighted exchange rate in order to represent the value of the US dollar against a composite currency basket. Any increase in the exchange rate means the depreciation of the local currency for all countries, including the case of dollar with respect to the trade-weighted basket. Second, in order to represent the bond markets, national bond market indices are used. Indices compiled by the FTSE are used for the Germany, Turkey, U.S. and Japan. Indices computed by J.P. Morgan and Citigroup are used for Korea and Mexico,, respectively. Weighted combination of government bonds with all maturities are composed of the national bond indices calculated by these three firms. The representative stock indices are; S&P 500, Nikkei 225, CDAX all shares, IPC 35, KOSPI 200 and ISE 100 for the U.S., Japan, Germany, Mexico, Korea and Turkey, respectively. In order to observe the effects on the entire stock market as possible, stock indices with a larger number of companies are chosen, except for Mexico owing to unavailability of such an index for the targeted period. All bond and stock indices are denominated in dollars.

3.1.2. Selection of Global Variables and Their Proxies

Due to the globalization and integration of the world financial markets, investors are able to choose from any kind of investment in any country. Ease of convertibility of the currencies and availability of the data make it possible to compute the net return of the investments in terms of local currencies of the investors. Therefore, national stock and bond investments are compared with their international counterparts. International stock, bond and commodity markets are benchmarks for the global investments. In this study, Barclays Global Aggregate Bond Index, Morgan Stanley Capital International All Country World Index and Rogers International Commodity Index are used as the representatives of the international bond, stock and commodity markets.

Using Barclays Bond Index instead of its alternatives is due to its superior explanatory power of the world bond markets. This index includes treasury, government, corporate and securitized bonds from different maturities, currencies and ratings. Moreover, bonds of from developed and emerging markets are included. Bonds with embedded options such as convertibles are excluded from the index.

Morgan Stanley Capital International All Country World Index is used as the proxy for global stock markets.. This index is chosen because of its well-diversified structure. Initially, this index enables to observe the movements of the entire world markets, since stocks from 45 emerging and developed countries are included. Furthermore, a variety of industries is represented in the index. The only weakness of the index is the high weight of the American shares due to their large market capitalization. This may lead to a minor problem, while trying to differentiate the effects of local and international stocks for the case of the United States.

Rogers International Commodity Index is used as a proxy for the global commodity markets and this index is preferred because of its better representation of the world commodity markets. This index is the weighted average of energy commodities, agricultural products and precious or industrial metals. The largest share of the index is composed from the energy commodities, particularly crude oil. The largest ones among subgroups are corn and wheat for the agricultural products, aluminum and copper for the industrial metals, and gold for the precious metals.

3.1.3. Selection of the Sample Countries

In order to analyze the volatility structure and spillovers, foreign exchange, bond and stock markets of the United States, Japan, Germany, Mexico, Korea and Turkey are selected as the sample for the study. This study aims to identify any differences in volatility aspects between the emerging and developed countries. Therefore, the number of emerging and developed markets is chosen to be equal. In order to encompass global markets, three separate geographies, which are Americas, Europe, Middle East and Africa (EMEA), and Asia are included. Each country represents its region and group of economy with respect to its development level. For instance, while Turkey is the representative of the emerging economies in EMEA, Japan is the representative of the developed economies in Asia. Country pairs in each regional group such as Germany-Turkey in the EMEA cluster are assigned by the strength of the interdependencies of these countries' financial markets and foreign trade channels. Lastly, the use of Brazil, Russia, India and China is avoided for their respective regions since the large share of these countries in the world financial markets may distort the clear distinction between emerging and developed markets. To sum up, the United States, Japan and Germany represent developed countries for the Americas, EMEA and Asia regions,, respectively. In addition, Mexico, Turkey and Korea are proxy countries for emerging markets in the Americas, EMEA and Asia regions,, respectively.

3.1.4. Selection of the Sample Period

In order to identify the volatility spillovers among financial markets, financial integration is the necessary condition. The last decade of the 20th century is the time for the increasing integration of world markets, particularly for the integration of emerging markets with the rest of the world. Therefore, a study including merely the new century will be more meaningful to define the volatility transmission in these countries. The second major goal of this study is to explain volatility structure regime changes after the global economic crisis. In order to make a clear distinction between pre- and post-crisis periods, it is appropriate to choose the beginning of the data as the starting days of the global economy without any recessions and turmoil in its markets. The chart below shows the real GDP growth rates for the countries in this study.

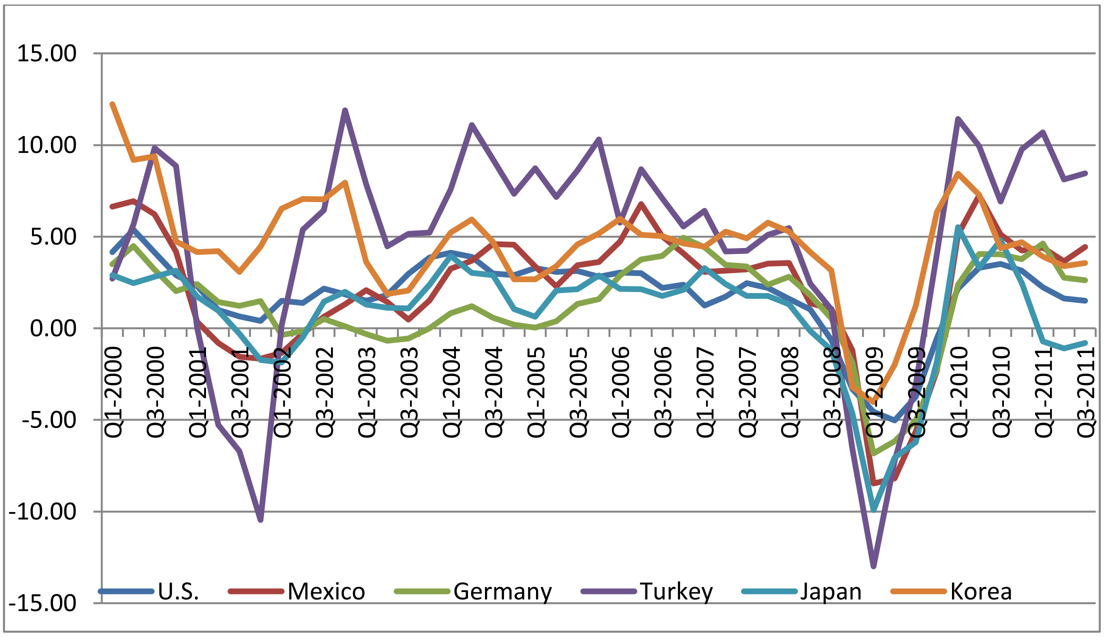

Figure 3.1. Real GDP Growth Rates for the Selected Economies

It is apparently seen from the chart that long-term common GDP growth began at the last quarter of the 2003. The last criterion for the data period selection is the availability of the data. Mexican local bond index computed by Citigroup is available only since the beginning of 2004. Therefore, the beginning of the sample period is taken as the first business day of 2004. The entire sample covers the January 2, 2004 - December 30, 2011 period with 2085 observations per series. Since it may make it possible to catch short term volatility spillovers, daily data are preferred. All price data are converted into log- returns. For the local and global bond and stock indices, dividend-adjusted data are not chosen since these adjustments do not affect the second moment of the returns according to studies of Poon and Taylor [49]. All the relevant data are retrieved from the Datastream.

3.1.5. Descriptive Statistics of the Variables

The table below presents some basic descriptive statistics. A negative sign in the mean of exchange rates represents an appreciation of the local currency. Standard deviations of the exchange rates can be interpreted as a simple risk measure. It is not surprising to observe that emerging market currencies have higher volatility compared to the currencies of developed economies. The mean of bond indices show the expected return for these markets.

Table 3.1. Mean and Standard Deviations of the Continuously Compounded Return Series

	Exchange		**Bond**		**Stock**	
	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.
U.S.	-0.000016	0.002426	0.000026	0.001241	0.000026	0.005930
Mexico	0.000048	0.002985	0.000108	0.003745	0.000251	0.007789
Germany	-0.000006	0.002937	0.000032	0.002931	0.000089	0.007376
Turkey	0.000064	0.004004	0.000141	0.004393	0.000142	0.010612
Japan	-0.000067	0.002909	0.000074	0.003108	0.000020	0.006736
Korea	-0.000007	0.003304	0.000103	0.003808	0.000174	0.007784
	Bond		**Stock**		**Commodity**	
	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.
Global	0.000003	0.000719	0.000036	0.005028	0.000094	0.005937

Higher risks related to emerging markets are associated with higher bond returns. The U.S. bond return mean is the lowest, as it is mostly accepted as the risk free instrument. Similar observations can be made for the stock returns. Mexico, Korea and Turkey have the highest returns due to their high risk structures. Bonds as a financial instrument consist of fewer risks than stocks. The main reason is the priority of the bond payments in the case of bankruptcy. Furthermore, bond indices only include the government bonds and this is the second reasonable explanation for the excess bond returns over stock returns. The only exception for this is the Japanese bond and stock markets. Global bond and stock indices are well-diversified portfolios of the securities around the world. Therefore, the global bond index has the lowest risk and return comparing with local bond indices. The same expectation holds partially for the stock market indices. The global stock index's standard deviation is the lowest due to its relatively better diversification. However, its return is higher than American and Japanese stocks, probably owing to the inclusion of the emerging market stocks with high returns. The global commodity index has higher risk and thus higher return than global bond and stock indices. This is not surprising since this index includes fewer instruments than global bond and stock indices. Moreover, there is no opportunity to facilitate the inter-countries diversification for the commodity index because of its unique structure around the world for the elimination of arbitrage.

The table below also supports the interpretations regarding the risk and return conditions of the different markets. Markets with higher risks such as emerging markets have a wider range for their returns. Stock and global stock indices have broader ranges with respect to bond and global bond indices,, respectively. Furthermore, there is no narrower range than the one for the global bond among local bond indices. The parallel finding is also valid for the stock indices.

Table 3.2. Min., Max. and Range of the Continuously Compounded Return Series

	Exchange			**Bond**			**Stock**		
	Min.	Max.	Range	Min.	Max.	Range	Min.	Max.	Range
U.S.	-0.0133	0.0109	0.0242	-0.0068	0.0066	0.0133	-0.0411	0.0476	0.0887
Mexico	-0.0411	0.0476	0.0532	-0.0244	0.0288	0.0571	-0.0331	0.0239	0.1124
Germany	-0.0190	0.0203	0.0393	-0.0168	0.0229	0.0397	-0.0426	0.0494	0.0920
Turkey	-0.0518	0.0306	0.0824	-0.0322	0.0320	0.0643	-0.0641	0.0688	0.1330
Japan	-0.0189	0.0205	0.0395	-0.0190	0.0198	0.0389	-0.0486	0.0506	0.0991
Korea	-0.0399	0.0310	0.0709	-0.0473	0.0582	0.1055	-0.0626	0.0693	0.1319
	Bond			**Stock**			**Commodity**		
	Min.	Max.	Range	Min.	Max.	Range	Min.	Max.	Range
Global	-0.0031	0.0032	0.0063	-0.0320	0.0387	0.0707	-0.0331	0.0273	0.0604

3.1.6. Distribution of the Variables

The table below presents evidence regarding whether each return series analyzed in the study is normally distributed. The major elements of the normal distribution are a constant mean and variance. In addition kurtosis and skewness numbers should be statistically equivalent to 3 and 0, respectively. In order to measure all these four elements simultaneously, Jarque-Bera Normality test can be applied. The null hypothesis of this test is the normal dispersion of the series. High values of Jarque-Bera test statistic or very low p-values clearly indicate the rejection of the null hypothesis at any significance level. The figures in the table suggest that none of the local and global series are normally distributed.

Table 3.3. Parameters of the Normal Distribution and UnivariateJarque-Bera Statistics

Exchange	Mean	St. Dev.	Kurtosis	Skewness	Jarque-Bera	p-value
U.S.	-0.000016	0.002426	1.547879	-0.050949	207.2796	0.000000
Mexico	0.000048	0.002985	12.370745	0.645375	13369.6600	0.000000
Germany	-0.000006	0.002937	3.289110	0.194800	946.8643	0.000000
Turkey	0.000064	0.004004	18.196071	-0.156350	28625.7700	0.000000
Japan	-0.000067	0.002909	4.508627	-0.108802	1759.3770	0.000000
Korea	-0.000007	0.003304	30.902168	-0.684832	82710.9400	0.000000
Bond	**Mean**	**St. Dev.**	**Kurtosis**	**Skewness**	**Jarque-Bera**	**p-value**
U.S.	0.000026	0.001241	2.368771	-0.040390	484.5144	0.000000
Mexico	0.000108	0.003745	11.135499	-0.610597	10844.6900	0.000000
Germany	0.000032	0.002931	4.249171	0.248856	1580.4300	0.000000
Turkey	0.000141	0.004393	525.898702	0.033260	23911.6870	0.000000
Japan	0.000074	0.003108	3.837039	0.173088	1281.4100	0.000000
Korea	0.000103	0.003808	42.468607	0.510726	15600.5500	0.000000
Stock	**Mean**	**St. Dev.**	**Kurtosis**	**Skewness**	**Jarque-Bera**	**p-value**
U.S.	0.000026	0.005930	10.320384	-0.302764	9235.4520	0.000000
Mexico	0.000251	0.007789	7.248360	-0.092687	4541.8190	0.000000
Germany	0.000089	0.007376	5.772921	-0.106250	2882.4290	0.000000
Turkey	0.000142	0.010612	3.845229	-0.364539	1322.5620	0.000000
Japan	0.000020	0.006736	6.414229	-0.359345	3598.7400	0.000000
Korea	0.000174	0.007784	11.829390	-0.347903	12134.7100	0.000000
	Mean	**St. Dev.**	**Kurtosis**	**Skewness**	**Jarque-Bera**	**p-value**
G. Bond	0.000003	0.000719	1.081594	-0.052059	101.5456	0.000000
G. Stock	0.000036	0.005028	8.552099	-0.453841	6390.6910	0.000000
G. Commodity	0.000094	0.005937	2.847504	-0.351797	742.5611	0.000000

3.1.7. Correlation Coefficient of the Variables

Table 3.4 presents the correlation coefficients among variables. The global and local stock indices seem to be highly correlated with the other markets. This is expected due to the integration of the world stock markets. However, the reason of high integration stock return of U.S. and global stock index is different. Due to the enormous size of the U.S. stock markets, it has the highest share in the global stock index (approximately 43%). The correlations of foreign exchange returns with bond and stock indices are also quite large for emerging markets with an exception of Korean Bond Index. This is expected as a result of the significant share of foreign investors in the stock and bond markets of these countries. There is also a negative correlation among the value of U.S. Dollar and global markets, particularly for global commodity markets. The main reason for these results may may be that the values of these indices denominated in terms of dollar. The natural result of this point is any depreciation of the U.S. Dollar will raise the dollar values of commodities. None of the correlations among these variables are close to 1 (unit correlation). This means that the phenomenon of multicollinearity is not serious problem. The choice of dollar denomination of local bond and stock indices instead of their denominations in terms of local currencies could be a reason for lowering the collinearity among exchange rates and bond and stock indices. Finally, it should be kept in mind that, these values are only simple correlation coefficients. Although two variables do not have high simple pairwise correlation among them, there may still be very high partial pairwise correlation.

Table 3.4. Correlation Matrix of the Continuously Compounded Return Series

U.S.	**Exchange**	**Bond**	**Stock**	**G. Bond**	**G. Stock**	**G. Commodity**
Exchange	1.0000					
Bond	-0.0416	1.0000				
Stock	-0.2572	-0.2445	1.0000			
G. Bond	-0.0692	0.7071	-0.2999	1.0000		
G. Stock	-0.4316	-0.3235	0.8545	-0.2974	1.0000	
G. Commodity	-0.4120	-0.1957	0.3547	-0.1897	0.5145	1.0000
GERMANY	**Exchange**	**Bond**	**Stock**	**G. Bond**	**G. Stock**	**G. Commodity**
Exchange	1.0000					
Bond	-0.6136	1.0000				
Stock	-0.4195	0.4463	1.0000			
G. Bond	-0.0015	0.2992	-0.2708	1.0000		
G. Stock	-0.3328	0.2961	0.8593	-0.2974	1.0000	
G. Commodity	-0.2456	0.2731	0.4770	-0.1897	0.5145	1.0000
JAPAN	**Exchange**	**Bond**	**Stock**	**G. Bond**	**G. Stock**	**G. Commodity**
Exchange	1.0000					
Bond	-0.9805	1.0000				
Stock	0.2466	-0.2939	1.0000			
G. Bond	-0.0391	0.0884	0.0503	1.0000		
G. Stock	0.0958	-0.1194	0.3481	-0.2974	1.0000	
G. Commodity	0.0641	-0.0738	0.1715	-0.1897	0.5145	1.0000
MEXICO	**Exchange**	**Bond**	**Stock**	**G. Bond**	**G. Stock**	**G. Commodity**
Exchange	1.0000					
Bond	-0.7257	1.0000				
Stock	-0.6475	0.7067	1.0000			
G. Bond	0.1611	-0.0798	-0.2654	1.0000		
G. Stock	-0.5952	0.5691	0.7997	-0.2974	1.0000	
G. Commodity	-0.4286	0.3733	0.4249	-0.1897	0.5145	1.0000

Table 3.4. Correlation Matrix of the Continuously Compounded Return Series (continued)

TURKEY	**Exchange**	**Bond**	**Stock**	**G. Bond**	**G. Stock**	**G. Commodity**
Exchange	1.0000					
Bond	-0.6566	1.0000				
Stock	-0.5600	0.7911	1.0000			
G. Bond	0.0614	-0.1518	-0.2052	1.0000		
G. Stock	-0.4128	0.5804	0.6042	-0.2974	1.0000	
G. Commodity	-0.2094	0.3615	0.3415	-0.1897	0.5145	1.0000
KOREA	**Exchange**	**Bond**	**Stock**	**G. Bond**	**G. Stock**	**G. Commodity**
Exchange	1.0000					
Bond	-0.0703	1.0000				
Stock	-0.5182	0.4149	1.0000			
G. Bond	-0.0249	-0.0517	-0.0996	1.0000		
G. Stock	-0.0523	0.3210	0.4140	-0.2974	1.0000	
G. Commodity	0.0239	0.1631	0.1890	-0.1897	0.5145	1.0000

3.1.8. Stationarity of the Variables

Table 3.5 summarizes the augmented Dickey-Fuller test results. First rows for each variable present the ADF statistic and the second rows provide the p-values. Similarly third rows are the parameter values of the trend series and the fourth rows are their p-values. Test results apparently show that there is no unit root for all local and global series. Moreover, all trend coefficients are statistically insignificant for even a 10% significance level. To sum up, log return series for the local and global variables are all stationary and there is no opportunity to observe the phenomena of spurious regression.

Table 3.5. Results of the Augmented Dickey-Fuller Test with Trend Variables

		U.S.	**Mexico**	**Germany**	**Turkey**	**Japan**	**Korea**
FX	level	-45.5407	-44.8839	-45.7417	-45.0235	-35.1068	-28.1939
		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	trend	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
		0.8549	0.5054	0.6498	0.3396	0.1740	0.4308
BOND	level	-46.4114	-41.3397	-45.7115	-20.8569	-47.7567	-45.1744
		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	trend	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
		0.2681	0.7064	0.9518	0.6160	0.1917	0.5703
STOCK	level	-36.4925	-40.3244	44.8609	-42.9103	-36.8760	-37.2892
		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	trend	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
		0.9467	0.3063	0.4015	0.3599	0.5347	0.4544

Table 3.5. Results of the Augmented Dickey-Fuller Test with Trend Variables (continued)

		Global
BOND	level	-40.7509
		0.0000
	trend	0.0000
		0.3200
STOCK	level	-32.3580
		0.0000
	trend	0.0000
		0.5535
COMMODITY	level	-47.0194
		0.0000
	trend	0.0000
		0.4224

The last table, Table 3.6, for this section displays the Kwiatkowski–Phillips–Schmidt–Shin (KPSS) test results. LM statistics are the major KPSS test statistics with the critical values of 0.2160, 0.1460 and 0.1190 for 1%, 5% and 10% significance levels,, respectively. It is observed that the null hypothesis of stationarity is failed to be rejected for all series. P-values of the trend parameters are also displayed in the following table. All these parameters are statistically insignificant even at the 90% confidence level.

Table 3.6. Results of the KPSS test with Trend Variables

		U.S.	**Mexico**	**Germany**	**Turkey**	**Japan**	**Korea**
FX	LM Stat.	0.0413	0.0528	0.0468	0.0391	0.0350	0.0850
	trend	0.8161	0.4806	0.6259	0.3066	0.2392	0.3950
BOND	LM Stat.	0.0332	0.0395	0.0264	0.0500	0.0418	0.0886
	trend	0.2668	0.6299	0.9255	0.9595	0.2126	0.5646
STOCK	LM Stat.	0.0930	0.0671	0.0658	0.0585	0.0549	0.0695
	trend	0.9278	0.2136	0.3795	0.2967	0.5788	0.3568
		Global					
BOND	LM Stat.	0.0356					
	trend	0.3712					
STOCK	LM Stat.	0.0864					
	trend	0.4980					
COMMODITY	LM Stat.	0.0901					
	trend	0.3987					

Combined results of the ADF and KPSS indicate that all local and global series are stationary.

3.2. Methodology

In this part, representations and derivations of all transformations, diagnostic tests and models are discussed.

3.2.1. Computation of Continuously Compounded Returns

In this study, continuously compounded returns are used. These returns are calculated by the

$$R_t=ln(P_t/P_{t-1}) \tag{3.1}$$

transformation. In these calculations, $R_t$is the log return and P_t is the price of the instrument in period t.

3.2.2. Test of Univariate Normality

In the data section of this thesis, dispersion of the variables is tested for their normality. For this purpose, the most popular normality test, the Jarque-Bera Test, is used (Jarque and Bera [30]). This test statistic is calculated as follows:

$$JB=\frac{n}{6}\left(S^2+\frac{1}{4}(K-3)^2\right) \tag{3.2}$$

In Equation (3.2) K is kurtosis and S is skewness.A normally distributed variable has the value of 3 for kurtosis and 0 for the skewness, which are the third and fourth moments, respectively.

H_0: $K=3$ *and* $S=0$

H_a: $K\neq3$ *or* $S\neq0$

The null hypothesis is that the variable is distributed normally. Therefore, the rejection of the hypothesis impliesnon-normality.

3.2.3. Test of Stationarity

Stationarity is the condition of time invariant mean and autocovariances of the series. The process of Y_t would be stationary or covariance-stationary if the following conditions hold:

$E(Y_t)=\mu$

$E[(Y_t-\mu)(Y_{t-j}-\mu)]=\gamma$ for all t and any j

Stationarity of the series in a regression is crucial since the lack of this property would cause spurious regression which could lead to concluding that there a relationship among variables which does not exist. Testing stationarity condition is necessary and there are different tests that can be employed for this purpose. The most widely used one is the augmented Dickey-Fuller test (ADF) (Dickey and Fuller [18]). The popularity of this test comes from preventing the effects of serial correlation on the auxiliary test regression.

$$\Delta Y_t=\alpha+\beta t+\gamma Y_{t-1}+\delta_1\Delta Y_{t-1}+\ldots+\delta_{p-1}\Delta Y_{t-p+1}+\mathcal{E}_t \tag{3.3}$$

The equation above shows the ADF test regression. Lags of the ΔY_t are the variables for the autocorrelation adjustment. The number of these lags could be determined by any information criteria method. In this study, the Akaike information criteria (AIC) is used (Akaike [2]). The AIC is calculated as follows:

$$AIC=-2ln(L(\theta \mid Y))+2k, \quad (3.4)$$

where k is the number of parameters and L is the maximized value for the likelihood function. The hypotheses for this test are formed as follows:

H_0: *$\gamma=0$ non-stationary*

H_a: *$\gamma\neq0$ stationary*

The null hypothesis of the ADF test is the existence of non-stationarity. In order to test it, the significance of the γ parameter should be checked. The critical value for this test is distributed as a τ-distribution, which is quite different than t-distribution. Moreover insignificance of the β parameter is also necessary due to risk of trend non-stationarity.

In addition to the ADF test, the Kwiatkowski–Phillips–Schmidt–Shin (KPSS) test is also applied due to their complementarities for each other (Kwiatkowski et. al. [36]). The null hypothesis of ADF is non-stationarity, whereas the null hypothesis for the KPSS test is stationarity. The KPSS test statistic is calculated as follows:

$$KPSS=\frac{\sum_{t=1}^{T} S_t^{2}}{\sigma_{\mathcal{E}}^{2}}. \quad (3.5)$$

In equation (3.5), $S_t=\sum_{i=1}^{T}\mathcal{E}_i$.

The hypotheses for this test are formed as follows:

H_0: *stationarity*

H_a: *non-stationarity*

The asymptotic distribution of this statistic is nonstandard. Rejection of null hypothesisat the predetermined significance level indicates that the variable is not stationary.

3.2.4. Test of Multivariate Cointegration

In the regression analyses, it is aimed to identify the long-run relationship among the variables. Therefore, the existence of long-run relationship among the variables should be tested initially. This long-run relationship, cointegration, may be tested for the cases with more than one equation by the Johansen cointegration test (Johansen[31]).

$$Y_t=a_1Y_{t-1}+\ldots+a_pY_{t-p}+\mathcal{E}_t \quad (3.6)$$

$$\Delta Y_t=\Pi Y_{t-1}+\sum_{i=1}^{p-1}\Gamma\Delta Y_{t-i}+\mathcal{E}_{t.} \quad (3.7)$$

In equation (3.7), $\Pi = \alpha\beta' = \sum_{i=1}^{p} a_i - I$ and $\Gamma_i = -\sum_{j=i+1}^{p} a_j$.

Since ΠY_{t-1} is stationary, multiplication of this term with $(\alpha'\alpha)^{-1}\alpha'$ would also be stationary, which means that each element of $\beta' Y t$ represents a cointegrating relation. α parameters are the short-term adjustment coefficients and r would give the number of cointegration rank .

$$LR_{trace}(r \mid k) = -T\sum_{i=r+1}^{k} log\ (1-\lambda_i). \quad (3.8)$$

In equation (3.8), λ_i isthe *i*-th largest eigenvalue of the Π matrix.
H_0: r cointegrating relations
H_a: k cointegrating relations

$$LR_{max}(r \mid r+1) = -Tlog(1-\lambda_{r+1}) \quad (3.9)$$

In equation (3.9), λ_{r+1} is the $(r+1)$-th eigenvalue of the Π matrix.
H_0: r cointegrating relations
H_a: r+1 cointegrating relations
In order to interpret the test results, there are two different statistics which are, trace statistic and maximum eigenvalue statistic. This process requires recursive testing of the new null hypothesis. The first null hypothesis is that there is no cointegrating relation. If this hypothesis is rejected, then the procedure will be repeated for the null hypothesis of one cointegrating relation until the end of rejection. In order to test the null hypothesis, trace or maximum eigenvalue statistics could be used and their critical values are asymptotically distributed as follows:

$$tr\left\{\int_0^1 (dW)\hat{W}' \left(\int_0^1 \hat{W}\hat{W}'dr\right)^{-1} \int_0^1 \hat{W}(dW)'\right\} \quad (3.10)$$

$$max\left\{\int_0^1 (dW)\hat{W}' \left(\int_0^1 \hat{W}\hat{W}'dr\right)^{-1} \int_0^1 \hat{W}(dW)'\right\} \quad (3.11)$$

In these equations, W is the dimensional and $\hat{W}$ is the demeaned Brownian motions.

3.2.5. Tests of Multivariate Autocorrelation

After the application of the VAR and VAR-GARCH models, existence of autocorrelation among the error terms should be checked due to the assumptions regarding error terms. One of the most mostly widely used tests for detecting serial correlation is the multivariate Q-statistic (Hosking[29]). Calculation of the multivariate Q-statistic is quite different than the univariate one, but the logic is the same.

$$MV\text{-}Q = T\sum_{i=1}^{h} tr(\ C_i' C_0^{-1} C_i C_0^{-1}) \quad (3.12)$$

In equation (3.12),

$$C_i = T^{-1}\sum_{t=i+1}^{T} (x_t - \bar{x})(x_{t-i} - \bar{x})' \quad (i=0,1,\ldots, h.) \tag{3.13}$$

The critical value for this statistic is dispersed with a $\chi^2_{(d)}$ distribution, where $d= n^2p$, n is the number of equations in the mean model and p is the number of lags selected for the Q-statistic.

H_0: *no autocorrelation*

H_a: *autocorrelation*

Rejection of null hypothesis in the predetermined significance level indicates the existence of autocorrelation.

3.2.6. Tests of Multivariate Heteroscedasticity

Condition of constant variance of the error terms is necessary for models estimated by Ordinary Least Squares (OLS). Violation of this condition would make the results of the OLS not interpretable, and, therefore, another estimation method, Maximum Likelihood (ML), should be used to model the non-constant error term variances. In order to check the applicability of OLS use, some heteroscedasticity diagnostic tests are required. In this thesis, the multivariate ARCH-LM test is applied since GARCH modeling would be used if the violation exists.

$$MV\text{-}LM=\frac{1}{2}Tn(n+1)\text{-}Ttr(\Sigma_{VECH} \quad \Sigma_0^{-1}) \tag{3.14}$$

In equation (3.14),T is the number of observation and n is the number of equations in the mean model. The critical value for this statistic is dispersed with $\chi^2_{(s)}$ distribution, where $s=\left(\frac{n(n+1)}{2}\right)^2 p$, n is the number of equations in the mean model and p is the number of lags selected for the LM-statistic.

H_0: *homoscedasticity*

H_a: *heteroscedasticity*

The null hypothesis of the test is homoscedasticity. Therefore, in case of violation of the assumption, the non-constant variances should be modeled.

3.2.7. Tests of Multivariate Normality

VAR and VAR-GARCH models are estimated under the assumption of normally distributed error terms. Any violation to this assumption results in a requirement of using robust standard errors. Skewness and kurtosis formulas for the multivariate cases are given below (Mardia [41]).

$$b_{M,1}=\frac{1}{T^2}\sum_{i=1}^{T}\sum_{j=1}^{T}[(x_i - \bar{x})' S^{-1}(x_i - \bar{x})]^3 \tag{3.15}$$

$$b_{M,2}=\frac{1}{T}\sum_{i=1}^{T}[(x_i - \bar{x})' S^{-1}(x_i - \bar{x})]^2 \tag{3.16}$$

In the equations above, $b_{M,1}$ is the skewness and $b_{M,2}$ is the kurtosis parameters. In order to diagnose the normality of the error terms, the multivariate Jarque-Bera test is implemented (Koizumi et al. [35]).

$$MV\text{-}JB = T\left[\frac{b_{M,1}}{6} + \frac{(b_{M,2} - n(n+2))^2}{8n(n+2)}\right] \quad (3.17)$$

In equation (3.17), n is the number of equations in the mean model.

The critical value for this statistic is asymptotically dispersed with $\chi_{f+1}{}^2$ distribution, where $f=\frac{n(n+1)(n+2)}{6}$.

H_0: normality

H_a: non-normality

Rejection of the null hypothesis shows the violation of multivariate normality of the error terms. In such a case, use of robust standard errors would be more appropriate.

3.2.8. VAR Modeling

The Vector Autoregressive model is the suitable way to examine the existence of any causality for the multivariate cases. In the basic VAR model, lags of the endogenous variables are inserted as independent variables for the regressions of remaining variables. The bivariate case with a single lag for this model is represented below.

$$\begin{bmatrix} Y_{1t} \\ Y_{2t} \end{bmatrix} = \begin{bmatrix} c_1 \\ c_2 \end{bmatrix} + \begin{bmatrix} A_{1,1} & A_{1,2} \\ A_{2,1} & A_{2,2} \end{bmatrix} + \begin{bmatrix} Y_{1t-1} \\ Y_{2t-1} \end{bmatrix} + \begin{bmatrix} e_{1t} \\ e_{2t} \end{bmatrix} \quad (3.18)$$

The maximum likelihood methodology would be used for the estimation due to availability of the GARCH procedure. A distribution must be assumed necessary for this methodology; therefore, the normal distribution is used. In case of violation of the normality assumption for the error terms, robust standard errors are estimated and used in analysis (Bollerslev and Wooldridge [8]).

$$vec(\mathcal{E}) = \begin{bmatrix} \mathcal{E}_1 \\ . \\ . \\ . \\ \mathcal{E}_T \end{bmatrix} \sim N(0, I_T \otimes \Sigma_{\mathcal{E}}) \quad (3.19)$$

$$f_{\mathcal{E}}(\mathcal{E}) = \frac{1}{(2\pi)^{KT/2}} |I_T \otimes \Sigma_{\mathcal{E}}|^{-1/2} exp\left[-\frac{1}{2}\mathcal{E}'(I_T \otimes \Sigma_{\mathcal{E}}{}^{-1}\right] \quad (3.20)$$

Since $\mathcal{E}=Y-\mu^*-(X' \otimes I_K)\alpha$ for $y=vec(Y)$ and $\mu^*=(\mu', ..., \mu')'$, then $f_y(y)=\left|\frac{\partial \mathcal{E}}{\partial y'}\right| f_{\mathcal{E}}(\mathcal{E})$.

$$lnL(\mu, \alpha, \Sigma_{\mathcal{E}}) = -\frac{KT}{2} ln(2\pi) - \frac{T}{2} ln(|\Sigma_{\mathcal{E}}| - \frac{1}{2} tr[(Y^0 - AX)' \Sigma_{\mathcal{E}}{}^{-1} (Y^0 - AX)] \quad (3.21)$$

In equation (3.21),$X=(Y_0{}^0, \ldots, Y_{T-1}{}^0)$, $\alpha=vec(A)$, $Y^0=(y_1 - \mu, \ldots, y_T - \mu)$ and $A=(A_1, \ldots, A_p)$.

The log likelihood function, which is aimed to be maximized, is given in the equation above. K, T and p represent the number of variables, observations and AR terms, respectively. μ is the mean vector and α is the matrix of the parameters of the AR terms, whereas Σ_ε is the covariance-variance matrix.

$$\frac{\partial lnL}{\partial \mu}=(I_K-\sum_i A_i)'\Sigma_\varepsilon^{-1}\sum_i (A_i y_{t-i}) \tag{3.22}$$

$$\frac{\partial lnL}{\partial \mu}=[I_K-A(j\otimes I_K)]'\Sigma_\varepsilon^{-1}\left[\sum_t(y_t-\mu-AY_{t-1}{}^0)\right] \tag{3.23}$$

In these equations,$j=(1,\ldots,1)'$ is a (p$\times$1) vector of ones.

$$\frac{\partial lnL}{\partial \alpha}=(X\otimes \Sigma_\varepsilon^{-1})(y-\mu^*)-(XX'\otimes \Sigma_\varepsilon^{-1})\alpha \tag{3.24}$$

$$\frac{\partial lnL}{\partial \Sigma_\varepsilon}=-\frac{T}{2}\Sigma_\varepsilon^{-1}+\frac{1}{2}\Sigma_\varepsilon^{-1}(Y^0-AX)(Y^0-AX)'\Sigma_\varepsilon^{-1} \tag{3.25}$$

By taking the first derivatives of the log likelihood function with respect to μ, α and Σ_ε and then setting them equalto zero, the estimators are computed (Lütkepohl [40]).

$$\tilde{\mu}=\frac{1}{T}(I_K-\sum_i A_i)^{-1}\sum_t(y_t-\sum_i A_i y_{t-i}) \tag{3.26}$$

$$\tilde{\alpha}=((XX')^{-1}X\otimes I_K)(y-\mu^*) \tag{3.27}$$

$$\widetilde{\Sigma_\varepsilon}=\frac{1}{T}(Y^0-AX)(Y^0-AX)' \tag{3.28}$$

The model used in this thesis is different from the general model mentioned previously. The VAR model in this study includes three endogenous variables which are the foreign exchange, bond and stock returns for each country. Moreover, there are three exogenous variables, which are the global bond, global stock and global commodity returns. FX, BOND, STOCK, GBOND, GSTOCK and GCOMMODITY represent the log returns of the foreign exchange, bond, stock, global bond, global stock and global commodity prices, respectively. Instead of testing with information criteria to find the appropriate lag length, a lag length of one is intuitively chosen due to the estimation difficulties of excessive number of parameters in a trivariate VAR model with exogenous variables and GARCH terms Since there is cointegration among the variables, error correction variables are also included. These variables are acquired by the regression of log prices of three endogenous variables together and they are the first lag of the residuals of the regression below. These variables measure whether the long-run equilibrium is formed at the same date, or with a delay of one day. The model used in this study is represented by the matrices below:

$$\begin{bmatrix} FX_t \\ BOND_t \\ STOCK_t \end{bmatrix} = \begin{bmatrix} c_1 \\ c_2 \\ c_3 \end{bmatrix} + \begin{bmatrix} d_{11} & 0 & 0 \\ 0 & d_{22} & 0 \\ 0 & 0 & d_{33} \end{bmatrix} \begin{bmatrix} RESIDECM_{t-1} \\ RESIDECM_{t-1} \\ RESIDECM_{t-1} \end{bmatrix} + \begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix} \begin{bmatrix} FX_{t-1} \\ BOND_{t-1} \\ STOCK_{t-1} \end{bmatrix} +$$

$$\begin{bmatrix} b_{11} & b_{12} & b_{13} \\ b_{21} & b_{22} & b_{23} \\ b_{31} & b_{32} & b_{33} \end{bmatrix} \begin{bmatrix} GBOND_{t-1} \\ GSTOCK_{t-1} \\ GCOMMODITY_{t-1} \end{bmatrix} + \begin{bmatrix} \mathcal{E}_1 \\ \mathcal{E}_2 \\ \mathcal{E}_3 \end{bmatrix} \tag{3.29}$$

3.2.9. Univariate GARCH Modeling

GARCH models (Bollerslev [9]) are a popular way of modeling the stochastic volatility. The univariate case of GARCH(1,1) model with the mean equation of AR(1) is represented as follows:

$$Y_t = \alpha_0 + \alpha_1 Y_{t-1} + u_t \tag{3.30}$$

$$\sigma_t^2 = \gamma_0 + \gamma_1 u_{t-1}^2 + \gamma_2 \sigma_{t-1}^2 \tag{3.31}$$

The sum of the volatility persistence parameters should be less than one. This is necessary since the modeled volatility would explode with a parameter total that is larger than 1.

$$\gamma_1 + \gamma_2 < 1 \tag{3.32}$$

Univariate GARCH processes are applied in this study, while acquiring the error terms of the exogenous variables to insert them into the variance equation of the multivariate GARCH model in the following manner:

$$GBOND_t = \alpha_0 + \alpha_1 GBOND_{t-1} + u_{1t} \tag{3.33}$$

$$\sigma_{GBOND,t}^2 = \gamma_0 + \gamma_1 u_{1t-1}^2 + \gamma_2 \sigma_{GBOND,t-1}^2 \tag{3.34}$$

$$GSTOCK_t = \alpha_0 + \alpha_1 GSTOCK_{t-1} + u_{2t} \tag{3.35}$$

$$\sigma_{GSTOCK,t}^2 = \gamma_0 + \gamma_1 u_{2t-1}^2 + \gamma_2 \sigma_{GSTOCK,t-1}^2 \tag{3.36}$$

$$GCOMMODITY_t = \alpha_0 + \alpha_1 GCOMMODITY_{t-1} + u_{3t} \tag{3.37}$$

$$\sigma_{GCOMMODITY,t}^2 = \gamma_0 + \gamma_1 u_{3t-1}^2 + \gamma_2 \sigma_{GCOMMODITY,t-1}^2 \tag{3.38}$$

3.2.10. Multivariate GARCH Modeling

Multivariate applications of the GARCH models were developed in the 1980s and became popular in 2000s owing to the relatively simpler structure of the new representations. The equation below is the most general representation of the multivariate GARCH, VEC models (Bollerslev et al. [9]). In spite of the simple interpretation of this representation, it is not very popular in empirical applications due to the possibility of acquiring non-positive semi-definite variance-covariance combinations.

$$vec(\Sigma_{\mathcal{E}})= \delta_0+ \sum_{j=1}^{q} \Gamma_j vec(\mathcal{E}_{t-j}\mathcal{E}'_{t-j}) + \sum_{j=1}^{p} G_j \, vec(\Sigma_{t-j}) \tag{3.39}$$

In order to solve the problem of positive definiteness, the BEKK representation below is proposed (Engle and Kroner [22]).

$$\Sigma_t = C_0^{*}{}' C_0^{*} + \sum_{i=1}^{T}\sum_{j=1}^{q} \Gamma_{ij}^{*}{}' \mathcal{E}_{t-j}\mathcal{E}'_{t-j}\Gamma_{ij}^{*} + \sum_{i=1}^{T}\sum_{j=1}^{p} G_{ij}^{*}{}' \Sigma_{t-j} G_{ij}^{*} \tag{3.40}$$

The BEKK model uses quadratic forms to ensure positive definiteness. The major drawback of this approach is the difficulty in computation and interpretation of the parameters. The model below is the BEKK representation denoted by linear algebra.

$$\Sigma_t = C''C + \Gamma'\Sigma_{t-1}\Gamma + G'\mathcal{E}_{t-1}\mathcal{E}'_{t-1}G \tag{3.41}$$

The examination of volatility in this thesis is conducted by using the GARCH methodology with a BEKK representation. In addition to the simple error terms and volatility series of the endogenous variables of the mean equation, squared residual series of the GBOND, GSTOCK and GCOMMODITY are included. These error terms are calculated by univariate GARCH process and their mean equations are autoregressive with a lag length of one (parallel to the lag length of the VAR model used). In the GARCH model, a single lag for both ARCH and GARCH terms is preferred due to the difficulty of calculation and convergence in the BEKK representation. Σ_t and $\mathcal{E}_t$ represent the variance-covariance matrix and error terms, respectively. X_{1t}, X_{2t} and X_{3t} are the exogenous variables in the variance equation, which are the residuals of the AR(1) model of the GBOND, GSTOCK and GCOMMODITY variables.

$$\Sigma_t = C'C + B'\Sigma_{t-1}B + A'\mathcal{E}_{t-1}\mathcal{E}'_{t-1}A + D'DX_{1t-1}{}^2 + E'EX_{2t-1}{}^2 + F'FX_{3t-1}{}^2 \tag{3.42}$$

$$A=\begin{bmatrix}\alpha_{ii} & \alpha_{ij} & \alpha_{ik}\\ \alpha_{ji} & \alpha_{jj} & \alpha_{jk}\\ \alpha_{ki} & \alpha_{kj} & \alpha_{kk}\end{bmatrix} B=\begin{bmatrix}\beta_{ii} & \beta_{ij} & \beta_{ik}\\ \beta_{ji} & \beta_{jj} & \beta_{jk}\\ \beta_{ki} & \beta_{kj} & \beta_{kk}\end{bmatrix} C=\begin{bmatrix}\gamma_{ii} & 0 & 0\\ \gamma_{ji} & \gamma_{jj} & 0\\ \gamma_{ki} & \gamma_{kj} & \gamma_{kk}\end{bmatrix}$$

$$D=\begin{bmatrix}\delta_{ii} & 0 & 0\\ \delta_{ji} & \delta_{jj} & 0\\ \delta_{ki} & \delta_{kj} & \delta_{kk}\end{bmatrix} E=\begin{bmatrix}\theta_{ii} & 0 & 0\\ \theta_{ji} & \theta_{jj} & 0\\ \theta_{ki} & \theta_{kj} & \theta_{kk}\end{bmatrix} F=\begin{bmatrix}\eta_{ii} & 0 & 0\\ \eta_{ji} & \eta_{jj} & 0\\ \eta_{ki} & \eta_{kj} & \eta_{kk}\end{bmatrix} \tag{3.43}$$

C matrix shows the constant parameters. A and B matrices represent the coefficients for the GARCH and ARCH terms, respectively. D, E and F matrices are lower triangular matrices and show the spillovers from exogenous variables to endogenous variables in the variance equation.

The BEKK representation is naturally positive definite but exogenous variables are a threat for this property. In order to prevent any violation, squared residuals are preferred instead of regular residuals. Moreover, the covariance stationarity is required and all eigenvalues of the coefficient matrices have modulus less than 1.

$$\sum_{j=1}^{q} \Gamma_j + \sum_{j=1}^{p} G_j < 1 \tag{3.44}$$

For the optimization of both univariate and GARCH models, the BFGS algorithm is applied. In order to have better initial values, the simplex methodology is used at the beginning and these values are the inputs of the BFGS algorithm (Broyden et al. [11]).

CHAPTER 4

ANALYSIS AND RESULTS

4.1. Results of the Multivariate Cointegration Tests

In this part of the thesis, results regarding group of variables or the regressions among them are examined. Test outcomes for individual series or descriptive statistics are already analyzed in the data part.

Table 4.1. Results of the Johansen Cointegration Tests

	U.S.		Germany		Japan	
	λ-stat.	p-value	λ-stat.	p-value	λ-stat.	p-value
None	0.1915	0.0001	0.2630	0.0001	0.1920	0.0001
At most 1	0.1739	0.0001	0.1780	0.0001	0.1727	0.0001
At most 2	0.1701	0.0000	0.1585	0.0000	0.1604	0.0000
	Mexico		**Turkey**		**Korea**	
	λ-stat.	p-value	λ-stat.	p-value	λ-stat.	p-value
None	0.2107	0.0001	0.2828	0.0001	0.3045	0.0001
At most 1	0.1964	0.0001	0.1784	0.0001	0.1777	0.0001
At most 2	0.1822	0.0000	0.1609	0.0000	0.1402	0.0000

Table 4.1 displays the eigenvalues and their p-values calculated by the maximum eigenvalue statistic for the Johansen cointegration test. For all six cases, the null hypotheses are rejected and the number of cointegrating relations is identified as three. The most important interpretation of the test results is the existence of cointegration or, in other words, a long-run equilibrium for the six different cases in this study.

4.2. Vector Autoregressive Model

The positive results of the Johansen Cointegration Test indicate the necessity of including an error correcting variable in the model in order to see whether the deviations from the long-run state disappear in the same period or not. This variable is the residual series of the cointegrating regression. Therefore, the cointegrating regressions are estimated and its residual series is inserted into the VAR model. Since all variables are in the log-return forms, variables of the cointegrating regression are the log-prices.

$$FX_t=\gamma_0+\gamma_1 BOND_t+\gamma_2 STOCK_t \tag{4.1}$$

The regression above is estimated separately for each of the six countries. The residuals of the regression of the log-price series are saved and their first lag is inserted into the VAR model.

Table 4.2. Coefficients of the Cointegrating Regressions and their p-values

	U.S.	Mexico	Germany	Turkey	Japan	Korea
	FX	**FX**	**FX**	**FX**	**FX**	**FX**
CONSTANT	11.3882	1.2383	3.6676	1.1692	4.6947	7.5325
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
BOND	-1.0924	0.6771	-0.6930	0.2625	-0.8887	-0.1464
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STOCK	-0.2573	-0.2801	-0.0829	-0.1985	-0.0194	-0.1203
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

In Table 4.2, it is seen that all variables are significant at the 99% confidence interval. After the formation of the error correcting variable series, the VAR model is established.

$$\begin{bmatrix} FX_t \\ BOND_t \\ STOCK_t \end{bmatrix} = \begin{bmatrix} c_1 \\ c_2 \\ c_3 \end{bmatrix} + \begin{bmatrix} d_{11} & 0 & 0 \\ 0 & d_{22} & 0 \\ 0 & 0 & d_{33} \end{bmatrix} \begin{bmatrix} RESIDECM_{t-1} \\ RESIDECM_{t-1} \\ RESIDECM_{t-1} \end{bmatrix} + \begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix} \begin{bmatrix} FX_{t-1} \\ BOND_{t-1} \\ STOCK_{t-1} \end{bmatrix} +$$

$$\begin{bmatrix} b_{11} & b_{12} & b_{13} \\ b_{21} & b_{22} & b_{23} \\ b_{31} & b_{32} & b_{33} \end{bmatrix} \begin{bmatrix} GBOND_{t-1} \\ GSTOCK_{t-1} \\ GCOMMODITY_{t-1} \end{bmatrix} + \begin{bmatrix} \mathcal{E}_1 \\ \mathcal{E}_2 \\ \mathcal{E}_3 \end{bmatrix} \qquad (4.2)$$

The model presented by matrices is regressed by using the ordinary least squares method. The results are seriously and adversely affected by the violations of the Gauss-Markov assumptions. In order to get the unbiased standard errors and efficient parameter estimations, these assumptions, which are homoscedasticity and no autocorrelation, are compulsory. Furthermore, to make inferences for the significance of these estimates, normality is also required. Unfortunately, the model regressed does not obey these assumptions so its coefficient estimates are not provided. The table below displays the outcomes of autocorrelation, heteroscedasticity and normality diagnostic tests.

Table 4.3. Diagnostic Test Statistics and their p-values

	U.S.	Mexico	Germany	Turkey	Japan	Korea
MV-Q	353.6173	431.4723	434.7076	539.3303	219.9617	1367.7040
	0.0000	0.0000	0.0000	0.0000	0.0226	0.0000
MV-LM	2881.9700	6273.3600	1344.3500	4597.8900	1673.3000	8142.8400
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
MV-JB	9169.5980	37888.5000	3298.1420	335182.8060	134255.6000	57906.9100
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

It is seen that the null hypotheses of normality, constant variance and no serial correlation of the residuals are rejected for all countries at any confidence level. Therefore, the reasons of these violations should be detected and modeled.

4.3. Results of the GARCH Model for the Whole Sample

4.3.1. Results of the Univariate GARCH Model

In order to tackle the problems resulting from the error terms, the GARCH methodology is used. Initially, the residual series of the global market returns are acquired by estimating univariate GARCH process. In order to make standardization for the model, the lag length for the AR process is chosen as one, the same with the VAR process.

$$GBOND_t = \alpha_0 + \alpha_1 GBOND_{t-1} + u_{1t} \tag{4.3}$$

$$\sigma_{GBOND,t}^2 = \gamma_0 + \gamma_1 u_{1t-1}^2 + \gamma_2\, \sigma_{GBOND,t-1}^2 \tag{4.4}$$

$$GSTOCK_t = \alpha_0 + \alpha_1 GSTOCK_{t-1} + u_{2t} \tag{4.5}$$

$$\sigma_{GSTOCK,t}^2 = \gamma_0 + \gamma_1 u_{2t-1}^2 + \gamma_2\, \sigma_{GSTOCK,t-1}^2 \tag{4.6}$$

$$GCOMMODITY_t = \alpha_0 + \alpha_1 GCOMMODITY_{t-1} + u_{3t} \tag{4.7}$$

$$\sigma_{GCOMMODITY,t}^2 = \gamma_0 + \gamma_1 u_{3t-1}^2 + \gamma_2\, \sigma_{GCOMMODITY,t-1}^2 \tag{4.8}$$

The outcomes of the estimation for the regressions above are presented in the following table.

Table 4.4. Coefficients of the Univariate GARCH Model and their p-values

	GBOND	**GSTOCK**	**GCOMMODITY**
Mean Eq.			
Constant	0.0000	0.0005	0.0006
	0.8958	0.0155	0.0530
AR(1)	0.1112	0.1641	-0.0237
	0.0000	0.0000	0.0390
Variance Eq.			
Constant	0.0000	0.0000	0.0000
	0.2281	0.0210	0.0587
ARCH(1)	0.0371	0.0903	0.0327
	0.0067	0.0000	0.0002
GARCH(1)	0.9534	0.9049	0.9587
	0.0000	0.0000	0.0000

Coefficients, excluding intercept terms, of the mean and variance equation are all significant at the 95% confidence interval. These results are expected and indicate the explanatory power of the model.

4.3.2. Results of the Mean Equation

By the production of the residual series of the global variables, multivariate GARCH model is suitable for the estimation. Both the mean and variance equation are estimated by the maximum likelihood procedure. By the estimation, 66 parameters, 24 of which are for the mean equation, are computed. The representation of the variance equation is given below with matrix notations.

$$\Sigma_t = C'C + B'\Sigma_{t-1}B + A'\mathcal{E}_{t-1}\mathcal{E}'_{t-1}A + D'DX_{1t-1}{}^2 + E'EX_{2t-1}{}^2 + F'FX_{3t-1}{}^2 \qquad (4.9)$$

Before the analyses of mean equation results, it should be kept in mind that positive returns in the foreign exchange markets imply the depreciation of the local currencies with respect to American dollar. For the U.S. case, depreciation is the decline in the value of dollar with respect to effective exchange rate. Moreover, all local bond and stock indices are valued by U.S. dollar. Therefore, any increases in theses indices indicate the revaluation in terms of U.S. dollar.

Table 4.5. Coefficients of the Mean Equation of the Multivariate GARCH Model and their p-values

	U.S.			Germany			Japan		
	FX	**BOND**	**STOCK**	**FX**	**BOND**	**STOCK**	**FX**	**BOND**	**STOCK**
CONSTANT	−0.0001	0.0000	0.0005	0.0000	0.0001	0.0008	0.0000	0.0001	0.0001
	0.2638	0.4546	0.0062	0.3918	0.1804	0.0004	0.7342	0.5616	0.7270
RESIDECM	−0.0125	−0.0011	0.0048	−0.0168	−0.0170	0.0209	−0.047	0.0366	−0.035
	0.0001	0.5043	0.3664	0.0056	0.0240	0.1954	0.0055	0.0357	0.2543
FX	−0.0062	−0.0226	−0.0599	−0.3390	0.0005	0.0246	0.1575	−0.2160	0.0634
	0.7563	0.0103	0.0626	0.0000	0.9830	0.5650	0.0000	0.0000	0.6365
BOND	0.0528	−0.4216	0.0548	−0.4778	−0.0581	0.1142	0.1518	−0.2087	−0.0704
	0.2467	0.0000	0.0011	0.0000	0.0177	0.0164	0.0000	0.0000	0.5653
STOCK	−0.0344	−0.0379	−0.0947	0.0077	−0.0505	−0.3611	−0.1245	0.1345	−0.2929
	0.0106	0.0000	0.0011	0.5473	0.0004	0.0000	0.0000	0.0000	0.0000
GBOND	−0.0562	0.9133	−0.1173	0.0611	0.5285	−0.1919	−1.4307	1.6469	0.1374
	0.4405	0.0000	0.4824	0.4265	0.0000	0.2337	0.0000	0.0000	0.3322
GSTOCK	0.0160	0.0137	0.0569	−0.0785	0.1094	0.6567	0.1162	−0.1338	0.7677
	0.3683	0.0414	0.1103	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
GCOMMODITY	−0.0054	0.0001	−0.0131	−0.0426	0.0432	−0.0272	−0.0305	0.0345	−0.0432
	0.5196	0.9743	0.3515	0.0000	0.0000	0.1230	0.0007	0.0003	0.0282

Table 4.5. Coefficients of the Mean Equation of the Multivariate GARCH Model and their p-values (continued)

	Mexico			Turkey			Korea		
	FX	**BOND**	**STOCK**	**FX**	**BOND**	**STOCK**	**FX**	**BOND**	**STOCK**
CONSTANT	0.0000	0.0005	0.0011	0.0002	0.0006	0.0008	0.0000	0.0005	0.0008
	0.2742	0.0000	0.0000	0.1035	0.0001	0.0397	0.5536	0.0000	0.0005
RESIDECM	−0.0068	−0.0011	0.0014	−0.0017	−0.0001	−0.0006	−0.0041	0.0024	0.0187
	0.0055	0.6837	0.8625	0.2518	0.9269	0.9071	0.0010	0.2168	0.0007
FX	−0.0006	−0.5850	−0.6224	−0.4510	0.0372	0.0929	0.0378	−0.0184	−0.1458
	0.9791	0.0000	0.0000	0.0000	0.0000	0.0153	0.0095	0.5099	0.0006
BOND	−0.0090	−0.2048	−0.1730	−0.5546	0.0297	0.1554	−0.5754	−0.0747	0.4560
	0.6546	0.0000	0.0004	0.0000	0.3424	0.0654	0.0000	0.0000	0.0000
STOCK	0.0017	0.0206	0.0557	−0.0157	0.0335	−0.0158	−0.0282	−0.0349	−0.1017
	0.7918	0.0087	0.0063	0.0484	0.0008	0.4977	0.0000	0.0000	0.0000
GBOND	−0.0373	0.3411	0.2872	−0.3506	0.2767	0.7734	−0.0055	0.5834	−0.1121
	0.4856	0.0000	0.0619	0.0000	0.0088	0.0039	0.8738	0.0000	0.4105
GSTOCK	−0.0362	0.0095	−0.0442	−0.1511	0.0938	0.3998	−0.0220	0.2246	0.5885
	0.0024	0.5148	0.1657	0.0000	0.0000	0.0000	0.0035	0.0000	0.0000
GCOMMODITY	0.0140	−0.0332	−0.0111	0.0149	−0.0018	−0.0449	0.0029	0.0248	−0.0472
	0.0664	0.0001	0.5877	0.1612	0.8943	0.2237	0.5194	0.0004	0.0176

Table 4.6. Significance Level and Sign of the Mean Equation Parameters

	U.S.			Germany			Japan		
	FX	**BOND**	**STOCK**	**FX**	**BOND**	**STOCK**	**FX**	**BOND**	**STOCK**
CONSTANT			+++			+++			
RESIDECM	−			———	——		———	++	
FX		——	−	———			+++	———	
BOND		———	+++		——	++	+++	———	
STOCK	——	———	———		———	———	———	+++	———
GBOND		+++			+++		———	+++	
GSTOCK		+		———	+++	+++	+++	———	+++
GCOMMODITY				———	+++		———	+++	——
	Mexico			**Turkey**			**Japan**		
	FX	**BOND**	**STOCK**	**FX**	**BOND**	**STOCK**	**FX**	**BOND**	**STOCK**
CONSTANT			+++		+++	++		+++	+++
RESIDECM	——						———		+++
FX		———	———	———	+++	++	+++		———
BOND		———	———	———		+	———	———	+++
STOCK		+++	+++	——	+++		———	———	———
GBOND		+++	+	———	+++	++		+++	
GSTOCK	——			———	+++	+++	———	+++	+++
GCOMMODITY	+	———						+++	++

The first noteworthy result is the negative and significant parameter of the error correcting variable for the regressions with the dependent variable of foreign exchange return except for Turkey. This means that, disequilibrium in the foreign exchange markets needs a day to revert back to equilibrium position. Initially, it is apparently observed that there is no general pattern for the effects of previous day foreign exchange return on the current day foreign exchange return. There is no significant relationship for the two North American markets, while German and Turkish currency markets have negative relationship, which means a mean reverting process. The opposite outcome is acquired for the far eastern markets with the positive sign. It shows the positive return in the foreign exchange market creates the same return expectation for the following day. The relationship between the previous and current day returns of the local bond markets is negative except for Turkey. This is the typical result of the mean reverting structure of the bond returns. Similar situation also exists for local stock markets excluding Mexico and Turkey.

There are also remarkable relationships for the different type of markets in the same countries. For instance, there is a negative relationship between stock and foreign exchange markets except for Mexican case. This shows that any increase of the dollar value of the stock market will also increase the value of the local currency. Local bond returns have a positive relationship with the local stock returns excluding Mexican and Japanese markets. The underlying reason may be the changes in the interest rates, which affects both indices positively according to the economic theory. Another interesting result is the negative effect of local stock returns on foreign exchange returns except for Germany and Mexico. This indicates thatany increase in the dollar value of the local stocks would support the local currencies.

In addition to the interaction among these local markets, global financial markets also have some meaningful impacts to local ones. There is a positive effect of the global bond markets on the local bond markets. Any increase or decrease in these global markets seems to directly affect the local ones for all countries. Similar outcome also exists on the local stock indices for the changes in the global stock markets with the exceptions of American and Mexican stock markets. The global commodity index is also an important factor for some markets but definitely not for the American and Turkish financial markets.

4.3.3. Results of the Variance Equation

The results in the next table are for the variance equations, which are the main emphasis of this study. Before interpreting the estimation results, it should be kept in mind that GARCH and ARCH terms represent the first lag of the variance series and residual series for any variable respectively. ARCH terms of the local variables are level of the residuals; whereas ARCH terms of the global variables are squared residuals due to provide positive definiteness of the variance-covariance matrix. The effect of these ARCH terms can be clusters as heat wave and meteor shower effects. The significant effects of the own ARCH term of the dependent variable is called the heat wave effect, whereas significance of the ARCH terms of other variables is called the meteor shower effect (Engle et al. [21]). Meteor shower effects can also be interpreted as news shock effects, since they transfer the sudden shocks in one market to another. On the other hand, GARCH parameters explain the volatility persistence. The higher total volatility persistence, which means the summation of the all GARCH coefficients, indicates long duration of the impacts of the previous day volatilities. The total volatility persistence should not exceed 1 in order to get finite variances.

Table 4.7. Coefficients of the Variance Equation of the Multivariate GARCH Model and their p-values

	U.S.			Germany			Japan		
	FX	**BOND**	**STOCK**	**FX**	**BOND**	**STOCK**	**FX**	**BOND**	**STOCK**
CONSTANT	0.0003	0.0003	-0.0009	0.0002	0.0004	-0.0011	0.0030	0.0002	0.0030
	0.0002	0.0000	0.0420	0.1496	0.0008	0.1271	0.0000	0.0005	0.0000
GARCH									
FX	0.9881	-0.0086	-0.0326	0.9822	0.0086	0.0039	0.5713	0.3763	-0.4902
	0.0000	0.0000	0.0000	0.0000	0.1709	0.8565	0.0000	0.0000	0.0380
BOND	0.0037	0.9660	-0.0546	-0.0059	0.9896	0.0362	-0.0864	0.5261	-0.1966
	0.5806	0.0000	0.0000	0.3969	0.0000	0.0370	0.0000	0.0000	0.1105
STOCK	0.0028	-0.0024	0.9428	0.0025	0.0004	0.9435	-0.0539	0.0552	0.8248
	0.0535	0.0303	0.0000	0.2143	0.7861	0.0000	0.0000	0.0000	0.0000
ARCH									
FX	0.1427	0.0362	0.0537	0.1424	-0.0131	-0.0297	0.2384	0.0331	0.4761
	0.0000	0.0004	0.0791	0.0000	0.6754	0.7006	0.0000	0.3407	0.0060
BOND	0.0777	0.1468	-0.1590	0.0114	0.1153	-0.0828	0.0481	0.2147	0.1328
	0.0082	0.0000	0.0096	0.6964	0.0000	0.1410	0.1846	0.0000	0.2256
STOCK	-0.0038	-0.0043	0.2439	-0.0202	0.0093	0.2866	-0.0117	0.0118	0.3058
	0.3793	0.3321	0.0000	0.0009	0.1265	0.0000	0.4558	0.4198	0.0000
GBOND	28.5289	22.7422	38.7986	33.0141	-1.0581	0.7213	138.8520	44.2067	108.1237
	0.0166	0.0015	0.3031	0.0333	0.0002	0.0254	0.0001	0.0386	0.1797
GSTOCK	-0.6035	-0.0675	1.4704	36.1416	-0.0777	0.0347	2.3741	-0.0762	-0.3079
	0.0039	0.4450	0.5180	0.0192	0.7695	0.8765	0.0000	0.2481	0.8803
GCOMMODITY	-0.3897	0.1168	-0.0564	-6.6365	-2.2897	-1.6256	1.3625	-0.2366	2.5111
	0.2111	0.1857	0.9666	0.9160	0.1958	0.1673	0.0007	0.0078	0.0222

Table 4.7. Coefficients of the Variance Equation of the Multivariate GARCH Model and their p-values(continued)

	Mexico			**Turkey**			**Korea**		
	FX	**BOND**	**STOCK**	**FX**	**BOND**	**STOCK**	**FX**	**BOND**	**STOCK**
CONSTANT	0.0005	0.0005	-0.0015	0.0020	0.0010	0.0035	0.0006	0.0000	-0.0005
	0.0000	0.0396	0.5838	0.0000	0.0000	0.0000	0.0000	0.9672	0.4306
GARCH									
FX	0.9644	-0.0099	-0.0309	0.9016	-0.0785	-0.1308	0.7670	-0.3872	-0.0608
	0.0000	0.6657	0.4685	0.0000	0.0000	0.0000	0.0000	0.0000	0.2420
BOND	0.0183	0.9214	-0.0447	0.0862	0.8199	-0.2912	0.1104	0.9560	-0.1353
	0.4846	0.0000	0.3642	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STOCK	0.0055	-0.0022	0.9457	-0.0088	0.0244	0.9896	0.0006	0.0039	0.9693
	0.0879	0.6482	0.0000	0.0000	0.0000	0.0000	0.8461	0.4801	0.0000
ARCH									
FX	0.2049	-0.0922	-0.0592	0.4453	-0.1824	-0.4581	0.2019	0.0874	0.0674
	0.0040	0.1643	0.5960	0.0000	0.0000	0.0000	0.0000	0.1531	0.3424
BOND	-0.0190	0.2243	0.0422	-0.0012	0.2783	0.2842	-0.3011	-0.0373	0.1524
	0.7219	0.0000	0.6504	0.9754	0.0000	0.0000	0.0000	0.2872	0.0000
STOCK	-0.0106	-0.0021	0.2471	0.0178	-0.0453	0.0471	-0.0026	-0.0255	0.1797
	0.1873	0.8538	0.0000	0.0000	0.0000	0.0032	0.4761	0.0010	0.0000
GBOND	-29.1778	1.6991	0.7990	60.1268	-74.5723	0.0000	18.7242	-41.2575	215.3928
	0.0338	0.0001	0.0071	0.0386	0.0272	0.2971	0.1198	0.3732	0.0000
GSTOCK	-14.3850	0.9409	1.2837	2.5319	-3.8695	1.7628	2.8621	2.5833	2.6593
	0.4168	0.0753	0.0000	0.0000	0.0000	0.0567	0.0000	0.0023	0.0000
GCOMMODITY	-21.7581	-0.4502	-1.7730	0.1117	1.7390	1.1288	0.6257	1.6464	-2.2658
	0.5181	0.6086	0.0142	0.7949	0.0001	0.0924	0.0123	0.2129	0.0078

Table 4.8 Significance Level and Sign of the Variance Equation Parameters

	U.S.			Germany			Japan		
	FX	**BOND**	**STOCK**	**FX**	**BOND**	**STOCK**	**FX**	**BOND**	**STOCK**
CONSTANT	+++	+++	−−		+++		+++	+++	+++
GARCH									
FX	+++	−−	−−−	+++			+++	+++	−−
BOND		+++	−−−		+++	++	−−−	+++	
STOCK	+++	−−	+++			+++	−−−	+++	+++
ARCH									
FX	+++	+++	+	+++			+++		+++
BOND	+++	+++	−−−		+++			+++	
STOCK			+++	−−−		+++			+++
GBOND	++	+++		++	−−−	++	+++	++	
GSTOCK	−−−			++			+++		
GCOMMODITY							+++	−−−	++
	Mexico			**Turkey**			**Korea**		
	FX	**BOND**	**STOCK**	**FX**	**BOND**	**STOCK**	**FX**	**BOND**	**STOCK**
CONSTANT	+++	++		+++	+++	+++	+++		
GARCH									
FX	+++			+++	−−−	−−−	+++	−−−	
BOND		+++		+++	+++	−−−	+++	+++	−−−
STOCK	+		+++	−−−	+++	+++			+++
ARCH									
FX	+++			+++	−−−	−−−	+++		
BOND		+++			+++	+++	−−−		+++
STOCK			+++	+++	−−−	+++		−−−	+++
GBOND	−−	+++	+++	++	−−				+++
GSTOCK		+	+++	+++	−−−	+	+++	+++	+++
GCOMMODITY			−−		+++	+	+++		−−−

The first point that should be examined in the variance equations is the significance of the own GARCH terms. All these parameters have positive sign and are significant even in the 1% significance level. This is an expected and natural result but the level of volatility persistence should also be checked.

Table 4.9. Total Volatility Persistence of the Variance Equations

	U.S.			Germany			Japan		
	FX	**BOND**	**STOCK**	**FX**	**BOND**	**STOCK**	**FX**	**BOND**	**STOCK**
Vol. Persistence	0.9946	0.9550	0.8556	0.9787	0.9986	0.9836	0.4310	0.9576	0.1380
	Mexico			**Turkey**			**Korea**		
	FX	**BOND**	**STOCK**	**FX**	**BOND**	**STOCK**	**FX**	**BOND**	**STOCK**
Vol. Persistence	0.9882	0.9094	0.8701	0.9790	0.7657	0.5675	0.8780	0.5727	0.7733

The table above presents the summation of the GARCH terms for each regression. Some of these values are relatively large and just less than 1. The border of 1 is certainly important and the values below this level indicate the finiteness of the variances. Higher values of total volatility persistence also show the long duration of the previous days volatilities such as in the case of the German bond market with a total volatility persistence of 0.9986. Some of the total volatility persistence numbers are very low due to the negative coefficient of some of the GARCH terms.

In addition to the own GARCH terms of the dependent variables, own ARCH terms of these variables are also meaningful. All coefficients of these variables are positive and significant with an exception of Korean bond market whose own ARCH parameter is statistically insignificant even in the 90% confidence level. These results show that any news shock in the previous day raises today's volatility.

The next set of analyses for the test results are the existence of any meteor shower effects in the same country financial markets. Mexico does not have any spillover among its own markets and Germany has only one spillover, which is from stock volatility to foreign exchange volatility. On the other hand, Turkey has news impact spillover for all local financial markets with a single exception of bond to foreign exchange volatility transmission. American markets follow the Turkish ones with two exceptions, which are stock volatility to bond and foreign exchange volatilities.

The distinctive feature of this thesis is testing the effects of global markets on local markets. Global bond markets have the most widespread impact on the local financial markets with respect to global stock and commodity markets. It has positive or negative effects on local markets but these effects are the weakest for the Korean local markets. On contrary, its effects are maximized for the German and Mexican markets. Even though global stock is not as influential as global bond market, it has distinguished effects on the emerging markets with respect to developed ones. Global stock volatility is only effective for the volatilities of the exchange rates of the developed economies. Global commodity markets have the weakest role for the volatility spillover among countries. It does not have any significant effects on the American and German financial markets. However, it would not be correct to generalize this effect for all developed markets since its effect on the Japanese markets is distinctively strong.

4.3.4. Results of the Diagnostic Tests

Table 4.10. Diagnostic Test Results and their p-values

	U.S.	Mexico	Germany	Turkey	Japan	Korea
Log-Likelihood	24493.08	22924.50	22476.	21298.85	25402.56	23205.24
MV-Q	201.61	203.23	324.13	303.29	192.79	630.22
	0.12	0.11	0.00	0.00	0.24	0.00
MV-LM	312.11	348.83	261.17	364.48	636.78	358.60
	0.00	0.00	0.00	0.00	0.00	0.00
MV-JB	389.72	373.49	245.63	487.89	936.44	172.33
	0.00	0.00	0.00	0.00	0.00	0.00

The diagnostic test results for the multivariate GARCH model are summarized in Table 4.10. The log-likelihood values are the maximum point for the log-likelihood functions. Multivariate Q-statistic is the test statistic to check whether there is autocorrelation among error terms or not. For the cases of U.S., Mexico and Japan, the null hypothesis of no autocorrelation is failed to be rejected. On the other hand, there are still some autocorrelation effects for the remaining countries, though these effects are much less than the previous VAR model for GARCH model. MV-LM statistic is used for diagnosing heteroscedasticity. Unfortunately, all countries still have significant problem of non-constant variance, although these adverse effects are sharply decreased thanks to GARCH modeling. The final statistic is the multivariate Jarque-Bera and detects normality violations if they exist. For the all cases, the distributions of the error terms are enormously different than the normal dispersion. However, this does not adversely affect the test inferences owing to the choice of using robust standard errors which remove the necessity of normality.

4.4. Structural Breaks in the Volatility Series

The probable reasoning of these assumption violations could be the structural breaks in the volatility series produced by the GARCH methodology. The graphs below illustrate the pattern of these series. It is seen that there is an outlier for all markets of all countries in the September of 2008. This is not shocking because the collapse of one of the leading investments banks, Lehman Brothers, occurred in those days. Examination of volatility structure and spillovers of these markets under two separate subperiods may tackle the problems related violations to Gauss-Markov assumptions.

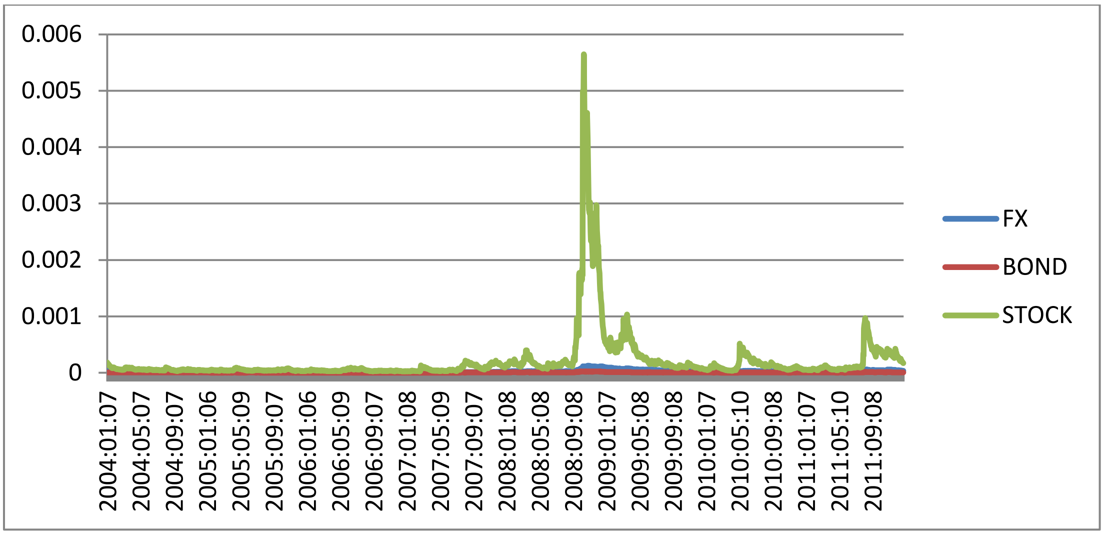

Figure 4.1. Variance Series of the Financial Markets of U.S.

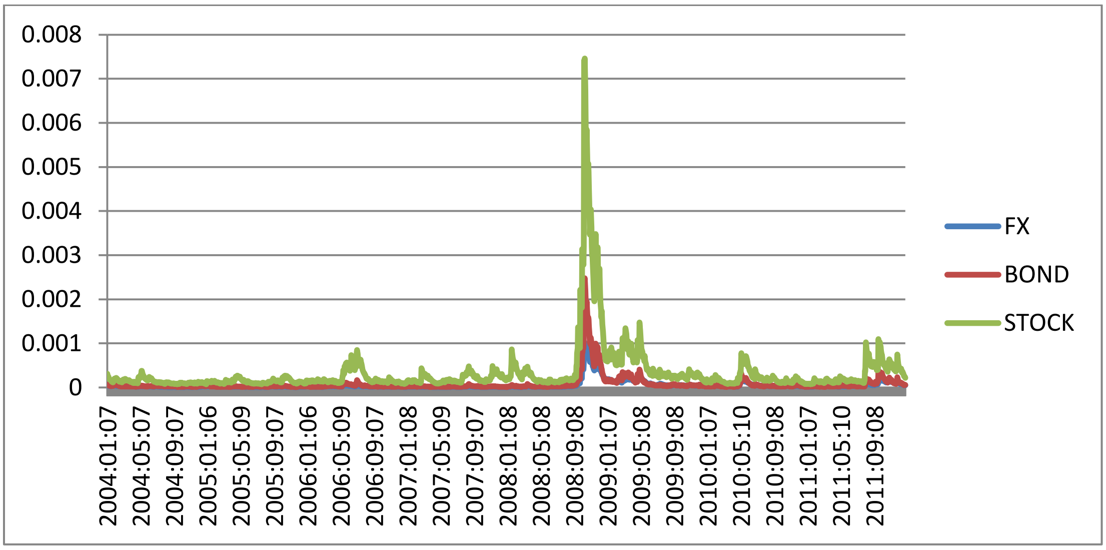

Figure 4.2. Variance Series of the Financial Markets of Mexico

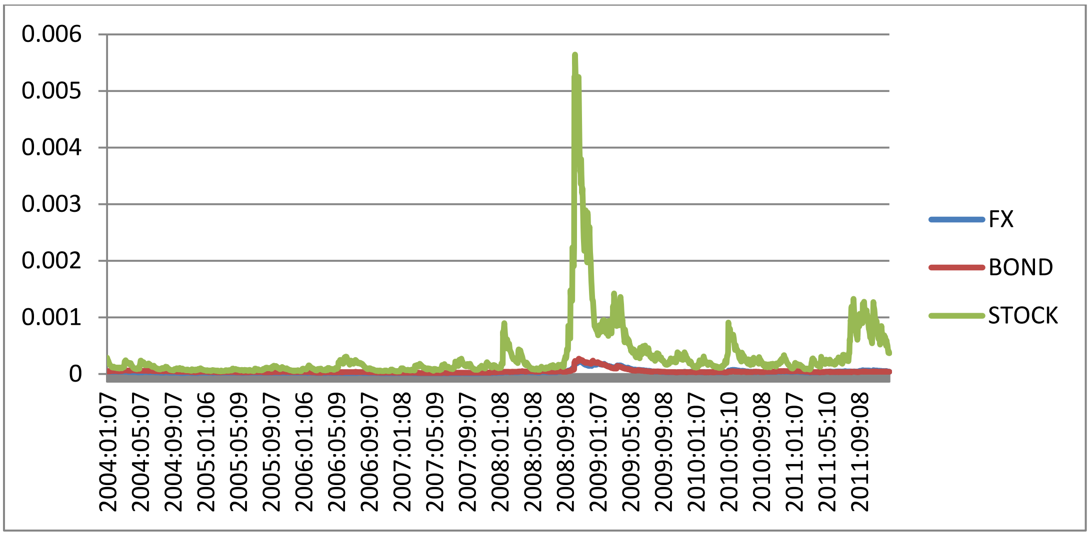

Figure 4.3. Variance Series of the Financial Markets of Germany.

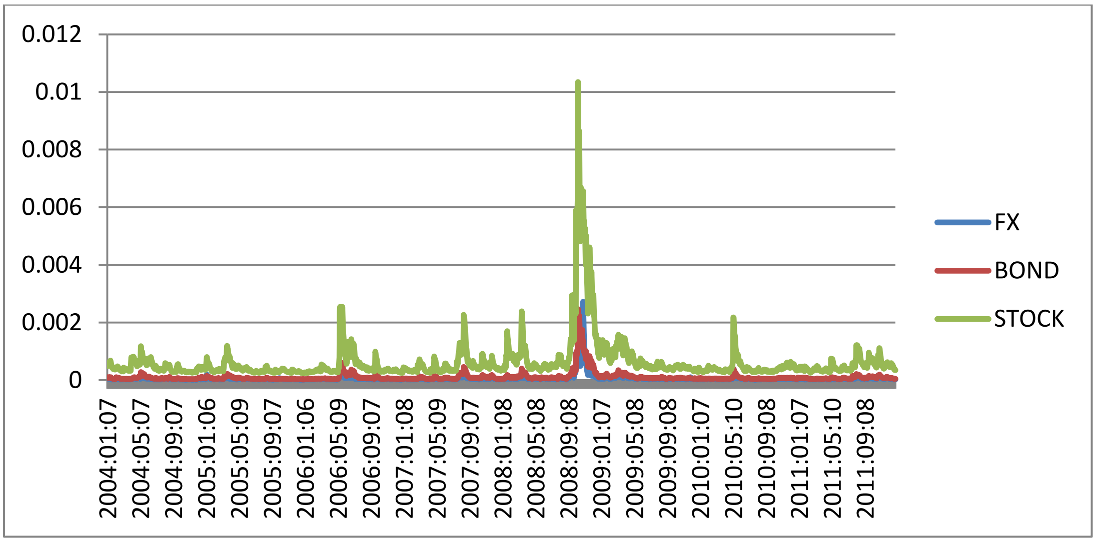

Figure 4.4. Variance Series of the Financial Markets of Turkey

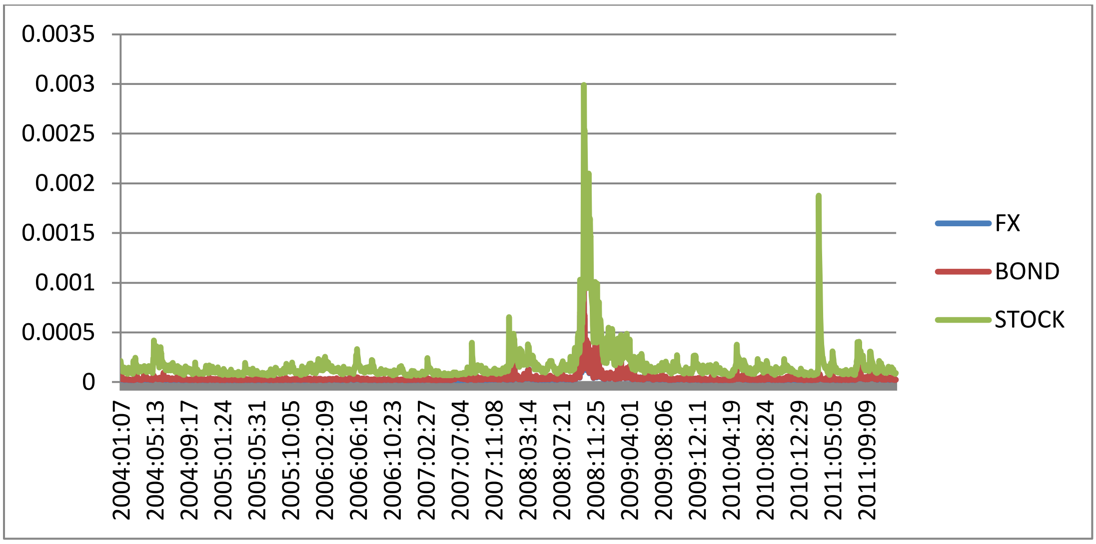

Figure 4.5. Variance Series of the Financial Markets of Japan

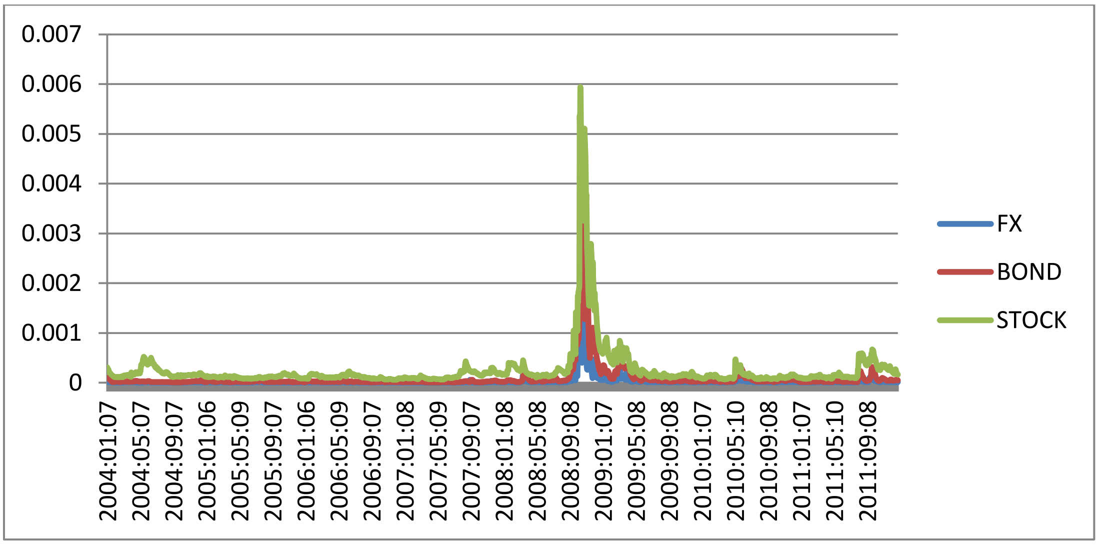

Figure 4.6. Variance Series of the Financial Markets of Korea

The sample is separated into two parts by removing the data between September 1, 2008 and December 31, 2008. The excluded data consist of the days with the highest volatilities for every series of all countries during the collapse of Lehman Brothers. By the exclusion, it would be possible to get healthier results for the period after the collapse, since such level of outliers distort the values of the parameters and these distortions could not be modeled. Moreover, it would make it possible to compare the spillovers before and after the most difficult days of the global crisis.

4.5. Results of the GARCH Model for the 1st Subsample

The first subsample is composed of the data from January 2, 2004 to August 29, 2008.

4.5.1. Results of the Univariate GARCH Model for the 1st Subsample

Table 4.11. Coefficients of the Univariate GARCH Model and their p-values

	GBOND	GSTOCK	GCOMMODITY
Mean Eq.			
Constant	0.0000	0.0004	0.0170
	0.3686	0.0409	0.2804
AR(1)	0.1242	0.1751	-0.0020
	0.0000	0.0000	0.0303
Variance Eq.			
Constant	0.0000	0.0000	0.0000
	0.2333	0.0349	0.5100
ARCH(1)	0.0222	0.0802	0.0210
	0.0000	0.0000	0.0840
GARCH(1)	0.9740	0.8971	0.9704
	0.0000	0.0000	0.0000

Coefficients, excluding constant terms, of both mean and variance equation are all statistically significant at the 90% confidence interval. These results are expected and indicate the explanatory power of the model.

4.5.2. Results of the Mean Equation for the 1st Subsample

The first remarkable point of these results is the significant and negative sign of the error correction parameters for the dependent variable of foreign exchange returns. This means that the deviation from the long-run equilibrium would be offset in the next day and it has a mean reverting process. In other words, the positive imbalances would be corrected by the negative ones in the following day.

Table 4.12. Coefficients of the Mean Equation of the Multivariate GARCH Model and their p-values

	U.S.			**Germany**			**Japan**		
	FX	**BOND**	**STOCK**	**FX**	**BOND**	**STOCK**	**FX**	**BOND**	**STOCK**
CONSTANT	-0.0002	0.0000	0.0003	-0.0001	0.0002	0.0009	0.0001	-0.0001	-0.0002
	0.1825	0.9348	0.1397	0.2101	0.1946	0.0011	0.8370	0.8546	0.5263
RESIDECM	-0.0147	-0.0030	0.0089	-0.0337	-0.0411	-0.0225	-0.0475	0.0269	-0.0917
	0.0014	0.1936	0.2317	0.0353	0.0284	0.4552	0.4278	0.7268	0.6703
FX	-0.0255	0.0020	-0.0737	-0.3132	0.0178	0.0338	0.0961	-0.2149	-0.0085
	0.3884	0.8845	0.0952	0.0000	0.6323	0.5381	0.7905	0.5761	0.9802
BOND	0.0319	-0.4347	0.0193	-0.4429	-0.1132	0.1141	0.0978	-0.2211	-0.0334
	0.6188	0.0000	0.8658	0.0000	0.0061	0.0463	0.7867	0.5732	0.9210
STOCK	-0.0390	-0.0546	-0.0900	0.0050	-0.0303	-0.3685	-0.1510	0.1572	-0.2815
	0.0505	0.0000	0.0337	0.7928	0.1758	0.0000	0.0000	0.0000	0.0003
GBOND	0.0121	0.8834	-0.0583	-0.0570	0.6119	-0.1665	-1.4538	1.7302	0.0869
	0.9097	0.0000	0.7703	0.5631	0.0000	0.3833	0.0007	0.0003	0.8600
GSTOCK	-0.0140	0.0393	0.0186	-0.1038	0.1135	0.6867	0.0929	-0.1280	0.9102
	0.5842	0.0024	0.7253	0.0012	0.0010	0.0000	0.2623	0.0889	0.0000
GCOMMODITY	-0.0107	0.0007	-0.0308	-0.0518	0.0531	-0.0366	-0.0313	0.0355	-0.0290
	0.3681	0.8984	0.0795	0.0000	0.0007	0.1336	0.4263	0.3417	0.3592

Table 4.12. Coefficients of the Mean Equation of the Multivariate GARCH Model and their p-values(continued)

	Mexico			Turkey			Korea		
	FX	**BOND**	**STOCK**	**FX**	**BOND**	**STOCK**	**FX**	**BOND**	**STOCK**
CONSTANT	-0.0002	0.0005	0.0014	0.0001	0.0011	0.0014	0.0001	0.0004	0.0006
	0.2300	0.0012	0.0007	0.5919	0.0000	0.0145	0.2525	0.0007	0.0222
RESIDECM	-0.0204	0.0126	0.1137	-0.0021	-0.0002	0.0286	-0.0158	-0.0162	-0.0001
	0.0110	0.2211	0.0007	0.6443	0.9757	0.0972	0.0108	0.1900	0.9974
FX	-0.0103	-0.5916	-0.7363	-0.4863	0.0451	0.1184	0.0444	0.0265	-0.2592
	0.0096	0.0000	0.0000	0.0000	0.2283	0.2590	0.0510	0.4360	0.0046
BOND	-0.0083	-0.1659	-0.1567	-0.5668	0.0043	0.1025	-0.5266	-0.0433	0.4820
	0.7660	0.0000	0.1066	0.0000	0.9110	0.3224	0.0000	0.0759	0.0000
STOCK	0.0025	0.0164	0.0240	-0.0127	0.0334	-0.0553	-0.0204	-0.0069	-0.1033
	0.7965	0.2376	0.5861	0.2113	0.0133	0.1236	0.0000	0.3429	0.0000
GBOND	-0.0389	0.3313	0.2060	-0.2084	0.1010	0.3819	0.0612	0.7410	-0.1561
	0.6259	0.0000	0.4456	0.0268	0.3791	0.2310	0.1876	0.0000	0.4007
GSTOCK	-0.0125	0.0068	0.0420	-0.2190	0.1893	0.7404	-0.0153	0.1854	0.7822
	0.4035	0.7670	0.5950	0.0000	0.0000	0.0000	0.1134	0.0000	0.0000
GCOMMODITY	0.0119	-0.0293	-0.0084	0.0087	0.0247	0.0242	0.0015	0.0123	-0.0126
	0.3089	0.0629	0.8212	0.5129	0.1223	0.5780	0.8377	0.2321	0.6437

Table 4.13. Significance Level and Sign of the Mean Equation Parameters

	U.S.			Germany			Japan		
	FX	**BOND**	**STOCK**	**FX**	**BOND**	**STOCK**	**FX**	**BOND**	**STOCK**
CONSTANT						+++			
RESIDECM	−−−			−−	−−				
FX			−	−−−					
BOND		−−−		−−−	−−−	++			
STOCK	−	−−−	−−			−−−	−−−	+++	−−−
GBOND		+++			+++		−−−	+++	
GSTOCK		+++		−−−	+++	+++		−	+++
GCOMMODITY			−	−−−	+++				
	Mexico			**Turkey**			**Korea**		
	FX	**BOND**	**STOCK**	**FX**	**BOND**	**STOCK**	**FX**	**BOND**	**STOCK**
CONSTANT		+++	+++		+++	++		+++	
RESIDECM	−−		+++	−−−		+	−−		
FX	−−−	−−−	−−−	−−−			+		−−
BOND		−−−					−−−	−	+++
STOCK					++		−−−		−−−
GBOND		+++		−−				+++	
GSTOCK				−−−	+++	+++		+++	+++
GCOMMODITY		−							

There are also noteworthy outcomes for the mean spillovers in the local markets. For instance, bond prices adversely affect the following day's bond prices for all cases except for Japan and Turkey. Furthermore, stock returns also affect the next day stock returns negatively with the exceptions of Mexico and Turkey. Foreign exchange and bond returns do not affect any of the dependent variables for the Japanese markets indicating the weakness of mean transmission in the local markets of Japan, but stock market is an important exception of this statement. Turkish financial markets are affected least for the local fluctuations. On the contrary, Korean markets are the most open to local effects.

Global variables are also effective on the first moment of the returns excluding global commodity market. Global bond and stock markets affect all individual bond markets with the exceptions of Turkey for the former, Japan and Mexico for the latter. Global stock returns are also influential for the stock returns with their positive impact excluding U.S. and Mexico markets. Mexico is the least affected by these global variables whereas Germany is the most affected.

4.5.3. Results of the Variance Equation for the 1st Subsample

The first point should be mentioned is the significance of the positive constant parameter for the foreign exchange dependent variable for all countries excluding U.S. The intuition behind this is that even in the case of no volatility or shocks during the previous business day, there will still be some volatility for the foreign exchange markets in the following day.

Regression results for the coefficients of the own GARCH terms of the dependent variables are not surprising due to their high significance and positiveness. In other words, the previous day volatilities directly affect the volatility of the current day.

Table 4.14. Coefficients of the Variance Equation of the Multivariate GARCH Model and their p-values

	U.S.			Germany			Japan		
	FX	**BOND**	**STOCK**	**FX**	**BOND**	**STOCK**	**FX**	**BOND**	**STOCK**
CONSTANT	0.0000	0.0003	0.0000	0.0002	0.0000	0.0000	0.0032	0.0000	0.0000
	0.8579	0.0001	0.9997	0.0000	0.7726	0.9999	0.0000	0.9395	0.9979
GARCH									
FX	0.9881	-0.0054	-0.0109	0.9826	0.0281	0.0325	0.2308	0.7657	-0.0117
	0.0000	0.3919	0.2283	0.0000	0.0000	0.0000	0.0000	0.0000	0.9275
BOND	-0.0105	0.9771	-0.0015	-0.0167	0.9563	0.0592	-0.2370	0.0885	0.1050
	0.2723	0.0000	0.5238	0.0000	0.0000	0.0000	0.0067	0.0000	0.4854
STOCK	-0.0015	-0.0025	0.9514	0.0067	-0.0045	0.8096	-0.0651	0.0643	0.7533
	0.7333	0.6318	0.0000	0.0000	0.0604	0.0000	0.0000	0.0000	0.0000
ARCH									
FX	0.1402	0.0209	0.0133	-0.0744	0.0648	0.0032	0.5149	-0.3795	0.2371
	0.0000	0.4567	0.7237	0.0000	0.0061	0.9706	0.0323	0.2316	0.3403
BOND	0.1082	0.1140	-0.2810	0.0237	-0.0983	0.0158	0.1184	0.0293	0.0243
	0.0137	0.0022	0.0210	0.0002	0.0000	0.8112	0.3186	0.8621	0.9470
STOCK	-0.0021	0.0007	0.1443	0.0040	0.0027	-0.2224	0.0382	-0.0364	0.1975
	0.8885	0.9464	0.0000	0.5266	0.7652	0.0000	0.4572	0.5058	0.4666
GBOND	38.5203	-30.9978	-0.0086	15.8653	-33.2439	-0.0129	92.7362	72.9460	-109.7787
	0.0056	0.0575	0.9998	0.3049	0.0395	0.9998	0.7692	0.5638	0.9536
GSTOCK	-0.1464	1.3110	0.0009	2.1101	0.1548	0.0009	6.4848	-0.0568	2.4973
	0.8171	0.8171	0.9997	0.0001	0.7618	0.9999	0.1930	0.9842	0.9721
GCOMMODITY	0.3551	-0.0013	-0.0002	-0.5198	-0.3966	-0.0003	1.6959	-0.8213	-0.9510
	0.4940	0.9964	0.9998	0.7449	0.2760	0.9997	0.1118	0.0006	0.9758

Table 4.14. Coefficients of the Variance Equation of the Multivariate GARCH Model and their p-values (continued)

	Mexico			Turkey			Korea		
	FX	**BOND**	**STOCK**	**FX**	**BOND**	**STOCK**	**FX**	**BOND**	**STOCK**
CONSTANT	0.0030	0.0002	0.0026	0.0009	0.0012	0.0015	0.0008	-0.0002	-0.0002
	0.0000	0.7642	0.0073	0.0078	0.0000	0.2537	0.0000	0.0112	0.6333
GARCH									
FX	0.1862	0.1200	-0.5107	0.7895	-0.1260	-0.2074	0.7078	-0.3956	0.0833
	0.0085	0.6980	0.4129	0.0000	0.0066	0.0025	0.0000	0.0000	0.1459
BOND	-0.2004	0.8647	-0.1868	0.1795	0.7213	-0.4545	0.1059	0.9302	-0.1701
	0.2890	0.0000	0.4990	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STOCK	-0.0679	0.0097	0.8859	-0.0249	0.0417	1.0345	-0.0011	0.0053	0.9465
	0.1898	0.8033	0.0000	0.0000	0.0000	0.0000	0.7223	0.2913	0.0000
ARCH									
FX	0.3106	-0.1163	0.1294	0.1002	0.1250	0.0611	0.1794	0.2493	0.1815
	0.0000	0.3977	0.5646	0.0808	0.1797	0.7818	0.0000	0.0188	0.1316
BOND	-0.0225	0.2286	0.2601	-0.2985	0.5226	0.8143	-0.3323	0.0253	0.2756
	0.7869	0.0008	0.1307	0.0000	0.0000	0.0000	0.0000	0.5653	0.0000
STOCK	0.0047	-0.0071	0.2252	0.0001	0.0020	0.0167	-0.0050	-0.0403	0.1531
	0.7658	0.7746	0.0001	0.9951	0.9227	0.7005	0.3134	0.0000	0.0000
GBOND	19.4768	20.2505	-69.1151	88.0758	-48.1326	405.6482	35.5065	53.7534	344.0920
	0.5679	0.5559	0.3460	0.0510	0.2118	0.0024	0.0286	0.1024	0.0000
GSTOCK	-2.8260	-3.4755	8.4896	6.9663	-5.5325	9.2574	1.0156	3.3106	-2.8558
	0.2339	0.0045	0.2650	0.0288	0.0842	0.0194	0.0921	0.0008	0.4100
GCOMMODITY	0.4111	2.0453	-0.4149	-0.7331	3.2217	2.6400	0.0841	2.1069	-5.4937
	0.5002	0.0003	0.8536	0.4136	0.0005	0.1482	0.7441	0.0001	0.0041

Table 4.15. Significance Level and Sign of the Variance Equation Parameters

		U.S.			Germany			Japan	
	FX	**BOND**	**STOCK**	**FX**	**BOND**	**STOCK**	**FX**	**BOND**	**STOCK**
CONSTANT		+++		+++			+++		
GARCH									
FX	+++			+++	+++	+++	+++	+++	
BOND		+++		−−−	+++	+++	−−−	+++	
STOCK			+++	+++	−	+++	−−−	+++	+++
ARCH									
FX	+++			−−−	+++		++		
BOND	++	+++	−−	+++	−−−				
STOCK			+++			−−−			
GBOND	+++	−			−−				
GSTOCK				+++					
GCOMMODITY								−−−	
		Mexico			**Turkey**			**Korea**	
	FX	**BOND**	**STOCK**	**FX**	**BOND**	**STOCK**	**FX**	**BOND**	**STOCK**
CONSTANT	+++		+++	+++	+++		+++	++	
GARCH									
FX	+++			+++	−−−	−−−	+++	−−−	
BOND		+++		+++	+++	−−−	+++	+++	−−−
STOCK			+++	−−−	+++	+++			+++
ARCH									
FX	+++			+			+++	++	
BOND		++		−−−	+++	+++	−−−		+++
STOCK			+++					−−−	+++
GBOND				+		+++	++		+++
GSTOCK		−−−		++	−	++	+	+++	
GCOMMODITY		+++			+++			+++	−−−

The second important analysis for the GARCH term parameters is the volatility persistence. The total volatility persistence should be less than one to provide finiteness to the volatility series. In the table below, total volatility persistence results are summarized. For all financial markets of the U.S. and Germany, there is very high volatility persistence. This means that the effects of the volatility shocks last for a long time. For the rest of the countries, there are also high volatility persistence numbers close to one in absolute value terms, but their total volatility persistence results are not that large because of negative signs of some of the GARCH parameters.

Table 4.16. Total Volatility Persistence of the Variance Equations

	U.S.			Germany			Japan		
	FX	BOND	STOCK	FX	BOND	STOCK	FX	BOND	STOCK
Vol. Persistence	0.9761	0.9691	0.9390	0.9726	0.9799	0.9012	-0.0713	0.9185	0.8466
	Mexico			**Turkey**			**Korea**		
	FX	BOND	STOCK	FX	BOND	STOCK	FX	BOND	STOCK
Vol. Persistence	-0.0821	0.9944	0.1884	0.9441	0.6370	0.3726	0.8125	0.5399	0.8597

For Turkey and Germany, GARCH spillovers are all significant with varying positive and negative signs. On the other hand, Mexican and American financial markets are not affected by the spillover from other local markets.

In order to measure the existence of the news shocks, examination of the ARCH term coefficients is necessary. All own ARCH term parameters are positive for all countries with the exceptions of the Turkish stock, Korean bond and Japanese both bond and stock markets. These effects are called the heat wave effects. Korean financial markets are open to all types of ARCH effects from the local financial markets. The interesting point for the ARCH terms significance is the lack of bidirectional spillover between foreign exchange and stock markets. The same situation also exists for the GARCH terms of these two variables with the exception of Germany. This implies the volatility independence of these two markets that existed before the global economic crisis.

Global variables are also effective for the pre-crisis period. This is definitely the case for the financial markets of Turkey and Korea. However, the effects of the commodity markets are relatively restricted with respect to the global bond and stock markets. The impact of global variables is very limited for the developed countries for this subsample.

4.5.4. Results of the Diagnostic Tests for the 1st Subsample

Table 4.17. Diagnostic Test Results and their p-values

	U.S.	Mexico	Germany	Turkey	Japan	Korea
Log-Likelihood	14759.2657	14001.6729	13734.8232	12564.0923	14829.7973	14210.5492
MV-Q	173.8890	186.3108	252.5541	255.83451	171.1363	417.3627
	0.6143	0.3580	0.0003	0.0002	0.6699	0.0670
MV-LM	188.5900	277.8400	246.5100	284.39	544.4000	233.1200
	0.3154	0.0000	0.0007	0.0000	0.0000	0.0047
MV-JB	128.9210	184.5840	134.5520	334.143	890.7940	136.0190
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

The table above displays the fundamental diagnostic test results. In this sub period, autocorrelation of the error terms are limited for U.S., Mexico, Japan and Korea. On contrary, there are still strong ARCH effects which are not modeled yet. The residuals are not normally distributed and this confirms the appropriateness of using robust standard errors.

4.6. Results of the GARCH Model for the 2nd Subsample

The second subsample is composed of the data from January 1, 2009 to December 30, 2011.

4.6.1. Results of the Univariate GARCH Model for the 2nd Subsample

The table below presents the results of the univariate GARCH for the global variables. The outcomes are not surprising that is all variables excluding intercept terms are statistically significant in the 95% confidence interval.

Table 4.18. Coefficients of the Univariate GARCH Model and their p-values

	GBOND	GSTOCK	GCOMMODITY
Mean Eq.			
Constant	0.0001	0.0006	0.0004
	0.2147	0.1838	0.3678
AR(1)	0.0647	0.1469	0.0124
	0.0405	0.0005	0.0237
Variance Eq.			
Constant	0.0000	0.0000	0.0000
	0.0621	0.0606	0.3581
ARCH(1)	0.0703	0.0712	0.0340
	0.0003	0.0031	0.0402
GARCH(1)	0.8924	0.9172	0.9473
	0.0000	0.0000	0.0000

4.6.2. Results of the Mean Equation for the 2nd Subsample

Except for the case of Japan, the error correction coefficient is statistically significant and negative for the regressions with a foreign exchange return as the independent variable. The intuition behind these results is that the long-run equilibrium is formed with a one day delay and there is reversion to the long-run equilibrium.

Another important outcome of these regressions is German, Turkish and Korean foreign exchange returns are negatively affected for almost all variables. The possible reason for this may be demand for the local securities decline the exchange rates or equivalently appreciate the local currencies.

Global commodity is the least effective one among the global variables. Global effects have serious roles for the cases of Germany, Japan and Korea. Since Korea also has the highest effects from the local variables, its financial markets are most open to both any local or global impacts for the time interval beginning with 2009.

Table 4.19. Coefficients of the Mean Equation of the Multivariate GARCH Model and their p-values

	U.S.			Germany			Japan		
	FX	**BOND**	**STOCK**	**FX**	**BOND**	**STOCK**	**FX**	**BOND**	**STOCK**
CONSTANT	-0.0001	0.0001	0.0009	0.0000	-0.0001	0.0006	-0.0002	0.0002	0.0002
	0.6510	0.5390	0.0044	0.9152	0.6578	0.2655	0.2988	0.3135	0.6414
RESIDECM	-0.0257	-0.0035	0.0139	-0.0627	-0.0855	-0.2205	-0.0823	0.0231	0.3351
	0.0001	0.3008	0.2496	0.0064	0.0003	0.0005	0.2465	0.7541	0.0204
FX	0.0843	-0.0487	-0.0164	-0.3580	0.0525	0.2361	-0.0161	0.0731	-0.8560
	0.0260	0.0064	0.8374	0.0000	0.0718	0.0019	0.9390	0.7399	0.0316
BOND	0.2010	-0.4292	0.1040	-0.4442	0.0391	0.2501	-0.0339	0.0921	-1.0446
	0.0235	0.0000	0.5340	0.0000	0.3258	0.0103	0.8658	0.6605	0.0055
STOCK	0.0019	-0.0376	-0.1625	-0.0117	-0.0202	-0.2255	-0.0993	0.1147	-0.3627
	0.9524	0.0080	0.0178	0.4878	0.1466	0.0000	0.0000	0.0000	0.0000
GBOND	-0.2004	1.0350	-0.3506	0.1843	0.5695	-0.4609	-1.3834	1.5611	0.2214
	0.1977	0.0000	0.2642	0.1262	0.0000	0.1690	0.0000	0.0000	0.3932
GSTOCK	0.0649	0.0132	0.0962	-0.0491	0.0628	0.4623	0.0769	-0.0913	0.7532
	0.1090	0.4737	0.2585	0.0885	0.0066	0.0000	0.0016	0.0003	0.0000
GCOMMODITY	-0.0050	-0.0030	0.0209	-0.0226	0.0180	-0.0028	-0.0106	0.0134	-0.0450
	0.7888	0.7005	0.5773	0.0859	0.1571	0.9399	0.5895	0.5073	0.2142

Table 4.19. Coefficients of the Mean Equation of the Multivariate GARCH Model and their p-values (continued)

	Mexico			Turkey			Korea		
	FX	**BOND**	**STOCK**	**FX**	**BOND**	**STOCK**	**FX**	**BOND**	**STOCK**
CONSTANT	-0.0002	0.0005	0.0009	0.0003	0.0000	0.0008	-0.0001	0.0007	0.0008
	0.3956	0.0117	0.0515	0.1662	0.9387	0.2174	0.5037	0.0001	0.0145
RESIDECM	-0.0212	0.0047	0.0097	-0.0510	0.0092	0.1624	-0.0515	0.0293	0.1402
	0.0805	0.7074	0.7045	0.0021	0.6721	0.0041	0.0000	0.0551	0.0000
FX	-0.0040	-0.5933	-0.5536	-0.4275	0.1098	0.1728	0.0126	-0.0630	-0.1161
	0.9311	0.0000	0.0000	0.0000	0.0149	0.1468	0.5996	0.0607	0.0642
BOND	-0.0560	-0.2105	-0.1252	-0.4915	0.0330	0.1225	-0.5751	-0.0661	0.4347
	0.1790	0.0000	0.1553	0.0000	0.5675	0.4220	0.0000	0.0277	0.0000
STOCK	0.0300	-0.0197	0.0276	-0.0153	0.0158	-0.0423	-0.0616	-0.0930	-0.1316
	0.3321	0.4905	0.6133	0.3478	0.4265	0.4283	0.0000	0.0000	0.0000
GBOND	0.1866	0.1304	-0.0411	-0.1516	0.1291	0.2789	-0.2214	0.0401	-0.1295
	0.2278	0.3862	0.8943	0.2401	0.4508	0.5335	0.0024	0.7323	0.5770
GSTOCK	-0.0586	0.0037	-0.0485	-0.0907	0.0446	0.1398	-0.0241	0.2293	0.5741
	0.1230	0.9244	0.5123	0.0022	0.2345	0.1430	0.0913	0.0000	0.0000
GCOMMODITY	0.0196	-0.0418	-0.0330	-0.0057	0.0100	0.0268	-0.0050	0.0438	-0.0321
	0.4046	0.0884	0.5241	0.7523	0.6723	0.6510	0.5868	0.0040	0.2186

Table 4.20. Significance Level and Sign of the Mean Equation Parameters

	U.S.			Germany			Japan		
	FX	**BOND**	**STOCK**	**FX**	**BOND**	**STOCK**	**FX**	**BOND**	**STOCK**
CONSTANT			+++						
RESIDECM	−−−			−−−	−−−	−−−			++
FX	++	−−−		−−−	+	+++			−−
BOND	++	−−−		−−−		++			−−−
STOCK		−−−	−−			−−−	−−−	+++	−−−
GBOND		+++			+++		−−−	+++	
GSTOCK				−	+++	+++	+++	−−−	+++
GCOMMODITY				−					
	Mexico			**Turkey**			**Korea**		
	FX	**BOND**	**STOCK**	**FX**	**BOND**	**STOCK**	**FX**	**BOND**	**STOCK**
CONSTANT		++	++					+++	++
RESIDECM	−−			−−−		+++	−−−	+	+++
FX		−−−	−−−	−−−	++			−	−
BOND		−−−		−−−			−−−	−−	+++
STOCK							−−−	−−−	−−−
GBOND							−−−		
GSTOCK				−−−			−	+++	+++
GCOMMODITY		−						+++	

4.6.3. Results of the Variance Equation for the 2nd Subsample

The first remarkable point in the analysis of the variance equation is the positiveness and significance of intercept terms for foreign exchange and stock return volatilities except for Korea. The financial intuition behind this outcome is there would be some volatility in these markets, even when all markets are stable including themselves in the previous day.

The second noteworthy point is the positively statistical significance of the own GARCH terms of the dependent variables except for German bond index and Japanese foreign exchange market. This is not surprising, and similar outcomes are also obtained in the first subsample and entire sample. Turkish and American financial markets have the highest number of local volatility transmission by GARCH terms. There is also bidirectional volatility transmission between foreign exchange bond returns with varying signs with the exceptions of Japan and Mexico. American and Turkish markets are open for all kind of GARCH volatility spillovers.

Table 4.21. Coefficients of the Variance Equation of the Multivariate GARCH Model and their p-values

	U.S.			Germany			Japan		
	FX	**BOND**	**STOCK**	**FX**	**BOND**	**STOCK**	**FX**	**BOND**	**STOCK**
CONSTANT	0.0004	0.0011	0.0000	0.0014	0.0012	-0.0011	0.0031	0.0001	0.0040
	0.0390	0.0000	1.0000	0.0000	0.0000	0.0005	0.0000	0.3335	0.0199
GARCH									
FX	0.9808	0.0058	0.0220	0.9589	-0.0390	-0.1239	0.2957	0.6218	-0.5105
	0.0000	0.3191	0.0772	0.0000	0.0000	0.0000	0.2859	0.0212	0.0033
BOND	-0.1513	0.8194	0.2998	0.0117	0.9155	-0.0126	-0.3633	0.1894	-0.7309
	0.0000	0.0000	0.0000	0.0000	0.0000	0.1376	0.1581	0.0000	0.0234
STOCK	-0.0096	-0.0106	0.6674	0.0061	-0.0007	0.9272	-0.1299	0.1243	0.3874
	0.0016	0.0075	0.0000	0.0011	0.6821	0.0000	0.0035	0.0046	0.0054
ARCH									
FX	-0.0209	0.0976	0.1332	-0.2419	-0.2419	-0.0758	-0.4273	0.6602	-0.1145
	0.5614	0.0003	0.1698	-0.0408	0.0000	0.2693	0.1920	0.0458	0.8694
BOND	0.0721	0.0676	0.1693	-0.0408	-0.1529	-0.4713	-0.4563	0.6847	-0.6643
	0.3329	0.1995	0.4234	0.1515	0.0000	0.0000	0.1364	0.0264	0.3381
STOCK	-0.0445	0.0058	0.3019	-0.0606	-0.0020	0.2964	-0.0129	0.0160	0.3827
	0.0056	0.6917	0.0000	0.0000	0.7203	0.0000	0.5538	0.4641	0.0000
GBOND	99.3732	-2.1480	0.0032	15.7708	103.2860	26.5253	89.6223	33.8437	12.6375
	0.0038	0.9199	1.0000	0.6208	0.0000	0.8947	0.0271	0.0000	0.9399
GSTOCK	1.0816	-0.5111	0.0001	-3.9734	-1.2901	0.1406	1.5350	0.0360	-7.6345
	0.0508	0.2013	1.0000	0.0000	0.0033	0.9719	0.0247	0.6449	0.0441
GCOMMODITY	-1.5304	0.3455	0.0003	1.8257	-0.0465	-1.9118	1.5372	-0.2566	1.0372
	0.0000	0.2794	1.0000	0.0000	0.8833	0.3153	0.0096	0.0000	0.6744

Table 4.21. Coefficients of the Variance Equation of the Multivariate GARCH Model and their p-values (continued)

	Mexico			Turkey			Korea		
	FX	**BOND**	**STOCK**	**FX**	**BOND**	**STOCK**	**FX**	**BOND**	**STOCK**
CONSTANT	0.0012	-0.0003	0.0001	0.0021	-0.0006	0.0031	0.0005	0.0002	-0.0006
	0.0000	0.4643	0.0000	0.0000	0.1923	0.0000	0.0000	0.2123	0.3753
GARCH									
FX	0.9352	-0.0114	-0.1249	0.9596	-0.3641	-0.7813	0.8418	-0.0826	0.0502
	0.0000	0.3397	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.2359
BOND	0.0000	0.9970	0.0319	0.0425	0.4183	-1.2849	0.0821	0.9662	-0.0695
	0.0000	0.0000	0.1386	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002
STOCK	0.0442	-0.0252	0.9100	-0.0624	0.1352	1.1299	-0.0059	-0.0039	0.9592
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0341	0.5178	0.0000
ARCH									
FX	0.2952	-0.1820	-0.2212	-0.0928	0.2398	0.8764	0.2182	-0.0002	-0.0504
	0.0000	0.0001	0.1080	0.0497	0.0003	0.0000	0.0000	0.9966	0.5506
BOND	0.2514	0.0000	-0.5917	0.1677	0.1507	0.3003	-0.2423	0.1664	0.1834
	0.0000	0.0000	0.0000	0.0001	0.0054	0.0717	0.0000	0.0000	0.0018
STOCK	-0.1014	0.0497	0.2779	-0.0077	-0.0241	0.1301	0.0059	-0.0158	0.1746
	0.0000	0.0005	0.0000	0.6466	0.1921	0.0533	0.5886	0.3600	0.0000
GBOND	-64.2389	112.6596	-16.0312	-49.5200	-110.6927	-227.2612	-115.8633	-163.4132	81.5580
	0.1777	0.0001	0.8747	0.3662	0.0118	0.3492	0.0258	0.0000	0.2073
GSTOCK	-2.1239	-0.0866	-0.1405	2.6664	-0.3079	-1.0957	3.4378	2.6559	4.1280
	0.0017	0.9372	0.9626	0.0001	0.6766	0.8146	0.0000	0.0000	0.0000
GCOMMODITY	0.9991	1.4606	-1.8046	-0.8158	1.8028	4.7718	0.7049	1.6557	0.2570
	0.1047	0.0049	0.0781	0.1586	0.0953	0.0031	0.0652	0.0003	0.7722

Table 4.22. Significance Level and Sign of the Variance Equation Parameters

	U.S.			**Germany**			**Japan**		
	FX	**BOND**	**STOCK**	**FX**	**BOND**	**STOCK**	**FX**	**BOND**	**STOCK**
CONSTANT	++		+++	+++	+++	+++	+++		++
GARCH					———				
FX	+++	+	+++	+++	+++	———		++	———
BOND	———	+++	+++	+++				+++	——
STOCK	———	+++	+++	+++		+++	———	+++	+++
ARCH									
FX			———	———	———			++	
BOND					———	———		++	
STOCK	———	+++	———	———		+++			+++
GBOND	+++				+++		++	+++	
GSTOCK	+		———	———	———		++		++
GCOMMODITY	———		+++	+++			+++	———	
	Mexico			**Turkey**			**Korea**		
	FX	**BOND**	**STOCK**	**FX**	**BOND**	**STOCK**	**FX**	**BOND**	**STOCK**
CONSTANT	+++		+++	+++		+++	+++		
GARCH									
FX	+++		———	+++	———	———	+++	———	
BOND	+++	+++		+++	+++	———	+++	+++	———
STOCK	+++	———	+++	———	+++	+++	——		+++
ARCH									
FX	+++	———		——	+++	+++	+++		
BOND	+++		———	+++	+++	+	———	+++	+++
STOCK	———	+++	+++			+			+++
GBOND		+++			——		——	———	
GSTOCK	———			+++			+++	+++	+++
GCOMMODITY		+++	−		+	+++	+	+++	

Total volatility persistence checking should not be ignored since its outcomes presents whether the volatility series explode owing to parameters greater than 1. All markets excluding Japanese and Turkish ones have total volatility persistence high but lower than 1. These two exceptional markets have lower values due to the negative sign of parameters of some of the GARCH terms.

Table 4.23. Total Volatility Persistence of the Variance Equations

	U.S.			**Germany**			**Japan**		
	FX	BOND	STOCK	FX	BOND	STOCK	FX	BOND	STOCK
Vol. Persistence	0.8200	0.8146	0.9892	0.9767	0.8757	0.7908	-0.1975	0.9355	-0.8540
	Mexico			**Turkey**			**Korea**		
	FX	BOND	STOCK	FX	BOND	STOCK	FX	BOND	STOCK
Vol. Persistence	0.9793	0.9604	0.8170	0.9397	0.1895	-0.9363	0.9181	0.8798	0.9400

For the second subsample beginning with 2009, there are plenty of significant ARCH effects. Excluding U.S. and Japanese financial markets, remaining markets have all significant heat wave effects. Local meteor shower effects are more often for the emerging markets than the developed ones.

Global variables are very effective for all countries particularly on Japan and Korea. The parameters of most of these variables are positive, which means that the spillovers increase the volatilities and, thus, risks. For example, the global stock variable has a positive sign for Korean financial markets and this means that any volatility increase will contribute to the volatility of the Korean markets. Another example is the Japanese foreign exchange volatility, which is positively affected by all global variables significantly, implying that external shocks fluctuates their financial markets.Volatility persistence, heat wave and meteor shower effects are widespread in this period for all countries but especially for the emerging markets.

4.6.4. Results of the Diagnostic Tests for the 2nd Subsample

Table 4.24. Diagnostic Test Results and their p-values

	U.S.	**Mexico**	**Germany**	**Turkey**	**Japan**	**Korea**
Log-Likelihood	8998.0700	8294.3041	8103.9358	8163.7831	9757.5962	8502.3472
MV-Q	182.0767	202.7397	221.8689	204.58697	188.7480	377.6600
	0.4427	0.1178	0.0183	0.1010	0.3125	0.0000
MV-LM	203.7500	314.2900	246.4200	224.11	236.8900	245.7500
	0.1014	0.0000	0.0000	0.0142	0.0029	0.0008
MV-JB	79.8970	63.0310	46.3960	81.254	370.7600	62.3010
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Test results whether subsampling solves the problems relating to the assumptions of the residuals are listed in Table 4.24. There is no autocorrelation for the countries U.S., Mexico, Turkey and Japan. However, Germany and Korea are still affected by this problem. Heteroscedasticity is still a problem for all cases excluding U.S., although its magnitude significantly declines compared to the pre-crisis period. Normality of the error terms is not satisfied, but the use of robust standard errors solves this problem.

4.7. Comparison of the Diagnostic Test Results of the All Models

The following table summarizes the diagnostic test results for VAR, GARCH for the whole sample, GARCH with the 1st subsample and GARCH with the 2nd subsample respectively. Any significant declines in the second column with respect to the first VAR column mean the success of the GARCH modeling. The declines in the GARCH-1 and GARCH-2 columns with respect to GARCH column are the contribution of separating the data into two and removing the 4 months in the middle. It is apparently observed that GARCH model is much better than the previous VAR model for realizing the assumptions regarding to residuals. Both GARCH-1 and GARCH-2 models have lower test statistics than the whole sample GARCH model. This indicates that breaking the data into two smaller clusters and removing the most volatile period is useful for the estimation purposes. By subsampling, there is no more violation of assumptions for the U.S.. Subsampling declined the degree of heteroscedasticityenormously; however, there are still some problems about it. This means that subsampling alleviates the negative consequences of these assumption violations but could not remove them totally. Inclusion of new variables to mean equation can lower the autocorrelation problem for the cases Germany, Turkey and Korea. Moreover, addition of new variables into the variance equation may decrease the heteroscedasticity matter. Instead of inclusion of new variables, higher lag lengths could also be used. However, the BEKK representation calculation with exogenous variables and robust standard errors is already too difficult and longer lag length would cause serious convergence failures in addition to the violation of principle of parsimonious modeling. GARCH modeling and recognizing the structural break also improves the normality of error terms, although they are still further away from normal dispersion. This is not such a big problem due to the use of robust standard errors.

Table 4.25. Comparative Diagnostic Test Results

U.S.	**VAR**	**GARCH**	**GARCH-1**	**GARCH-2**
MV-Q	353.6173	201.6136	173.8890	182.0767
	0.0000	0.1290	0.6143	0.4427
MV-LM	2881.9700	312.1100	188.5900	203.7500
	0.0000	0.0000	0.3154	0.1014
MV-JB	9169.5980	389.7250	128.9210	79.8970
	0.0000	0.0000	0.0000	0.0000
Mexico	**VAR**	**GARCH**	**GARCH-1**	**GARCH-2**
MV-Q	431.4723	203.2321	186.3108	202.7397
	0.0000	0.1131	0.3580	0.1178
MV-LM	6273.3600	348.8300	277.8400	314.2900
	0.0000	0.0000	0.0000	0.0000
MV-JB	37888.500	373.4900	184.5840	63.0310
	0.0000	0.0000	0.0000	0.0000
Germany	**VAR**	**GARCH**	**GARCH-1**	**GARCH-2**
MV-Q	434.7076	324.1351	252.5541	221.8689
	0.0000	0.0000	0.0003	0.0183
MV-LM	1344.3500	261.1700	246.5100	246.4200
	0.0000	0.0001	0.0007	0.0000
MV-JB	3298.1420	245.6370	134.5520	46.3960
	0.0000	0.0000	0.0000	0.0000

Table 4.25. Comparative Diagnostic Test Results (continued)

Turkey	**VAR**	**GARCH**	**GARCH-1**	**GARCH-2**
MV-Q	539.3303	303.2991	255.8345	204.587
	0.0000	0.0000	0.0002	0.1010
MV-LM	4597.8900	364.48	284.39	224.11
	0.0000	0.0000	0.0000	0.0142
MV-JB	335182.80	487.896	334.143	81.254
	0.0000	0.0000	0.0000	0.0000
Japan	**VAR**	**GARCH**	**GARCH-1**	**GARCH-2**
MV-Q	219.9617	192.7987	171.1363	188.7480
	0.0226	0.2438	0.6699	0.3125
MV-LM	1673.3000	636.7800	544.4000	236.8900
	0.0000	0.0000	0.0000	0.0029
MV-JB	134255.60	936.4420	890.7940	370.7600
	0.0000	0.0000	0.0000	0.0000
Korea	**VAR**	**GARCH**	**GARCH-1**	**GARCH-2**
MV-Q	1367.7040	630.2225	417.3627	377.6600
	0.0000	0.0000	0.0670	0.0000
MV-LM	8142.8400	358.6000	233.1200	245.7500
	0.0000	0.0000	0.0047	0.0008
MV-JB	57906.910	172.3340	136.0190	62.3010
	0.0000	0.0000	0.0000	0.0000

4.8. Comparison of the Results of the 1st, 2nd Subsamples and Whole Sample

Global financial crisis in 2008 is a milestone for the integration of the local and global markets. Since its impact is inescapable and enormous, it is modeled by dividing the data into two groups. The six tables below present the changes in the significance, sign and direction of the volatility structure and spillovers during the pre- and post-crisis periods. Significant differences between these two periods prove the necessity of examining the period into two sub parts.

As it is expected, for both of the periods, own GARCH terms of the dependent variables are significant and positive for the U.S., implying that previous day's volatility would trigger the next day's volatility. The volatility transmission by GARCH terms of the local markets is all significant for the second sample, while all are insignificant in the 1st subsample except for the diagonal volatilities. ARCH term effects, which are the heat wave and meteor shower effects, also change in the second sub-period. For instance, before the collapse of Lehman Brothers, foreign exchange volatility was subjected to shocks from local bond market, but it is disappeared in the second period. Influence of the global variables increases after the worst days of the crisis. Although global stock and global commodity do not affect the volatility of the American financial markets before the crisis, they are significant for the post-crisis period.

Table 4.26. Comparative Regression Results for U.S.

U.S.	GARCH			GARCH-1			GARCH-2		
	FX	BOND	STOCK	FX	BOND	STOCK	FX	BOND	STOCK
CONSTANT	+++	+++	−−		+++		++		+++
GARCH									
FX	+++	−−	−−−	+++			+++	+	+++
BOND		+++	−−−		+++		−−−	+++	+++
STOCK	+++	−−	+++			+++	−−−	+++	+++
ARCH									
FX	+++	+++	+	+++					−−−
BOND	+++	+++	−−−	++	+++	−−			
STOCK			+++			+++	−−−	+++	−−−
GBOND	++	+++		+++	−		+++		
GSTOCK	−−−						+		−−−
GCOMMODITY							−−−		+++

For both of the periods in Mexico, parameters of the GARCH terms are positively significant. In addition, there are also numerous volatility transmissions by GARCH terms in the 2nd sub period. A similar outcome is also obtained when the ARCH terms significances are examined. Local markets transmit their volatility shocks widely for the 2nd sub sample. For instance, there exist newer meteor shower effects from the foreign exchange to bond, from stock to foreign exchange and from bond to stock with the negative signs in the post-crisis period. The effectiveness of global variables increase, but they do not have the prominent role for the volatility of the dependent variables.

Table 4.27. Comparative Regression Results for Mexico

Mexico	GARCH			GARCH-1			GARCH-2		
	FX	BOND	STOCK	FX	BOND	STOCK	FX	BOND	STOCK
CONSTANT	+++	++		+++		+++	+++		+++
GARCH									
FX	+++			+++			+++		−−−
BOND		+++			+++		+++	+++	
STOCK	+		+++			+++	+++	−−−	+++
ARCH									
FX	+++			+++			+++	−−−	
BOND		+++			++		+++		−−−
STOCK			+++			+++	−−−	+++	+++
GBOND	−−	+++	+++					+++	
GSTOCK		+	+++		−−−		−−−		
GCOMMODITY			−−		+++			+++	−

Germany is an exceptional case due to its decreasing volatility integration in its local markets after the collapse of Lehman Brothers. In order to illustrate, GARCH spillover from bond to bond, from stock to bond and bond to stock disappear in the post-crisis period. This pattern is not the case for the ARCH terms. On contrary, there is an increase in the impact of global markets slightly. Meteor shower effects have usually negative signs indicating the shocks in the other markets lower the riskiness of German markets, which is opposite to the contagion of the financial shocks. Although, the main problem of Germany is debt crisis in the continental Europe after the 2008 global crisis, investors may describe German markets as credible investment locations due to decreasing risks as a reaction to the increasing shocks in the other markets.

Table 4.28. Comparative Regression Results for Germany

Germany	**GARCH**			**GARCH-1**			**GARCH-2**		
	FX	**BOND**	**STOCK**	**FX**	**BOND**	**STOCK**	**FX**	**BOND**	**STOCK**
CONSTANT		+++		+++			+++	+++	+++
GARCH								−−−	
FX	+++			+++	+++	+++	+++	+++	−−−
BOND		+++	++	−−−	+++	+++	+++		
STOCK			+++	+++	−	+++	+++		+++
ARCH									
FX	+++			−−−	+++		−−−	−−−	
BOND		+++		+++	−−−			−−−	−−−
STOCK	−−−		+++			−−−	−−−		+++
GBOND	++	−−−	++		−−			+++	
GSTOCK	++			+++			−−−	−−−	
GCOMMODITY							+++		

The most noteworthy outcome for the analysis of Turkish markets is there is no change in the volatility structure due to the same sign and significance level of GARCH terms pre and post crisis. This indicates that the worst days of the global crisis do not change the log-run structure. On the other hand, there are plenty of changes in the sign and significance of the parameters of the ARCH terms. Vulnerability of the volatility of the Turkish financial markets increases such as shocks resulted from foreign exchange volatility is one of the most important shocks for Turkish markets in the post crisis era. Interestingly, meteor shower effects of the global variables also change, for instance, global bond does not affect the foreign exchange and stock market volatilities, instead affects local bonds merely.

The most fluctuating days of the financial crisis also alter the volatility structure of the Japanese financial markets excluding its bond markets. There is also a minor shift for the ARCH effects. Japanese markets are vulnerable to the external shocks due to the increasing number of significant global parameters. Their positive signs indicate the increasing risk of these markets owing to the external volatility shocks, which mean risk level of Japanese securities, are defined according to the events in the other local markets and global markets.

Table 4.29. Comparative Regression Results for Turkey

Turkey	**GARCH**			**GARCH-1**			**GARCH-2**		
	FX	**BOND**	**STOCK**	**FX**	**BOND**	**STOCK**	**FX**	**BOND**	**STOCK**
CONSTANT	+++	+++	+++	+++	+++		+++		+++
GARCH									
FX	+++	−−−	−−−	+++	−−−	−−−	+++	−−−	−−−
BOND	+++	+++	−−−	+++	+++	−−−	+++	+++	−−−
STOCK	−−−	+++	+++	−−−	+++	+++	−−−	+++	+++
ARCH									
FX	+++	−−−	−−−	+			−−	+++	+++
BOND		+++	+++	−−−	+++	+++	+++	+++	+
STOCK	+++	−−−	+++						+
GBOND	++	−−		+		+++		−−	
GSTOCK	+++	−−−	+	++	−	++	+++		
GCOMMODITY		+++	+		+++			+	+++

Table 4.30. Comparative Regression Results for Japan

Japan	**GARCH**			**GARCH-1**			**GARCH-2**		
	FX	**BOND**	**STOCK**	**FX**	**BOND**	**STOCK**	**FX**	**BOND**	**STOCK**
CONSTANT	+++	+++	+++	+++			+++		++
GARCH									
FX	+++	+++	−−	+++	+++			++	−−−
BOND	−−−	+++		−−−	+++			+++	−−
STOCK	−−−	+++	+++	−−−	+++	+++	−−−	+++	+++
ARCH									
FX	+++		+++	++				++	
BOND		+++						++	
STOCK			+++						+++
GBOND	+++	++					++	+++	
GSTOCK	+++						++		++
GCOMMODITY	+++	−−−	++		−−−		+++	−−−	

Korea also has minor changes after the global financial crisis similar to the case of Turkey. All GARCH term parameters have the same sign and significance in the 2nd sub sample with respect to 1st sub sample. The only exception is that the effect from stock to foreign exchange begins after the crisis. The similar pattern is also valid for the ARCH terms, which makes Korea unique since ARCH effects changed marginally for the case of Turkey. The explanation behind these outcomes is the lack of a specific impact from the global crisis on the risk structure and vulnerability of the Korean financial markets. Korean financial markets are open to local and international effects widely, and this is the situation for the pre -and post-crisis periods.

Table 4.31. Comparative Regression Results for Korea

Korea	**GARCH**			**GARCH-1**			**GARCH-2**		
	FX	**BOND**	**STOCK**	**FX**	**BOND**	**STOCK**	**FX**	**BOND**	**STOCK**
CONSTANT	+++			+++	++		+++		
GARCH									
FX	+++	–––		+++	–––		+++	–––	
BOND	+++	+++	–––	+++	+++	–––	+++	+++	–––
STOCK			+++			+++	––		+++
ARCH									
FX	+++			+++	++		+++		
BOND	–––		+++	–––		+++	–––	+++	+++
STOCK		–––	+++		–––	+++			+++
GBOND			+++	++		+++	––	–––	
GSTOCK	+++	+++	+++	+	+++		+++	+++	+++
GCOMMODITY	+++		–––		+++	–––	+	+++	

By using the findings listed above, it is possible to make some generalizations according to a country's market development level and geographical location. Although developed economies are financially more integrated with the global markets, these integration effects are only significantly visible for the period after the global economic crisis in 2008. Emerging markets, on the other hand, are exposed to volatility spillovers from the global markets for both sub-periods. Furthermore the spillovers among their own financial markets are more widespread than the internal spillovers of the financial markets of their developed counterparts. Emerging markets are not good risk diversification locations due to their vulnerability to internal or external financial shocks. North American markets, U.S. and Mexico, have significant parameters for their own GARCH variables only for the pre-crisis period. Local and global heat wave and meteor shower effects are higher and their effects increase in the 2nd sub sample. On the other hand, European markets in this study, which are Germany and Turkey, have a lot of significant GARCH terms indicating the integrated structure of their financial markets. They are also open to the internal and external shocks and this vulnerability rises after the collapse of Lehman Brothers. Third geographic location of this study, Far East with the representatives of Japan and Korea, has remarkable GARCH interactions, which mean the high integration of their local markets. Moreover, they are also exposed to the global shocks and the level of vulnerability dramatically increases in the period just after the global financial crisis.

CHAPTER 5

CONCLUSION

The purpose of this study is to examine the volatility spillover among a country's foreign exchange, bond and stock markets and the volatility transmission from the global bond, stock and commodity markets to these local financial markets. The sample for the study includes data from both emerging and developed economies in the time period between 2004 and 2011. A multivariate GARCH methodology with the BEKK representation is applied for the local financial markets and global variables are included as exogenous variables into the model.The sample countries are the U.S., Mexico, Germany, Turkey, Japan and Korea. The global market movements are proxies by using three indices: Barclays Global Aggregate Bond Index, Morgan Stanley Capital International All Country World Index and Rogers International Commodity Index respectively. The sample period is from January 2, 2004 to December 30, 2011

As a result of detecting cointegration or a long-run relationship among the variables, error correction parameters are included for each equation of the VAR model. Diagnostic test results of the VAR model indicate serious violations of the necessary assumptions for the error terms: the error terms exhibit autocorrelation, heteroscedasticity and non-normality. Therefore, a multivariate GARCH approach is adopted in order to model the error terms of the regressions. Residuals of the global residuals are acquired by estimating a univariate GARCH model with a lag length of one for both mean and variance equations. The multivariate GARCH model with a BEKK representation includes the squared residuals of the global variables as exogenous variables and is estimated by the maximum likelihood method. Most of the diagnostic test results are improved after the use of multivariate GARCH modeling; however, some assumptions are still violated. The possible reason behind these violations can be the time-varying structure of the parameters. In order to solve this problem, the sample is divided into two sub-periods. The break point is determined as September 1, 2008, a date that marks the beginning of the speculations about the collapse of Lehman Brothers. The first sub-period is from January 2, 2004 to August 21, 2008 and the second sub period begins on January 1, 2009 and ends on December 31, 2011. Same methodologies are applied for these sub-periodsand meaningful results are acquired. Diagnostic test results are significantly improved once again but the violations of assumptions could not be totally removed for all countries. The possible reason for this problem may be choosing the lag lengths as one in the multivariate GARCH models. Higher lag lengths may solve some of these violations but the difficulty of converging to the log likelihood maximum point in a GARCH model with a trivariate BEKK representation, three exogenous variables and robust standard errors made it necessary to run the most parsimonious model possible with a single lag length.

The overall findings suggest that although developed economies are financially more integrated with the global markets, these integration effects are only significantly visible for the period after the global economic crisis in 2008. Emerging markets, on the other hand, are exposed to volatility spillovers from the global markets for both sub-periods. Furthermore the spillovers among their own financial markets are more widespread than the internal spillovers of the financial markets of their developed counterparts. Emerging markets are not good risk diversification locations due to their vulnerability to internal or external financial shocks. North American markets, U.S. and Mexico, have significant parameters for their own GARCH variables only for the pre-crisis period. Local and global heat wave and meteor shower effects are higher and their effects increase in the 2^{nd} sub sample. On the other hand, European markets in this study, which are Germany and Turkey, have a lot of significant GARCH terms indicating the integrated structure of their financial markets. They are also open to the internal and external shocks and this vulnerability rises after the collapse of Lehman Brothers. Third geographic location of this study, Far East with the representatives of Japan and Korea, has remarkable GARCH interactions, which mean the high integration of their local markets. Moreover, they are also exposed to the global shocks and the level of vulnerability dramatically increases in the period just after the global financial crisis.

Although this study aims to make the previously mentioned innovative contributions to the literature, there are still some further improvements that can be achieved. In this thesis, each geographic location is represented by only two countries and this makes it difficult to offer generalizations. For future studies, the sample can include a larger number of countries, especially countries like Russia, Brazil, China and India. Finally GARCH models can include asymmetric parameters to measure the impact of positive and negative shocks separately.

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