Volatility and Contagion effect from US and GIIPS to the largest European economies

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Abstract

This research paper explores the nature of the mean and volatility spillovers from the US and aggregate GIIPS to the largest GDP countries for the EMU and non-EMU countries. I develop a three step univariate volatility spillover model followed by Christiansen (2007) and Ng (2000) to analyze the relevance of local (own country), regional (aggregate GIIPS) and global (US) shocks. Empirical evidence supports the existence of asymmetric spillover effects, which subsequently leads to a higher return volatility than a positive shock of equal magnitude. I find that that both regional and global shocks are relevant for the European equity markets volatility, but global factors tend to have a greater impact. Also, in the Subprime crisis sample, the EMU countries suffer from a strong GIIPS mean and volatility spillover effects. Finally, the Conditional Spillover shows the relevance of the time varying information variables included in the model as a mean and volatility drivers from US and GIIPS in the countries under consideration. These findings are extremely relevant for financial economists and international portfolio managers when defining their optimal portfolio asset allocation decisions.

Keywords — contagion, GIIPS, subprime crisis, eurozone, mean, spillover, unconditional,time-varying, asymmetric, EMU, non-EMU

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1
Introduction

The structure and operation of financial markets has suffered an important transformation from the 1970s to date. Shortly before then, during the 1950s and 1960s, most of the economies imposed limitations on capital flows to external economies, restricting these flows to national boundaries.

Since the 1970s the world's financial markets have adjusted to a new paradigm where markets are deeply integrated, often with the formation of free-trade areas or currency unions, and capital transactions have become more complex. The increased market integration leads to an increasing impact of world factors on volatility. This globalization of the marketplace, along with the economic importance of multinational corporations and central banking has emphasized the importance of international portfolio diversification (Andrikopoulos, 2014).

This new international framework, in which trading activity occurs through international channels, focuses our attention on the spillover that takes place between national and foreign markets during crisis periods. Specifically, we focus our attention on the global financial crisis of 2007-2009, which originated in the United States and had enormous repercussions at a global level.

This period of world recession, characterized by the collapse of big financial institutions at a global level, is directly linked to the sovereign debt crisis that struck the Eurozone during the following years, 2009 onwards. The shock in the United States quickly caused turmoil in the Eurozone, demonstrating that market integration generates intensified responses to shocks and increases the speed of contagion in the financial system.

In this context, the purpose of this paper Thesis is to analyze a time lapse spanning from 2002 to 2014, and explore the existence of mean and volatility spillovers from the US and aggregate GIIPS grouping (Greece, Italy, Ireland, Portugal and Spain) to the largest GDP European countries. The countries analyzed will consist of some EMU countries and also some non-EMU countries, which will be introduced later in this Thesis. A wide range of literature review have shed light on volatility spillover and contagion effect, especially after the "Tequila crisis" of 1994-95, the "Asian flu" of 1997 and the "Russian virus" of 1998. Yet, not much research from US and GIIPS to developed countries in Europe is available, with a distinction in countries within Eurozone and outside the Eurozone. Furthermore, the findings emerging for this Thesis are found to be extremely relevant for financial economists and international portfolio managers when defining their optimal portfolio asset allocation decisions.

Many reasons have been proclaimed to try to explain volatility. Globalization has been pointed out as playing an important role in volatility spillover, since it sets the basis for a scenario in which a high amount of diversified investors all act as a herd in the presence of asymmetric information, leading to financial excesses.

Furthermore, the rating agencies have also been identified as sources of exacerbation of financial market volatility. Credit rating agencies, such as Standard and Poor's, Moody's and Fitch (known as the "Big Three"), are of determining importance in modern financial systems and have been heavily criticized for aggravating tense economic and political situations by centering their attention on the most exposed and vulnerable countries within a region (Host et al., 2012).

Contagion is an extensively used term, and there is little agreement on what it precisely involves. It is defined as a significant increase in a set of financial asset markets during a period of financial turmoil, compared to those existing in a non-crisis period (Baig & Goldfajn, 1999; Forbes & Rigobon, 2002). Another definition of the term contagion is given by Bekaert et al. (2005), where contagion is defined as a "correlation over and above what one would expect from economic fundamentals".

During tranquil times, a correlation can be found between the change in the volatility of asset prices or financial flows in one market and the volatility of the same quantities in other markets. When a country is hit by financial distress, contagion can be observed when the degree in which this comovements in asset prices across markets is considered to exhibit a disproportionate relation (Corsetti et al., 2005;Dornbusch et al., 2000).

The means by which contagion occurs has been analyzed in numerous theoretical papers. One of the channels by which a country-specific crisis can strike markets of different sizes and structures is through trade (Forbes, 2000). Trade has been identified as a source of spillover effects, since an alteration in the prices and quantity of the goods exchanged by two economies could represent a channel by which a crisis can be transmitted to another country.

Discrepancies can be found on what contagion really is, in fact, although most of recent studies try to explain contagion as an increased correlation during turbulent periods (Bae et al., 2003;Forbes & Rigobon, 2002) expresses contagion not only in the means of an increased correlation during crisis periods, but introduces the term "shift- contagion" to distinguish it from existing definitions. Shift-contagion also involves an increase in cross-market linkages between two markets after a shock in one of them.

Shortly after Lehman's Brothers bankruptcy in late 2008, the deterioration in the government finances in the Eurozone led to a loss in confidence in sovereign debt markets. The first consequences of this deterioration was the downgrading of Greek sovereign credit rating in 2009. In order to preserve financial stability and mitigate a possible financial contagion across Europe, the European Financial Stability Facility (EFSF) was created on May 2010 to provide with financial aid to Eurozone countries in need of financial assistance. These were the first signs indicating a European debt crisis. The creation of the EFSF was followed by the approval of a 110 billion euro bailout Greek package on May 2010. In November 2010, Ireland applied for assistance and a 85 billion euro package was approved, followed by Portugal, with a bailout of 78 billion euro, on May 2011. Finally, a second Greek bailout was agreed in February 2012.

As it was mentioned earlier, credit agencies contributed to the exacerbation of the sovereign debt crisis in the Eurozone by centering their attention in certain economies of the union. Examples of such countries are the GIIPS grouping within the Eurozone (Greece, Italy, Ireland, Portugal and Spain), which have been successively downgraded and been given low sovereign credit ratings (Paterson and Gauthier, 2013; Host et al., 2012). Studies suggest that the downgrading in GIIPS countries led to higher interest rates on government bonds which furtherly exacerbated the European sovereign debt crisis (Gärtner et al., 2011).

Due to the amount and magnitude of these consecutive negative ratings, the benchmarks provided by these agencies have been questioned as being the best source for regulating other financial institutions. Studies also demonstrate how exposure of banks to foreign sovereign debt may lead to international contagion in sovereign debt markets (Bolton and Jeanne, 2011). We focus our attention on Greece, Italy, Ireland, Portugal and Spain, commonly known as the GIIPS. These economies are considered the weak fiscal links of the union (Andrikopoulos, 2014).

In this paper, a three step univariate spillover model in constructed, similar to the one in Ng (2000) and Christiansen (2007), and the relevance of local, regional and global shocks in analyzed. Regional innovations constitute shocks coming from aggregate GIIPS equity markets, while global innovations are directly related with shocks from the US equity markets. It is of particular interest to explore to what extent the return volatility of the six European biggest GDP equity markets have been explained by global factors or local factors. In the empirical section, the existence of asymmetries in the volatility spillover model is investigated, and evidence that negative return shocks imply higher volatility than positive contemporary residuals of the same magnitude. Also, the univariate unconditional spillover model is employed in three subsample periods - Pre-Crisis, Subprime Crisis and Eurozone Sovereign Debt Crisis periods. In the final section, a time-varying spillover model is presented, known as the Conditional Spillover Model. This model allows regional and global factors to vary freely over time, with no time constraint.

This research paper is organized as follows: Section 2 covers the relevant literature. Section 3 provides the data and preliminary analysis, with a brief description of the selected markets and indices. Section 4 presents the empirical models of volatility spillovers. Empirical findings are set forth in Section 5. Section 6 concludes the paper.

2
Literature Review

2.1 Empirical evidence on international market interdependence

The current century is distinguished for exhibiting a strong interdependence between the different countries in the world. How these cross-country linkages vary during periods of financial crisis have been subject to numerous studies. Furthermore, the importance of international factors against country-specific factors in portfolio holdings, and thus the expected benefits that international portfolio diversification can provide to the investor, are also investigated in this section.

A number of research papers have demonstrated the evident increase of correlations in volatile periods among the major stock markets. For instance, using a global and regional market shocks model, Baele and Inghelbrecht (2010) found out that for a set of fourteen different countries, market integration has increased over the past three decades as is implied by the increase in global and regional market exposures and interdependence. This increase in interdependence since the 1980s was already supported by Arshanapalli and Doukas (1993).Indeed, these changes occurred since the 1980s have allowed a high integration, deregulation and a massive capital flow across world financial markets. This shows an increased sensitiveness of exchange rates to stock market shocks, cross-country hedging and portfolio investments around the world (Yang and Doong, 2004; Kester,1995). Therefore, the outcome of capital market liberalization transformed segmented stock markets into an interconnected economy, leading to the propagation of the crisis in the domestic economy to be highly influenced by globalization factors (Taskin and Muradoglu, 2003).

An extensive amount of research papers can be found regarding cross-market correlation tests. Despite high wages of globalization across economies and liberalization of markets during the past decades, there is weak evidence of an increase of correlation of cross-market co-variation (Longuin and Solnik, 1995). Although, quite a few authors prove the instability of international correlations over time (King et al., 1994; Kaplanis, 1988; Bennet and Kelleher, 1988). Indeed, Login and Solnik, 1995 use a bivariate GARCH model and claim that correlations increase in periods of high volatility, a function which is dependant of the magnitude of the volatility shocks.

King and Wadhwani (1990) analyses the increase of cross-correlations among United States, United Kingdom and Japan markets with interesting results of increased correlation after the US stock market collapse on 1987. A couple of years later, Lee and Kim (1993) present an extended version of this analysis, by studying a twelve stock markets and found empirical evidence of contagion. Also, the 1994 Mexican peso crisis was analysed by Calvo and Reinhart (1995), who found further evidence of correlation in equity markets.

Forbes and Rigobon (2002) paper suggests there is an insignificant increase of unconditional correlation coefficients during the dramatic 1987 Black Monday, the Asian crisis of 1997 and the Tequila Crisis in 1994, but finds a high degree of market comovement which is known as interdependence. The author shows the biasedness of correlation coefficients in periods of turmoil, with no evidence of contagion once corrected the effect previously mentioned. In contrast, Corsetti et al (2005) calls into question the assertion of "no contagion, only interdependence" due to the limitations on the variance of country shocks, which are based on bivariate correlation analysis during the 1987 Black Monday crash in Hong Kong. Also, Ahmad et al (2013) study was undertaken in an effort to differentiate contagion from interdependence effects of GIIPS (Greece, Ireland, Italy, Portugal, Spain), UK, US and Japan on BRIICKS (Brazil, Russia, India, Indonesia, China, South Korea and South Africa) equity markets during the European Sovereign Debt crisis period. The results obtained by these studies report interdependence only in the case of Indonesia and South Korea.

Regarding regional cross-market correlation, Koch and Koch (1991) use a dynamic simultaneous equation model to analyse the regional interdependence between eight equity markets. Their results suggest an increasing regional interdependence since 1972 and to a growing influence of the Japan market to rival that of the USA. Samarakoon (2011) examines the interdependence of US, frontier and emerging markets and shows the relevance of US shocks when it comes to interdependence while contagion are driven more by emerging markets.

A matter of deep concern for the test of interdependence and contagion is the presence of omitted variables and heteroskedasticity, so a more robust test is proposed using the so called DCC test (Billio and Pelizzon, 2003) or a frequency domain framework (Bodart and Candelon, 2009), among others. Indeed, high interdependence has helped to the diffusion of the Asian Financial crisis.

Shifting the frame of reference to the importance of portfolio diversification over portfolios consisting of only one asset, Grubel (1968) demonstrated the usefulness of these multi-asset portfolios, which are models developed by Markowitz in line with Sharpe - Lintner Capital Asset Pricing model (CAPM) economic equilibrium and optimization (Sharpe, 1964; Lintner, 1965). Grubel (1968), Levy and Sarnat (1968), and Solnik (1974) were the pioneers in reporting the benefits of international portfolio diversification. Numerous studies have emphasized the analysis of stock market linkages, for instance the studies conducted by Asgharian and Nossman(2013), Jefferis (2001), Hilliard (1979) or Ripley (1973). The majority of these papers show the important role of international factors against purely domestic ones, and the incredibly low correlations among returns to national stock markets, supporting the diversification of investment portfolios.

Furthermore, studies carried out by Driessen and Laeven (2007) report that the benefits of portfolio diversification are shown to be greatest for investors in developing countries, when investing in a region different from the home country's, and in countries with high country risk. The effects of portfolio diversification on stock returns have been studied in terms of country and industry factors. Heston and Rouwenhorst (1994) states that "Diversification across countries within an industry is much more effective tool for risk reduction than industry diversification within a country". Solnik (1974) already highlighted the dominance of country effects versus industry effects as an effective tool for lowering risk exposure. However, we would expect this to hold true for a marketplace with scarce integration, and on the contrary, a growth of economic or financial integration should conduct to a dominance of global factors (i.e. cross market industry factors) over local (or country) factors (Serra, 2000). Baca et al. (2000) and Cavaglia et al. (2000) argues the equal importance of industry factors with respect to country factors for the explanation of low correlation between country indices. Some authors believe that the explanation behind the surprisingly low cross-country correlation between countries is due to the varied industrial structures in each and every country, where the pure industry factors do not play a relevant role according to Heston and Rouwenhorst (1994) and Serra (2000).

Rezayat and Yavas (2006) studied the impact of exogenous shocks, more precisely the introduction of the euro by the EU and the terrorist events in September 11, 2001, in international market interdependence. The results suggest that international portfolio diversification can still bring benefits to investors, even if interdependencies among markets are significant. Driessen and Laeven (2006) found that the benefits brought by portfolio diversification have decreased, for the countries used in their samples, during the two decades previous to their study, i.e. the decades of 1980s and 1990s.

2.2 Further evidence on volatility spillover and contagion effect

The increasing flow of capital in global equity markets during the past decades has led to the increase in foreign exchange market trades and thus, a higher degree of volatility and idiosyncratic risk in the respective portfolio decision process. The empirical literature has used different approaches to identify the sources of contagion between different economies. For instance,Forbes and Rigobon (2002) defines contagion based on the effectiveness of international diversification in reducing portfolio risk during periods of crisis. Other research papers define contagion based on the analysis of cross-market linkages (Baig and Goldfajn, 1997; Dornsbusch et al., 2000).

Moreover, in order to test spillover and contagion effect four different methods have been used: GARCH model, cross-market correlation coefficients tests[1], probit models, and cointegration analysis.

Primarily, the very popular autoregressive conditional heteroskedastic ARCH model (Engle, 1982) has been extensively applied as well as the Generalized GARCH model. Furthermore, Day and Lewis (1992) demonstrated the limitations of the implied volatility from Black Scholes model to forecast future volatilities of the underlying assets in comparison with other models like GARCH and Exponential GARCH. Amin and Ng (1993) found differences in option pricing between using predictable and unpredictable models. Wiggins (1987) and Hull and White (1987) showed pricing biases of the Black Scholes option pricing model. However, it has been demonstrated that EGARCH models could be suitable for warrants valuation (Kuwahara and Marsh, 1992).

Early studies including Hamao et al. (1990) analyzed three largest stock markets of New York, London and Tokyo in order to find price volatility spillover effects, with evidence of contagion from New York to London, New York to Tokyo, London to Tokyo but no significant spillovers the other way round. Supporting evidence is given by the popular Koutmos and Booth (1995) research paper, which captures price spillovers within the same equity markets. Chiang and Yang (2003) demonstrates the visible spillover effects and clustering phenomenon between the US and powerful equity markets as being significantly related to the degree of stock returns developement. In contrast, Theodossiou and Lee (1993) reveals the non existence of asymmetric volatility and return phenomenon. Also, Susmel and Engle (1994) reports the minimal duration of volatility spillovers between London and New York stock markets, lasting a maximum of an hour.

Kanas (2000) was considered one of the pioneers on measuring volatility spillovers between stock returns and exchange rate changes as well as demonstrating international financial integration after 1987, by implementing Nelson's (1991) EGARCH model in G7 countries. This research paper and

[1] A test which measures the significant change of correlation between two markets returns during a non-crisis period (stable) and after a shock.

posterior studies (e.g. Aloui, 2007; Nieh and Lee, 2001; Yang and Doong, 2004) highlighted the role of the euro as a key factor for international financial markets integration.

Ng (2000), Christiansen (2007) and Bae et al (2003) have constructed volatility spillovers model to capture significant time-varying nature of volatility spillovers model from the US to six Pacific-Basin stock markets and US to thirteen local European equity markets respectively and found significant spillovers. Also, Liu (2007) found strong evidence of mean and volatility spillover effects from USA and China to ASEAN equity markets using a GARCH spillover model. Hassan and Malik (2007) documented the relevant transmission of shocks and volatility across a varied number of sectors employing a multivariate GARCH model using US daily stock returns before global financial crisis, from 1 January, 1992 to 6 June, 2005.

Besides the use of GARCH and EGARCH to measure volatility spillovers, more robust models can be found. Indeed, Asgharian and Nossman (2013) extended Bekaert and Harvey's (1997) model by developing a stochastic volatility model. This model allowed jumps in returns and volatility to study risk spillover across international markets of the European countries during 1982 to 2007 timeframe. Results show the relevance of a large US market volatility to contaminate other economies, and the significant increment of the US volatility in periods just after jumps.

A couple of years later, Asgharian and Nossman (2013) concentrated in Asian equity markets to further analyze spillover effects with shocks from the U.S.market, shocks from the regional market and local shocks. In addition, they studied the dependence of spillover on financial and economic integration variables.

In addition to these methods, other sophisticated approaches have been used, for instance Baig and Goldfajn (1998) investigated the reasons behind the transmission of shocks among countries by studying the comovements, correlations and impact of own-country and cross-border news with 1995-1998 daily vector autoregression (VAR) model. Moreover, if contagion is driven due to panic-driven herd behaviour, he gives priority to policy actions to effectively tackle financial market contagion.

Evidence of contagion in the recent sovereign debt crisis in the eurozone has been analyzed by different authors. Samitas and Tsakalos (2013) showed the existence of contagion effect in the recent debt crisis between Greece and European countries applying a A-DCC (asymmetric dynamic conditional correlation model) and copula functions. However, the results does not give support to the existence of contagion during the Greek debt crisis, but to recent crash periods. On the contrary, Arghyrou and Kontonikas (2012) found evidence of contagion during the european sovereign debt crisis, especially among peripheral countries. During the first period studied (2007 - 2009) they conclude Greece is the main source of stress during european sovereign debt crisis. The following years, they identify different sources of contagion, mainly Greece, Ireland, Portugal and Spain.

3

Data and Preliminary Analysis

3.1 Data Description

The data used in this research includes weekly closing stock prices in terms of US dollars from different European Union (EU) countries, including countries that participate in the EMU (Greece, Ireland, Italy, Portugal, Spain, France, Germany and the Netherlands) and countries not participating in the EMU (United Kingdom, Sweden and Switzerland), and the US market. The aggregate GIIPS index is a market value weighted average of the indices of Greece, Italy, Ireland, Portugal and Spain. The European countries under study are determined based on the largest gross-domestic product (GDP), according to the statistics of the World Bank 2014.

The analysis uses empirical data is sampled weekly for the period of January 2002 until December 2014, using a total of 680 observations, with data collected from DataStream. We have splitted our sample in three sub-periods in order to crearly differentiate the impacts of the 2007 financial crisis, and analyze the Eurozone sovereign debt crisis starting from 2010.

Firstly, a pre-crisis period is defined from 1st January 2002 until 8th August 2007. The date 9th August 2007 is defined as the cut-off point separating two periods, in line with existing studies (e.g. Andrikopoulos, 2014; Attinasi et al., 2009; Oliveira et al., 2012; Arghyrou and Kontonikas, 2012). This day can be approximated as a starting point for the financial crisis of 2007, coinciding with the freezing of three hedge funds by BNP Paribas and the date the first emergency loan to European banks was issued by the European Central Bank.

The second period extends from 9th August 2007 to 22nd April 2010. The date 23rd April 2010 has been chosen as the starting point of the Eurozone sovereign debt crisis corresponding to the day the Greek government officially requested financial support.

Finally, the period corresponding to the Eurozone sovereign debt crisis spans from 23rd April until 31st December 2014.

Stock return series were obtained using the differences in successive logarithms of prices.

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

3.2 GIIPS countries : History and Relevance

During 2010 the Eurozone endured a severe financial and economic downturn, starting with Greece being unable to repay its debt and its interest rates rising to levels that made fiscal policy unsustainable. Policymakers feared that a Greek national bankruptcy would spillover to other highly indebted countries in the Eurozone, especially to four other countries of the Eurozone that, together with Greece constitute the GIIPS countries (Greece, Ireland, Italy, Portugal and Spain).

The GIIPS grouping consists of the aggregate of EU countries that report weaker economies, with high sovereign debt, and suffered deep economic stress during the financial crisis. Budget and external deficit, along with considerably high domestic and foreign debt characterizes these countries (Algieri, 2012).

Not many studies have systematically analyzed the GIIPS grouping and researched on contagion in the current sovereign debt crisis in the Eurozone. Some noticeable exceptions are Missio and Watzka (2011), Afonso et al. (2011) or Andrikopoulos (2014).Indeed, Missio and Watzka (2011) argues that there are good chances that downgrades by rating agencies for Greece were translated to Portugal and Spain, while rating cuts did not affect other countries in the GIIPS grouping. Alfonso et al. (2011) concludes that there is evidence of contagion from lower rated countries to higher rated countries. Moreover, due to the restrictions imposed by union policies, the GIIPS grouping are less capable of exhibiting the national government's responsiveness, pro-activeness and capability of adapting their economy to upcoming difficulties. This is due to the fact that GIIPS countries cannot alter their exchange-rate, i.e. inflate or deflate their currency, which makes them less robust with regard to monetary flexibility, investment risk and sovereign debt crisis (Paterson and Gauthier, 2003).

Without monetary flexibility, these countries had to turn to internal devaluation and austerity measures. Andrikopoulos (2014) argues how, in this scenario, international creditors hesitated to provide liquidity to these countries private and public sectors due to the decrease in domestic demand and competitiveness of their output caused by policies of austerity. For further information, a brief description of the indices of the GIIPS equity markets are presented (Bloomberg.com, 2016).

- Stock Exchange of Greece: the ASE General Index reflects the evolution of Greek stocks listed on the Athens Stock Exchange. It is a capitalization-weighted index which has a base value of 100 as of December 31, 1980.
- Stock Exchange of Italy: FTSE MIB, consisting of the 40 most liquid and capitalised stocks listed on the Borsa Italiana.
- Stock Exchange of Ireland: ISEQ Overall Index, which is a capitalisation-weighted index created with a base value of 1000 as of January 4th 1988.
- Stock Exchange of Portugal: PSI 20 is a capitalization-weighted index, created with a base value of 3000 as of December 31, 1992, which includes the 20 most liquid stocks listed on the Lisbon Stock Exchange.
- Stock Exchange of Spain: the IBEX 35, consisting of the 35 most liquid stocks that are traded on the Continuous market. It was created with a base value of 3000 as of December 29, 1989.

3.3 Preliminary Analysis

3.3.1 Descriptive Statistics

In this section, a snapshot of the sample statistics of the returns series is presented. Table 3.3.1 provides the descriptive statistical properties of the eight selected equity market index returns. The primary goal of this section is to give an overall idea of the statistics and distribution, which are considered a relevant early visual processing of the data structure.

The table shows positive weekly market returns for the whole sample period, where the DAX 30 equity market encounters the highest return on average, and the aggregate GIIPS index the slowest increase. As we see from the table, the eight equity markets show similar volatility results. Sweden appears to be the most volatile market with the biggest standard deviation of 0.039, while the US is the least with a 0.024 standard deviation. The results are consistent, since the more developed the country the lower standard deviation.

Table 3.3.1:

Summary Statistics
This table provides the summary statistics of the selected equity markets. The sample period is from January 2002 to December 2014. The data includes weekly closing stock returns in terms of US dollars, and gives a total of 680 observations for each market.

	US	GIIPS	DE	FR	NL	UK	SE	CH
Mean	0.001	0.001	0.004	0.001	0.001	0.001	0.002	0.002
Median	0.002	0.002	0.004	0.002	0.003	0.002	0.004	0.003
Maximum	0.102	0.113	0.138	0.135	0.162	0.110	0.141	0.104
Minimum	-0.165	-0.155	-0.179	-0.176	-0.187	-0.152	-0.211	-0.142
Std.Dev.	0.024	0.036	0.037	0.036	0.036	0.029	0.039	0.027
Skewness	-0.745	-0.399	-0.800	-0.556	-0.751	-0.620	-0.732	-0.461
Kurtosis	8.944	4.956	6.380	5.925	6.960	6.430	6.651	5.475
Jarque-Bera	1060.715	126.015	395.074	276.764	506.750	375.827	437.039	196.985
Probability	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Sum	0.578	0.129	0.932	0.222	0.133	0.305	0.835	0.846
Sum Sq.Dev.	0.389	0.863	0.918	0.853	0.889	0.585	1.011	0.490
Observations	678	678	678	678	678	678	678	678

US, United States; GIIPS, aggregate index Greece, Italy, Ireland, Portugal, Spain; DE, Germany; FR, France; NL, Netherlands; UK, United Kingdom; SE, Sweden; CH, Switzerland.

Furthermore, the returns of the price indices suggest features of heteroskedasticity A.2.2, volatility clustering and negatively skewed distribution. The non zero skewness implies in the conditional variance equation to have an ARCH order larger than one. Thus, GARCH (1,1) becomes a more proper model than an ARCH (p) model, due to its powerful capacity to deal with data. To finish, the equity markets seem to be leptokurtic, which suggests an scenario of not normal distribution stock market returns. This theory is supported by the Jarque-Bera test, where the null hypotheses of normality is rejected at a very high significance level.

The selection of an optimal number of lags becomes relevant. The Lag Length selection criteria have been employed. The Akaike Information Criteria reveals 2 lags to be the proper number of lags. However, Hannan-Quinn and Schwarz suggest 0 lags to be the optimal number of lags for the model. Thus, 1 lag, which is the middle point of the two tests is applied as the lag number.

3.3.2 Stationary test

The preliminary analysis commences testing for "Stationarity" in time series data. A wide range of financial datasets tend to be "heavy-tailed" so, testing for covariance stationarity is considered one of the most relevant test (Loretan and Phillips, 1992) so as to identify spurious relationships if we encounter with non-stationary data. According to Brooks (2008), stationarity is defined as having a constant mean, constant variance and constant auto covariances for each and every given lag. An important feature of a non stationary data is that shocks never die away, which misleading results in the hypothesis tests about the parameters of the regression.

Several methods can be used to identify stationarity or non - stationarity data. In this research paper, the Augmented Dickey-Fuller (ADF) test and Phillips-Perron (PP) test were applied.

The very popular Augmented Dickey Fuller have been used (Dickey and Fuller, 1979), which tests for the presence of a unit root in our AR (1) simple specification:

$$y_t = c + \varphi y_{t-1} + e_t \tag{3.2}$$

where:

$$\begin{cases} H_0 : \varphi = 1(non - stationary) \\ H_1 : \varphi < 1(stationary) \end{cases}$$

The sample dataset is stationary if the absolute value of the test statistic is significantly larger than the corresponding critical value. In this case,we cannot reject the null hypotheses of stationarity, and we conclude that stock indices at price level are non-stationary. We run again the ADF test, but the first difference is taken and the null hypothesis is rejected, leading to a stationary sample dataset.

Also, Phillips and Perron (1988) test has been used for the analysis of the financial time series. The Phillips Perron (PP) in comparison with the Augmented Dickey Fuller (ADF) test faces heteroskedasticity and serial correlation in the errors differently, using a modified version of the test statistics t. The test has been performed both in the price and return level with similar outcomes. These results can be found in Appendix A.1.3 and A.1.4.

3.3.3 Cross-Country Correlation of Prices

To see the comovements between the country index returns specified in this thesis paper, the Pearson Product-Moment Correlation coefficient test has been performed. It gives powerful insights about the model specified. Also, it is important to highlight that more features need to be considered for dependence which are far beyond from a simple correlation test. See the following sections if you aim to draw conclusions in interdependence.

1. Pre-Crisis. Subsample : 01/01/2002 - 08/08/2007

Table 3.3.2:

Pre-Crisis Correlation Matrix of Returns
This tables present the cross-correlation matrix of returns. The data spans from January 2002 to August 2007. The sample is organized on a weekly basis, which contains 294 observations for each countries' series.

	US	**GIIPS**	**DE**	**FR**	**NL**	**UK**	**SE**	**CH**
US	N/A	0.708	0.773	0.760	0.766	0.679	0.708	0.689
GIIPS	0.708	N/A	0.902	0.932	0.887	0.823	0.828	0.860
DE	0.773	0.902	N/A	0.913	0.896	0.770	0.817	0.829
FR	0.760	0.932	0.913	N/A	0.949	0.866	0.860	0.895
NL	0.766	0.887	0.896	0.949	N/A	0.858	0.834	0.875
UK	0.679	0.823	0.770	0.866	0.858	N/A	0.799	0.837
SE	0.708	0.828	0.817	0.860	0.834	0.799	N/A	0.804
CH	0.689	0.860	0.829	0.895	0.875	0.837	0.804	N/A

US, United States; GIIPS, aggregate index Greece, Italy, Ireland, Portugal, Spain; DE, Germany; FR, France; NL, Netherlands; UK, United Kingdom; SE, Sweden; CH, Switzerland.

2. Global Financial Crisis. Subsample: 09/08/2007 - 22/04/2010

Table 3.3.3:

Subprime Crises Correlation Matrix of Returns
This tables exhibits the cross-correlation matrix of returns. The data spans from August 2007 to April 2010. The sample is organized on a weekly basis, which contains 294 observations for each countries' series.

	US	**GIIPS**	**DE**	**FR**	**NL**	**UK**	**SE**	**CH**
US	N/A	0.792	0.805	0.838	0.831	0.814	0.783	0.762
GIIPS	0.792	N/A	0.947	0.958	0.932	0.884	0.870	0.864
DE	0.805	0.947	N/A	0.972	0.942	0.885	0.875	0.864
FR	0.838	0.958	0.972	N/A	0.959	0.914	0.890	0.908
NL	0.831	0.932	0.942	0.959	N/A	0.923	0.891	0.877
UK	0.814	0.884	0.885	0.914	0.923	N/A	0.866	0.850
SE	0.783	0.870	0.875	0.890	0.891	0.866	N/A	0.822
CH	0.762	0.864	0.864	0.908	0.877	0.850	0.822	N/A

US, United States; GIIPS, aggregate index Greece, Italy, Ireland, Portugal, Spain; DE, Germany; FR, France; NL, Netherlands; UK, United Kingdom; SE, Sweden; CH, Switzerland.

3. Eurozone Sovereign Debt Crisis. Subsample : 23/04/2010 - 31/12/2014

Table 3.3.4:

Eurozone Sovereign Debt Crises (ESDC) Correlation Matrix of Returns

This tables displays the cross-correlation matrix of returns. The data spans from April 2010 to December 2014. The sample is organized on a weekly basis, which contains 246 observations for each countries' series.

	US	GIIPS	DE	FR	NL	UK	SE	CH
US	N/A	0.741	0.831	0.831	0.839	0.853	0.794	0.732
GIIPS	0.741	N/A	0.874	0.936	0.897	0.813	0.766	0.787
DE	0.831	0.874	N/A	0.945	0.931	0.888	0.875	0.846
FR	0.831	0.936	0.945	N/A	0.959	0.894	0.864	0.858
NL	0.839	0.897	0.931	0.959	N/A	0.914	0.880	0.867
UK	0.853	0.813	0.888	0.894	0.914	N/A	0.878	0.833
SE	0.794	0.766	0.875	0.864	0.880	0.878	N/A	0.817
CH	0.732	0.787	0.846	0.858	0.867	0.833	0.817	N/A

US, United States; GIIPS, aggregate index Greece, Italy, Ireland, Portugal, Spain; DE, Germany; FR, France; NL, Netherlands; UK, United Kingdom; SE, Sweden; CH, Switzerland.

As mentioned earlier, the Pearson Product-Moment Correlation coefficient test has been performed among the selected stock markets. The results of this test together with the subperiods of interest give us an insight on the fluctuations of cross-correlation between the stock markets. Furthermore, the aggregate GIIPS index have been assigned a weight with respect to its market capitalization, therefore the dependency between this grouping and the remainder of the sampled markets is provided.

During the pre-crisis period, the GIIPS grouping shows highest cross-correlation coefficient with France and Germany among the selected markets, with a value over 0.90 for both cases. It is evident from the results that there is a cross-correlation increase from the pre-crisis sub period to the global financial crisis (subprime crisis) subperiod.The subprime crisis period is characterized for an increase in level of dependency among all the selected markets, including the cross-correlation between the GIIPS and the so called "bigs" (Germany, France, UK) and the US.

Finally, the Eurozone sovereign debt crisis subperiod, singled out by the Greek bailout during 2010, is characterized for showing a high volatility between the selected stock markets, although at a lower level in comparison to the subprime crisis period. During this period, the cross-correlation coefficients exhibit a decrease to values lower than those of the pre-crisis period for some of the markets. This could be due to the fact that some third parties, like speculators, tried to take advantage of the Greek financial situation and the structure of the Eurozone by employing aggressive strategies in order to gain benefits (Samitas and Tsakalos, 2013).

3.3.4 Cointegration Johansen Test

The Cointegration test has become a very useful tool to identify if two non-stationary variables share a common stochastic trend, and thus they are cointegrated. Cointegration is defined as a statistical property of long-term equilibrium relationships that encounter many of the financial time series datasets. Indeed, one would find most of the economic variables to deviate from the equilibrium in the short run, but revert to the equilibrium in the long run. It is important to highlight that if we work with to non-stationary variables, it is very likely to write the first difference I(1) or second difference I(2) so as to make the data stationary and avoid spurious linkages between them. Commonly, two non-stationary variables with differing order of integration share a linear combination which is the highest of the two orders. According to Engle and Granger (1987) approach cointegrating combinations are seen as "equilibria". Thus, it is necessary to identify and model these relationships, since they are sharing a common stochastic trend that it is said to be cointegrated.

It is therefore widely believed that if there are two variables, a single unique linear cointegration relationship can be found. Here, the power of the traditional Johansen Cointegration 1988 test will be the allowance of multivariate settings in order to test for all possible cointegrating vectors across different stock markets.

In this research paper, the Johansen Cointegration test has been computed to discover if the analyzed six equity markets are cointegrated, leading to a higher probability of volatility spillover and contagion effect. See tables 3.3.5 and 3.3.6.

Results in Trace statistic suggest that at 5% significance level 1 cointegration equation does exist. However, the Maximum Eigenvalue statistics indicated at 5% significance level no cointegration.

As we can see from the tables, contradictory results were found in the case of the trace statistic or Max-eigenvalue statistics. Trace statistics indicates 1 cointegration equation whereas the Maximum eigenvalue statistic none. Thus, in this scenario, it becomes own choice to choose the proper number of cointegrating equations. Moreover, in previous section have been mentioned that our sample data is non-stationary at price which is translated that the stock indices share same stochastic trend but convert in the long run equilibrium.

Table 3.3.5:

Johansen Unrestricted Cointegration Rank Test (Trace)

Unrestricted Cointegration Rank Test (Trace)				
Hypothesized No. of CE(s)	**Eigenvalue**	**Max-Eigen Statistic**	**0.05 Critical Value**	**Prob. ****
None*	0.068	162.689	159.530	0.033
At most 1	0.055	114.795	125.615	0.189
At most 2	0.036	76.467	95.754	0.489
At most 3	0.025	51.708	69.819	0.562
At most 4	0.023	34.261	47.856	0.488
At most 5	0.013	18.206	29.797	0.551
At most 6	0.011	9.502	15.495	0.321
At most 7	0.003	2.128	3.841	0.145

Max-eigenvalue test indicates 1 cointegration eqn(s) at the 0.05 level.
* denotes rejection of the hypothesis at the 0.05 level.
** McKinnon-Haug-Michelis (1999) p-values.

Table 3.3.6:

Johansen Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)				
Hypothesized No. of CE(s)	**Eigenvalue**	**Max-Eigen Statistic**	**0.05 Critical Value**	**Prob. ****
None	0.068	47.895	52.363	0.134
At most 1	0.055	38.328	46.231	0.272
At most 2	0.036	24.759	40.078	0.782
At most 3	0.025	17.447	33.877	0.904
At most 4	0.023	16.055	27.584	0.661
At most 5	0.013	8.703	21.132	0.856
At most 6	0.011	7.375	14.265	0.446
At most 7	0.003	2.128	3.841	0.145

Max-eigenvalue test indicates no cointegration at the 0.05 level.
* denotes rejection of the hypothesis at the 0.05 level.
** MacKinnon-Haug-Michelis (1999) p-values.

3.4 Granger Causality Test

Here, we are working in a multivariate setting, so the analysis of interdependence among dependant variables becomes relevant.

Therefore, Granger causality test investigates the dynamic relation between weekly stock returns (dependent variable) and the respective lags and other weekly stock returns (independent variable). Indeed, causality test gives practical information to see the effectiveness of past equity price movements to forecast current and future movements in stock markets. The selection of number of lags is based on Akaike Information criterion and Schwarz Information criterion.

This test have to be computed with stationary data, and results can be both unidirectional or bidirectional, see Appendix A.1.1. In our case, the Causality test have been performed by R-program, and results suggest that GIIPS countries Granger cause US countries. Bidirectional causality between the UK and US, and Netherlands and US. Also, the results implies that US Granger causes Sweden and Switzerland, but France only Granger cause US. Results do not inform about the sign of the the effect of the causality.

Important to mention, this section is just a Preliminary analysis, so it is not recommendable to draw any conclusions about volatility spillover and the contagion effect. Furthermore, we have applied a number of volatility spillover model in order to analyze and reach a conclusion about contagion.

4

Empirical Models

In this section, Ng (2000), Christiansen (2007) and Liu (2007) volatility and mean spillover models have been followed. The empirical model specified in these research papers is a two step model which analyses volatility and price spillover effects from a global and regional perspective.

Firstly, an univariate AR-GARCH model has been implemented to measure the global effect of the return of the US stock market. Secondly, an extended univariate AR-GARCH model has been estimated so as to analyse the regional effect of the aggregate return of GIIPS equity stock markets in six powerful equity markets in Europe, both outside and inside the Eurozone. The selected six equity markets are known as "the big", and are the largest GDP countries in Europe according to the World Bank index. The study of both global and regional effects presents a deeper picture of the contagion effect.

Moreover, the model requires an optimal lag number which is selected according to the lag Length Selection criteria test, Akaike and Schwarz Information criterion results. A one period lagged US and GIIPS returns were used. Also, the first regression gives the contemporary US and GIIPS residuals, which are consequently introduced as explanatory variables in the second regression to measure the extent of contagion effect. The reason behind the usage of the three step univariate AR-GARCH model followed by Christiansen (2007) is to overcome the limitations of orthogonalization between the contemporary idiosyncratic shocks of the US and GIIPS equity markets, and thus, the causality to be defined from US to GIIPS equity markets. Furthermore, a model for the measurement of asymmetric responses has also been included in this research paper. Finally, apart from the Unconditional Spillover model, a Conditional Spillover has been examined so as to analyze the time-varying spillover intensities, and the significance of the inclusion of economic and financial variables in the model.

4.1 Unconditional Spillover Model

In this first section, the return of the US stock index is used, $R_{US,t}$. The one period lag autoregressive model has been applied, AR (1).It englobes the mean equation of an AR-GARCH model.

$$R_{US,t} = c_{0,US} + c_{1,US} R_{US,t-1} + e_{US,t} \tag{4.1}$$

The conditional variance equation has the features of a GARCH (1,1) specification, and the mean of the idiosyncratic shock is 0 and normally distributed, $e_{US,t}$.

$$\sigma^2_{US,t} = \omega_{US} + \alpha_{US} e^2_{US,t-1} + \beta_{US} \sigma^2_{US,t-1} \tag{4.2}$$

The same logic has been used for the AR (1) specification of the aggregate GIIPS index, $R_{GIIPS,t}$:

$$R_{GIIPS,t} = c_{0,GIIPS} + c_{1,GIIPS} R_{GIIPS,t-1} + \gamma_{GIIPS} R_{US,t-1} + \varphi_{GIIPS} e_{US,t} + e_{GIIPS,t} \tag{4.3}$$

The aggregate return of GIIPS index is described by its own lagged return as a dependent variable and also the lagged US return and the contemporary US residual. On the one hand, the scope of mean spillover effect is measured by the respective lagged US return, $R_{US,t-1}$. On the other hand, it is also aim to identify volatility spillover effect from the US to aggregate GIIPS equity markets by way of the US idiosyncratic shock, $e_{US,t}$. Prior assumption, the idiosyncratic shocks of $e_{GIIPS,t}$ is zero mean and the conditional variance $\sigma_{GIIPS,t}$ follows a GARCH (1,1) model:

$$\sigma^2_{GIIPS,t} = \omega_{GIIPS} + \alpha_{GIIPS} e^2_{GIIPS,t-1} + \beta_{GIIPS} \sigma^2_{GIIPS,t-1} \tag{4.4}$$

Finally, the same logic is followed, but this time for the six stock markets of Europe, of which three are part of the EMU countries (Germany, France and the Netherlands) and the remaining three are non-EMU (United Kingdom, Sweden and Switzerland)countries. The one period lag AR (1) has been applied. It is important to highlight the specification of the mean spillover effects of both US and aggregate GIIPS equity markets by the lagged returns $R_{US,t-1}$ and $R_{GIIPS,t-1}$. See the following mean equation for country i, $i = 1, \ldots N$:

$$R_{i,t} = c_{0,i} + c_{1,i}R_{i,t-1} + \gamma_i R_{US,t-1} + \delta_i R_{GIIPS,t-1} + \varphi_i e_{US,t} + \psi_i e_{GIIPS,t} + e_{i,t} \tag{4.5}$$

When it comes to volatility spillover effect from the US and GIIPS countries to each of the individual economies constituting "the bigs" European economies, the US and GIIPS idiosyncratic shocks have been included in the regression, $e_{US,t}$ and $e_{GIIPS,t}$. Here as well, it is assumed that the idiosyncratic shock of each country i, $e_{i,t}$ has zero mean and a conditional variance equation described by the following equation:

$$\sigma_i^2 = \omega_i + \alpha_i e_{i,t-1}^2 + \beta_i \sigma_{i,t-1}^2 \tag{4.6}$$

Note that, the so called unexpected returns, ε_t, are included in the mean equation specification. Indeed, the previously mentioned unsystematic shocks $e_{US,t}$, $e_{GIIPS,t}$ and $e_{i,t}$ for each country i are under the assumption of independence. See the following:

$$\varepsilon_{US,t} = e_{US,t} \tag{4.7}$$

$$\varepsilon_{GIIPS,t} = \varphi_{GIIPS} e_{US,t} + e_{GIIPS,t} \tag{4.8}$$

$$\varepsilon_{i,t} = \varphi_{i,t} e_{US,t} + \psi_i e_{GIIPS,t} + e_{i,t} \tag{4.9}$$

Here, the conditional variance of the unexpected return for each country i, $h_{i,t}$ is described by the variance of the coefficient of the contemporary US, GIIPS and each country residuals. Indeed, the conditional variance of the unexpected return is build on the information contained at time t-1, I_{t-1}. Regarding the conditional variance of the US unexpected return, this quantity is just defined by its own idiosyncratic volatility. The conditional variance of the aggregate GIIPS equity market is dependent on its own idiosyncratic shock and US volatility.

$$h_{i,t} = E(\varepsilon_{i,t}^2 | I_{t-1}) = \varphi_i^2 \sigma_{US,t}^2 + \psi_i^2 \sigma_{GIIPS,t}^2 + \sigma_{i,t}^2 \tag{4.10}$$

Finally, and perhaps most importantly, the sign and significance of the variables φ_i and ψ_i dictates the existence of volatility-spillover effects from the US and GIIPS countries in each country i. Moreover, variance ratios have been defined so as to identify the portion of the variance of the unexpected returns resulting from both the US and GIIPS volatility spillover effects. Pure local effects are the source of the remaining part of the variance of the unexpected return of each country i. See equations 4.10 to 4.12.

$$VR_{i,t}^{US} = \frac{\varphi_{i,t-1}^{2}\sigma_{US,t}^{2}}{h_{i,t}} \tag{4.11}$$

$$VR_{i,t}^{GIIPS} = \frac{\psi_{i,t-1}^{2}\sigma_{GIIPS,t}^{2}}{h_{i,t}} \tag{4.12}$$

4.2 Asymmetric Spillover Model Specification

Understanding the asymmetric volatility transmission becomes crucial. There is an extensive research regarding whether or not asymmetric effects for volatility exist. A wide number of findings support the fact that volatility transmission is asymmetric, spillovers being more pronounced for negative news ("bad news") than positive news ("good news") (e.g. Bae and Karolyi, 1994; Booth and Martikainen, 1997; Ng, 2000).

This section aims to prove the existence of asymmetric effects in the returns of each of the six equity markets of Europe. In the asymmetric mean equation, variables that contain upturns and downturns information are included, and also positive and negative idiosyncratic shocks of both US and GIIPS stock markets.

$$\begin{aligned} R_{i,t} = & c_{0,i} + c_{1,i}R_{i,t-1} + \gamma_{1,i}R_{US,t-1}^{+} + \gamma_{2,i}R_{US,t-1}^{-} + \delta_{1,i}R_{GIIPS,t-1}^{+} + \delta_{2,i}R_{GIIPS,t-1}^{-} + \\ & \varphi_{1,i}e_{US,t}^{+} + \varphi_{2,i}e_{US,t}^{-} + +\psi_{1,i}e_{GIIPS,t}^{+} + \psi_{2,i}e_{GIIPS,t}^{-} \end{aligned} \tag{4.13}$$

4.3 Time Varying Volatility Spillover Model

In the first model, the unconditional spillover model, I worked under the constant spillover effects scenario to analyse the existence of mean and volatility spillovers from US and GIIPS to each powerful European markets. Thus, the mean and volatility spillover parameters $\gamma_{i,t-1}$, $\delta_{i,t-1}$, $\varphi_{i,t-1}$ and $\psi_{i,t-1}$ were assumed to be constant for all t . In this section a more challenging model will be performed, where the coefficient of the time-varying spillover model are allowed to vary over time.

4.3.1 Selected Market Integration Variables

In this paper, we include a variety of integration variables and relate to a financial and economic integration scenario.

Trade

Trade is considered the primary channel for market integration. Prior research found evidence that bilateral trade has a significant implication in the stock market comovements if there exists economic linkages between two economies (e.g. Bracker et al., 1999; Asharian and Nossman, 2013; Poncet, 2003).

Bilateral trade is specified as a ratio of the sum of exports and imports divided by the gross domestic product (GDP) of the respective country. The GDP data is on monthly basis and thus, the same value is used for all the weeks corresponding to the same month.

Foreign Direct Investment

Foreign Direct Investment (FDI) is considered another relevant channel for economic integration. Moreover, it is widely believed that FDI enables balanced, long-lasting and direct relationships among countries (OECD, 2008).

Indeed, Yannopoulos, 1990 reveals a significant increase in the FDI flows to the six original countries of the European Community (EC), specially from the US, during the EC formative years.

Moreover, "FDI flows are very strongly positively related to source-country stock market valuations " (Baker et al, 2008) and able to explain stock market integration (Shi et al., 2010).

Thus, I included the aforementioned market integration variable, which is the direct investment between the US and regional markets, divided by the monthly gross domestic product (GDP) for the relative weighting of the country under consideration.

Exchange Rates

We should mention the inclusion of exchange rates in the model, in order to measure the substantial importance of currency effects in volatility and correlation stock markets. "The volatility of real exchange rates appears to depress the volume of international trade" (Kenen and Rodrik, 1986).

Now, we can specify our time-varying information variables, and complete the conditional spillover model aforementioned.

See the following:

$$\begin{cases} \gamma_{i,t-1} = v' X^{US}_{i,t-1} \\ \varphi_{i,t-1} = w' X^{US}_{i,t-1} \\ \delta_{i,t-1} = p' X^{GIIPS}_{i,t-1} \\ \psi_{i,t-1} = q' X^{GIIPS}_{i,t-1} \end{cases}$$

where v and w corresponds to a $< 4 * 1 >$ vector of parameters, which measure the effect of both economic and financial variables on the spillover effects from the US stock market. Then, p and q are $< 4 * 1 >$ vector of parameters which involve both economic and financial variables volatility spillovers from the aggregate GIIPS equity market. The extent of market integration and market's sensitivity with respect to shocks could be related to the degree of financial and economical integration across the countries (Asgharian and Nossman, 2013). According to Baele, 2005 country´s trade and inflation rate are the factors that play a significant role when it comes to asses volatility spillovers to the respective country i.

So, the estimated economic variables in $X^{US}_{i,t-1}$ contain a constant, change of exchange rate (currency of the country i under consideration against US dollars), trade against the US as ratio to the analyzed country i gross domestic product (GDP) and foreign direct investment with the US divided by the GDP of the country i under consideration. For $X^{GIIPS}_{i,t-1}$, the same approach has been followed, which contains a constant variable consisting of the trade with aggregate GIIPS countries divided by the GDP of the country under consideration and FDI with GIIPS relative to the country i GDP.

Thus, here the constant spillover assumption is relaxed and offers a more global vision of contagion analysis, followed by Ng (2000). Earlier studies have supported evidence of time-varying correlations between a variety of markets (e.g. Ng, 2000; Karolyi and Stulz, 1996). The inclusion of this model provides a more realistic standpoint for the study of return and volatility spillovers, and thus, allows for parameters to be freely weighted according to the local information variables and their time variation in correlations. Taking into consideration that international relationships change over time, conditional spillover model allows time variation in the mentioned spillover intensity parameters.

5
Empirical Results

In this section, the estimation results will be analyzed for countries with spillover from both the global market of the US and regional markets (GIIPS). The data spans from January 2002 to December 2014. The entire sample is divided into three subsample periods, which are the pre-crisis, the subprime crisis and the Eurozone Sovereign Debt crisis periods, and consequently spillover effects are tested for each subsample period.

The asymmetric spillover model is also included in the research paper. Finally, the conditional spillover model is estimated and extends the model allowing volatility spillover effects to be time-varying.

5.1 Symmetric Unconditional Spillover Model

5.1.1 Whole Sample Period Model (01/01/2002 to 31/12/2014)

This first section estimates the coefficients of the unconditional spillover model for the whole sample period, from 1 January 2002 to 31 December 2014. Table 5.1.1 reports the aforementioned coefficients. To start with, the return on the US index evolves according to an Autoregressive of order one process. Results for the univariate model of the US return shows negative and insignificant first order autocorrelation at 1% level, but with stationarity features in the variance of the US return ($\alpha+\beta < 1$).

The unconditional spillover model shows no significant mean-spillover effect from the US to the aggregate GIIPS stock market. However, the coefficient of the contemporary US residual is positive and significant, which indicates a substantial US volatility spillover effect to GIIPS.

The same model has been applied individually for each of the six countries under consideration. Results suggest weak first order autocorrelation, only in France, Sweden and Switzerland. Results show a significant one-period lagged returns of US at 1% significance level for all countries, except for France. In contrast, no evidence of mean-spillover effects of GIIPS is found in the countries i. The null hypothesis of no spillover effects of US and GIIPS have been rejected for all the countries under 1% significance level.

It is important to mention that the conditional volatility process is stationary, $\alpha + \beta < 1$. Granger and Newbold (1974) demonstrated that non-stationary regressions are unreliable, and thus, it is an important feature to take into consideration while performing the tests.

Table 5.1.1:

Unconditional Spillover Model Coefficient Estimates Whole Sample Period
This table provides the coefficient estimates for the constant spillover model, or the so-called unconditional spillover model. The data spans from January 2002 to December 2014 on a weekly basis. Each market series affords 680 observations. γ is the mean spillover effect from the US to regional markets, δ is the mean spillover effect from GIIPS to regional markets, φ is the constant volatility spillover effects from the US to regional markets and ψ is the constant volatility spillover effects from the GIIPS to regional markets.

	DE	FR	NL	UK	SE	CH
γ	0.102***	0.061***	0.121***	0.098***	0.201***	0.113***
	(0.001)	(0.004)	(0.000)	(0.010)	(0.000)	(0.000)
δ	-0.009	0.028	-0.020	0.004	0.049	-0.007
	(0.815)	(0.407)	(0.599)	(0.894)	(0.206)	(0.807)
φ	1.227***	1.189***	1.162***	0.948***	1.229***	0.773***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
ψ	0.703***	0.761***	0.619***	0.424***	0.614***	0.459***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)

Note: p-values are denoted in parentheses. ***,**,* represents the levels of significance at 0.01, 0.05 and 0.10. US, United States; GIIPS, aggregate index Greece, Italy, Ireland, Portugal, Spain; DE, Germany; FR, France; NL, Netherlands; UK, United Kingdom; SE, Sweden; CH, Switzerland.

Table 5.1.2:

Whole Sample Period Wald Test
This table provides the robust joint Wald test of no spillover effects from US and GIIPS. The sample period is from January 2002 to December 2014.

	Wald$_1$	**Wald$_2$**	**Wald$_3$**	**Wald$_4$**
DE	5209.303***	1315.239***	10.175***	6560.589***
	(0.000)	(0.000)	(0.006)	(0.000)
FR	7496.268***	2566.638***	8.299**	9244.190***
	(0.000)	(0.000)	(0.015)	(0.000)
NL	3447.323***	1198.947***	14.583***	4408.098***
	(0.000)	(0.000)	(0.001)	(0.000)
UK	1750.905***	435.609***	6.916**	2060.074***
	(0.000)	(0.000)	(0.031)	(0.000)
SE	1983.478***	502.008***	22.332***	2515.730***
	(0.000)	(0.000)	(0.000)	(0.000)
CH	1277.848***	642.609***	13.908***	1522.647***
	(0.000)	(0.000)	(0.001)	(0.000)

Note: The test statistic is performed under $\chi^2(2)$ distribution. p-values are expressed in parentheses. ***, **,* represents the levels of significance at 0.01, 0.05 and 0.10. US, United States; GIIPS, aggregate index Greece, Italy, Ireland, Portugal, Spain; DE, Germany; FR, France; NL, Netherlands; UK, United Kingdom; SE, Sweden; CH, Switzerland.

For further support, the Wald Test has been performed. See the following hypothesis for the aforementioned test.

$H_0^1 : \gamma_i = \varphi_i = 0$
$H_0^2 : \delta_i = \psi_i = 0$
$H_0^3 : \gamma_i = \delta_i = 0$
$H_0^4 : \varphi_i = \psi_i = 0$

Table 5.1.2 presents the robust Wald Tests, which englobes the following null hypotheses: no US spillover effects (H_0^1), no GIIPS spillover effects (H_0^2), no mean spillover effects (H_0^3), and finally, no volatility spillover effects(H_0^4).

The Wald test confirms substantial US volatility spillover effects (null hypothesis rejected), in concordance with the results obtained previously. For the other six powerful countries analysed, there is substantial evidence of US mean-spillover and volatility-spillover effects under 1% significance level. γ and φ are positive and significant. So the null hypothesis of H_0^1 is rejected under 1% significance level.

Not only that, the joint robust Wald test has been computed (see table 5.1.2) for each country to verify whether or not GIIPS spillover effects exist. Results demonstrate strong evidence of GIIPS spillover effects for the index returns of the so called big countries.

Nevertheless, hypothesis H_0^3 has been tested with the same test for each individual country, and results vary. Germany, Netherlands, Sweden and Switzerland show powerful support for mean spillover effects at 1% level. However, France and UK seem to not contain substantial mean spillover effects. So, for France and UK the null H_0^3 of no mean-spillover effects has not been rejected under 1% significance level.

Finally, the robust joint Wald test rejects H_0^4 for each individual country, and expresses significant volatility spillover effects for all the countries under 1% level.

All in all, there exists a strong evidence of both US mean-spillover and volatility-spillover effects, but weak evidence of GIIPS mean-spillover effect for the six powerful European countries under consideration for the whole sample period.

Table 5.1.3:

Variance Ratios Summary Statistics

The table below expounds the summary statistics of the variance ratios. The US and GIIPS proportions on the six equity markets under consideration are displayed.The data spans from January 2002 to December 2014.

		DE	FR	NL	UK	SE	CH
US	Mean	0.587	0.603	0.608	0.567	0.541	0.466
	Std. Dev.	0.126	0.127	0.119	0.117	0.127	0.130
GIIPS	Mean	0.228	0.289	0.212	0.161	0.148	0.186
	Std. Dev.	0.092	0.110	0.092	0.075	0.061	0.078
Country i	Mean	0.184	0.108	0.180	0.272	0.310	0.348
	Std. Dev.	0.072	0.044	0.078	0.087	0.095	0.107

US, United States; GIIPS, aggregate index Greece, Italy, Ireland, Portugal, Spain; DE, Germany; FR, France; NL, Netherlands; UK, United Kingdom; SE, Sweden; CH, Switzerland.

Table 5.1.4:

Variance Ratios Mean Min. and Max.
This table provides the average of the minimum and maximum values of the variance proportions US and GIIPS shocks on the variance of country i.

VR^{US}	Min.	0.466
	Max.	0.608
VR^{GIIPS}	Min.	0.148
	Max.	0.289
VR^{i}	Min	0.108
	Max.	0.348

US, United States; GIIPS, aggregate index.

In table 5.1.3 and 5.1.4 the Variance Ratios of the Unconditional Spillover Model are presented, which become a useful source to measure the quantitative relevance of the US and GIIPS volatility-spillover shocks on the variance of the unexpected return of the country i under consideration.

On average, all three Eurozone equity markets are heavily driven by foreign US shocks, which accounts for a maximum mean of 60.8%. Also, the aggregate GIIPS volatility-spillover effects are found to be smaller than pure local volatility effects for the three eurozone countries, a maximum of just 28.9% VR^{GIIPS} and a minimum of 21.2%. The other three non-EMU equity markets account for larger pure local volatility-spillover shocks than GIIPS variance shocks, with a maximum of 34.8% and a minimum of 27.2% pure local shocks. Please see Table 5.1.4 for further explanation, which displays the minimum and maximum values of the corresponding variance ratios of the aforementioned European countries.

The reason behind poor local effects in the case of Germany, France and the Netherlands in comparison with the three outside euro area countries under study may be due to the fact that the EMU countries account for a higher integration with the global markets, and thus its higher VR^{US}. Not only that, the euro area countries present higher GIIPS volatility-spillover effects than the other three outside eurozone countries, and it is not surprising, since the first three are part of the same monetary union.

5.1.2 Pre-crisis, Subprime Crisis and Eurozone Sovereign Debt Crisis

In this section, the whole sample is divided into three sub-sample periods in order to provide some insight into volatility and spillover effects during the Pre-Crisis, Subprime Crisis and Eurozone Sovereign Debt crisis.

Results are displayed in table 5.1.5 for the Pre-Crisis subsample. Strong evidence of volatility spillover is displayed from US and GIIPS to the selected largest GDP European equity markets. For the majority of the countries, no significant mean spillover from US and GIIPS is found except for Germany, where mean spillover from US does exist. The dependant variable of the contemporary US residual is insignificant at 1% level, but there is evidence of mean spillover from US.

In the case of first-order autocorrelation, no substantial evidence of First-Order autocorrelation is shown, except for GIIPS and Sweden. Also, innovation in conditional variance is stationary for all the six equity markets under study, $\alpha + \beta < 1$.

Table 5.1.5:

Pre-Crisis Unconditional Spillover Model coefficient estimates
This table shows the estimated coefficients for the unconditional spillover model. The data spans from January 2002 to August 2007. The sample is organized on a weekly basis, and contains 294 observations for each series. γ is the mean spillover effect from the US to regional markets, δ is the mean spillover effect from GIIPS to regional markets, φ is the constant volatility spillover effects from the US to regional markets and ψ is the constant volatility spillover effects from the GIIPS to regional markets.

	DE	FR	NL	UK	SE	CH
γ	0.115***	-0.031	-0.012	-0.006	0.168**	0.025
	(0.003)	(0.387)	(0.864)	(0.918)	(0.046)	(0.635)
δ	0.041	0.025	-0.072	-0.026	0.177**	-0.092
	(0.560)	(0.715)	(0.370)	(0.664)	(0.038)	(0.179)
φ	1.416***	1.259***	1.341***	0.913***	1.388***	1.021***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
ψ	0.933***	0.913***	0.847***	0.638***	0.882***	0.825***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)

Note: p-values are denoted in parentheses. ***,**,* represents the levels of significance at 0.01, 0.05 and 0.10. US, United States; GIIPS, aggregate index Greece, Italy, Ireland, Portugal, Spain; DE, Germany; FR, France; NL, Netherlands; UK, United Kingdom; SE, Sweden; CH, Switzerland.

Table 5.1.6 reports the joint Wald test for the first subperiod problem. The test concludes with similar results, the null hypothesis for no US spillover effects as well as GIIPS spillover effects are strongly rejected for all the equity markets under consideration by the $\chi^2(2)$ distribution. Results conclude with no substantial mean spillover effects, except for Germany and Sweden. Furthermore, the hypothesis of volatility spillover surpasses mean spillover effects, which implies weak mean spillover effects but pronounced volatility spillovers in the case of US and GIIPS countries to European equity markets aforementioned.

Table 5.1.6:

Pre-Crisis Wald Test
This table provides the robust joint Wald test for the null hypothesis of no spillover effects from US and GIIPS.

	Wald$_1$	**Wald$_2$**	**Wald$_3$**	**Wald$_4$**
DE	1277.916***	508.883***	9.144***	1476.684***
	(0.000)	(0.000)	(0.010)	(0.000)
FR	2813.514***	1299.588***	1.235	3738.840***
	(0.000)	(0.000)	(0.539)	(0.000)
NL	1356.500***	388.098***	0.807	1598.572***
	(0.000)	(0.000)	(0.667)	(0.000)
UK	649.372***	212.353***	0.326	671.025***
	(0.000)	(0.000)	(0.849)	(0.000)
SE	1408.826***	251.669***	9.648***	1478.398***
	(0.000)	(0.000)	(0.008)	(0.000)
CH	698.777***	333.561***	1.807	846.713***
	(0.000)	(0.000)	(0.405)	(0.000)

Note: The test statistic is performed under $\chi^2(2)$ distribution. p-values are expressed in parentheses. ***, **,* represents the levels of significance at 0.01, 0.05 and 0.10. US, United States; GIIPS, aggregate index Greece, Italy, Ireland, Portugal, Spain; DE, Germany; FR, France; NL, Netherlands; UK, United Kingdom; SE, Sweden; CH, Switzerland.

$H_0^1 : \gamma_i = \varphi_i = 0$
$H_0^2 : \delta_i = \psi_i = 0$
$H_0^3 : \gamma_i = \delta_i = 0$
$H_0^4 : \varphi_i = \psi_i = 0$

The robust Wald Tests null hypothesis for the pre-crisis period indicates the following: no US spillover effects (H_0^1), no GIIPS spillover effects (H_0^2), no mean spillover effects (H_0^3), and finally, no volatility spillover effects(H_0^4).

Moreover, the Subprime Crises have been analysed and results can be found in Table 5.1.7. The second sub period spans from 9th August 2007 to 22nd April 2010. For further support, table 5.1.8 presents the results for the same four hypothesis mentioned previously but in this time frame, which allows the coefficients to vary.

In this second part, strong GIIPS mean and volatility effects were encountered for almost all the countries of the Eurozone (Germany and Netherlands). It seems straightforward, since they are part of the Euro area. Not only that, the null hypothesis of no US spillover effect and GIIPS spillover effect is strongly rejected for each and every country. Not significant first order autocorrelation.

Also in this sub period, the volatility spillover contagion is much more powerful that mean contagion from US and GIIPS.

Table 5.1.7:

Subprime Crises Unconditional Spillover Model Coefficient Estimates
This table exhibits the estimated coefficients for the unconditional spillover model during the Global Financial Crises period, denoted as Subprime Crises. The data spans from August 2007 to April 2010. The sample is organized on a weekly basis, which contains 294 observations for each countries' series. γ is the mean spillover effect from the US to regional markets, δ is the mean spillover effect from GIIPS to regional markets, φ is the constant volatility spillover effects from the US to regional markets and ψ is the constant volatility spillover effects from the GIIPS to regional markets.

	DE	FR	NL	UK	SE	CH
γ	-0.036	0.074	0.143**	0.177**	0.098	0.109
	(0.590)	(0.154)	(0.027)	(0.030)	(0.315)	(0.123)
δ	-0.239***	-0.119	-0.187*	0.001	-0.037	0.059
	(0.010)	(0.159)	(0.055)	(0.985)	(0.725)	(0.386)
φ	1.067***	1.164***	1.169***	1.018***	1.278***	0.743***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
ψ	0.845***	0.832***	0.827***	0.568***	0.731***	0.504***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)

Note: p-values are denoted in parentheses. ***,**,* represents the levels of significance at 0.01, 0.05 and 0.10. US, United States; GIIPS, aggregate index Greece, Italy, Ireland, Portugal, Spain; DE, Germany; FR, France; NL, Netherlands; UK, United Kingdom; SE, Sweden; CH, Switzerland.

Table 5.1.8:

Subprime Crises Wald Test
This table provides the robust joint Wald test for the null hypothesis of no spillover effects from US and GIIPS.

	Wald$_1$	**Wald$_2$**	**Wald$_3$**	**Wald$_4$**
DE	1206.043***	1606.529***	8.918**	2752.062***
	(0.000)	(0.000)	(0.012)	(0.000)
FR	5741.650***	874.855***	5.266*	6038.043***
	(0.000)	(0.000)	(0.072)	(0.000)
NL	747.628***	277.885***	9.822*	1208.754***
	(0.000)	(0.000)	(0.007)	(0.000)
UK	323.623***	123.466***	4.709*	443.866***
	(0.000)	(0.000)	(0.094)	(0.000)
SE	483.045***	159.507***	1.086	575.756***
	(0.000)	(0.000)	(0.581)	(0.00)
CH	491.770***	170.259***	4.169	412.642***
	(0.000)	(0.000)	(0.124)	(0.00)

Note: The test statistic is performed under $\chi^2(2)$ distribution. p-values are expressed in parentheses. ***, **,* represents the levels of significance at 0.01, 0.05 and 0.10. US, United States; GIIPS, aggregate index Greece, Italy, Ireland, Portugal, Spain; DE, Germany; FR, France; NL, Netherlands; UK, United Kingdom; SE, Sweden; CH, Switzerland.

Note the following:

$H_0^1 : \gamma_i = \varphi_i = 0$

$H_0^2 : \delta_i = \psi_i = 0$

$H_0^3 : \gamma_i = \delta_i = 0$

$H_0^4 : \varphi_i = \psi_i = 0$

The same four hypothesis have been computed for the Subprime crisis period: No US spillover effects (H_0^1), no GIIPS spillover effects (H_0^2), no mean spillover effects (H_0^3), and finally, no volatility spillover effects(H_0^4).

Finally, the third sub-sample constitutes the Eurozone Sovereign Debt Crisis, and the data spans from 23rd April 2010 to 31st December 2014 [please see table 5.1.9]. Interestingly, half of the countries show significant mean-spillover, which are France, Netherlands and Sweden. These two EMU countries provide significant and positive lagged US return and the contemporary US idiosyncratic shock. In the case of Switzerland the coefficient of the lagged US return is significant but negative at 5% significance level. GIIPS mean and volatility spillover are found only in the Netherlands at 5% significance level.

Indeed, Wald test concludes with the same results, and results can be found in table 5.1.10. The null hypothesis of the jointly test for no significant US spillover in strongly rejected under 1% significance level, and also the GIIPS volatility spillover.The null hypothesis of the joint no mean spillover effects is rejected in the case of the Netherlands, France and Sweden. In the case of Sweden, the null hypothesis is rejected at 5% level. Again, the null hypothesis of volatility spillover is rejected for all the countries, implying a higher relevance of volatility-spillover effects than mean-spillovers.

Table 5.1.9:

Eurozone Sovereign Debt Crises (ESDC) Unconditional Spillover Model coefficient estimates

This table presents the estimated coefficients for the unconditional spillover model during the ESDC period. The data spans from April 2010 to December 2014. The sample is organized on a weekly basis, which contains 246 observations for each countries' series. γ is the mean spillover effect from the US to regional markets, δ is the mean spillover effect from GIIPS to regional markets, φ is the constant volatility spillover effects from the US to regional markets and ψ is the constant volatility spillover effects from the GIIPS to regional markets.

	DE	FR	NL	UK	SE	CH
γ	-0.008	0.021***	0.143**	0.080	0.119	0.128
	(0.908)	(0.000)	(0.027)	(0.242)	(0.250)	(0.048)
δ	0.001	0.016	-0.187*	0.033	0.093*	-0.009
	(0.996)	(0.686)	(0.055)	(0.320)	(0.055)	(0.824)
φ	1.187***	1.199***	1.169***	1.00***	1.212***	0.738***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
ψ	0.466***	0.628***	0.827***	0.270***	0.333***	0.311****
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)

Note: p-values are denoted in parentheses. ***,**,* represents the levels of significance at 0.01, 0.05 and 0.10. US, United States; GIIPS, aggregate index Greece, Italy, Ireland, Portugal, Spain; DE, Germany; FR, France; NL, Netherlands; UK, United Kingdom; SE, Sweden; CH, Switzerland.

Table 5.1.10:

Eurozone Sovereign Debt Crises Wald Test
This table provides the robust joint Wald test for the null hypothesis of no spillover effects from US and GIIPS during the ESDC sub-period.

	Wald$_1$	**Wald$_2$**	**Wald$_3$**	**Wald$_4$**
DE	1270.280***	208.887***	0.014	1639.869***
	(0.000)	(0.000)	(0.993)	(0.000)
FR	137.738***	1674.995***	201307***	1397697***
	(0.000)	(0.000)	(0.000)	(0.000)
NL	747.628***	277.885***	9.822***	1208.754***
	(0.000)	(0.000)	(0.007)	(0.000)
UK	706.634***	86.569***	2.664	1115.447***
	(0.000)	(0.000)	(0.264)	(0.000)
SE	520.431***	79.197***	6.355**	836.946
	(0.000)	(0.000)	(0.042)	(0.000)
CH	332.762***	114.805***	4.250	518.109***
	(0.000)	(0.000)	(0.119)	(0.000)

Note: The test statistic is performed under $\chi^2(2)$ distribution. p-values are expressed in parentheses. ***, **,* represents the levels of significance at 0.01, 0.05 and 0.10. US, United States; GIIPS, aggregate index Greece, Italy, Ireland, Portugal, Spain; DE, Germany; FR, France; NL, Netherlands; UK, United Kingdom; SE, Sweden; CH, Switzerland.

Note the following:
$H_0^1 : \gamma_i = \varphi_i = 0$
$H_0^2 : \delta_i = \psi_i = 0$
$H_0^3 : \gamma_i = \delta_i = 0$
$H_0^4 : \varphi_i = \psi_i = 0$
The same four hypothesis have been computed for the Eurozone Sovereign Debt crisis period: No US spillover effects (H_0^1), no GIIPS spillover effects (H_0^2), no mean spillover effects (H_0^3), and no volatility spillover effects(H_0^4).

5.2 Asymmetric Spillover Specification

This section covers the analysis of asymmetric spillovers in the six powerful European stock markets. The asymmetric extension of the GARCH (1,1) model refers to the 4.5, followed by Ng (2000) and Glosten et al. (1993). Table 5.2.1 provides the results for the full sample period for the six European stock markets under consideration.

It is commonly believed that negative return shocks imply higher volatility than positive contemporary residuals of the same magnitude, which may show that the covariance is asymmetric. Ng (2000) concludes that if the cause of the asymmetric effect is the existence of leverage effect, then a modification to the leverage of the firm will modify the covariance of other entities and its own.

In the case of the eurozone countries, asymmetric effects can be found. Results suggest positive and significant coefficient for $R_{US,t-1}$ for the three EMU countries. For example, in Germany the magnitude of γ_2 for (0.093) (p=0.00) is larger than γ_1 (0.017) (p=0.371) which suggests a downturn in the US stock market to have a larger impact in Germany market than a positive shock of an equal magnitude. A similar scenario is found in the case of the Netherlands, where the size of the US one-period negative lagged return is significant and bigger than the US one-period positive lagged return. So, here we give further evidence about the existence of asymmetries.

Moreover, all the three EMU countries have significant positive and negative contemporary residuals in the US market. Indeed, the size of all the three euro countries present a larger $\varphi_{2,i}$ than a $\varphi_{1,i}$, which corresponds to the case in which the investor reacts more strongly to a negative shock than a positive shock of equal size either on the the US or GIIPS market. The coefficient for $\psi_{2,i}$ is bigger than $\psi_{1,i}$.

In the case of the three non-EMU countries, asymmetric spillovers are found. Interestingly, the aforementioned countries present significant US positive lagged returns, which means that the investor reacts more strongly to an increase in the US market than to a decrease of the same size in the US equity market. However, evidence is found for the existence of asymmetric responses of negative and positive from US and GIIPS stock markets. Also, greater reactions to US and GIIPS bad news are found in comparison to positive news of equal size. The size of φ_2 is larger than the size of φ_1.

Table 5.2.1:

Asymmetric Spillover Model Coefficient Estimates
This table reports the coefficient estimates of the asymmetric spillover model with the whole sample period, from January 2002 to December 2014. γ^1 and γ^2 are the positive and negative mean spillover effects from US; , δ^1 and δ^2 are the positive and negative mean spillover effects from GIIPS; φ^1 and φ^2 are the positive and negative shocks from US; ψ^1 and ψ^2 are the positive and negative shocks from GIIPS.

	DE	**FR**	**NL**	**UK**	**SE**	**CH**
γ_1	0.017	0.057	0.113**	0.108	0.297**	0.140
γ_2	0.093***	0.056***	0.192***	0.122	-0.002	0.049
δ_1	0.022	0.091	0.050	0.052	0.081	-0.015
δ_2	-0.031	0.054	-0.058	-0.059	0.055	0.013
φ_1	1.159***	1.143***	1.145***	0.863***	1.067***	0.742***
φ_2	1.280***	1.224***	1.271***	1.035***	1.328***	0.849***
ψ_1	0.667***	0.743***	0.599***	0.462***	0.532***	0.480***
ψ_2	0.704***	0.738***	0.673***	0.446***	0.618***	0.442***

Note: p-values are expressed in parentheses. ***, **,* represents the levels of significance at 0.01, 0.05 and 0.10. US, United States; GIIPS, aggregate index Greece, Italy, Ireland, Portugal, Spain; DE, Germany; FR, France; NL, Netherlands; UK, United Kingdom; SE, Sweden; CH, Switzerland.

Table 5.2.2 reports the results of the robust Wald test for the asymmetric spillover model for the full sample period. The Wald test is computed with $\chi^2(1)$ statistic.

The robust joint Wald test supports the existence of asymmetries to US shocks, so the null hypothesis of no asymmetries is strongly rejected for all the countries outside Eurozone, except for the case of Switzerland. Indeed, Sweden shows large response to the downturn of the US equity market, where the null hypothesis of H_0^1: $\gamma_1 = \gamma_2$ is rejected under 5% significance level. Subsequently, the robust joint Wald test has been performed for the three euro area countries [see table 5.2.2 for reference]. The null hypothesis of no significant asymmetries to GIIPS shocks is not rejected under 5% significance level.

These results suggest the stronger impact of global shocks on outside eurozone markets, whereas the euro area countries display a larger effect of regional shocks on their markets.

Table 5.2.2:

Asymmetric Spillover Model Wald Test
This table offers the robust joint Wald test of the null hypothesis of no asymmetric spillover effects from US and GIIPS to the countries under consideration for the whole sample period.

	Wald$_1$	**Wald$_2$**	**Wald$_3$**	**Wald$_4$**
DE	0.7962	0.798	2.623	0.240
	(0.372)	(0.372)	(0.105)	(0.624)
FR	0.001	0.710	2.195	0.008
	(0.984)	(0.400)	(0.138)	(0.927)
NL	15.880***	3.265*	2.864*	0.977
	(0.001)	(0.070)	(0.091)	(0.322)
UK	0.027	3.619*	5.654**	0.045
	(0.868)	(0.057)	(0.017)	(0.831)
SE	6.672***	0.099	6.604***	0.721
	(0.010)	(0.753)	(0.010)	(0.395)
CH	1.092	0.220	1.943	0.248
	(0.295)	(0.640)	(0.163)	(0.620)

The test statistic is performed under $\chi^2(1)$ distribution. p-values appear in parentheses. ***, **,* represents the levels of significance at 0.01, 0.05 and 0.10. US, United States; GIIPS, aggregate index Greece, Italy, Ireland, Portugal, Spain; DE, Germany; FR, France; NL, Netherlands; UK, United Kingdom; SE, Sweden; CH, Switzerland.

Note the following:

H_0^1: $\gamma_1 = \gamma_2$

H_0^2: $\delta_1 = \delta_2$

H_0^3: $\varphi_1 = \varphi_2$

H_0^4: $\psi_1 = \psi_2$

The Wald Test englobes the following null hypotheses: no asymmetric effects with respect to US one period lagged returns (H_0^1), no asymmetric effects to GIIPS one period lagged returns (H_0^2), no asymmetric effect to US shocks (H_0^3), and finally, no asymmetric effects to GIIPS shocks(H_0^4).

5.3 Time varying Spillover Model

This final section focuses on the conditional spillover model, where the spillover parameters are allowed to vary freely over time. The scope is to analyze the time-varying repercussions of the US and GIIPS parameters on volatility. In the equation 4.5, three economic instruments are included: exchange rate changes, ratio trade to GDP and foreign direct investment to GDP (Asgharian and Nossman, 2013; Ng, 2000; Liu, 2007). Table 5.3.1 displays the results for the US and GIIPS time-varying spillover parameters.

On one hand, the results for the EMU countries parameters show the importance of the trade variable on mean spillover from US, except for France. For both Germany and the Netherlands the mean spillover from US is positively related to the variable trade. In contrast, GIIPS mean spillover seems to be explained by something else than the suggested information variables, which are exchange rate change, trade/GDP and FDI/GDP. Furthermore, the parameters estimation for all the three euro area countries under study allege that the GIIPS influence on volatility appears to be more significant when the size of the foreign direct investment increases. Also, there is evidence that the impact of the US on the euro area volatility becomes more relevant when the local currency appreciates. However, mean spillover from GIIPS is generally found to be dependent on some other factors rather than foreign direct investment.

On the other hand, the three non-EMU countries are studied. Interestingly, on average these countries are more influenced by the US factors than the news from the GIIPS countries. Indeed, Swiss mean and volatility spillovers from GIIPS are not significant at any meaningful level for any information variable. To contrast, the fluctuations of the volatility spillover from US seem to be dependent on the exchange rate change, under 5% significance level.

The case of United Kingdom differs to the one of Switzerland. The output of the results considers mean and volatility spillover from US to be strongly related to the exchange rate change. Indeed, the effect of the mean spillover from US to the UK equity market heightens when the local currency depreciates, while an increase in the local currency enhances the US influence on volatility.

In Sweden, the mean spillover from GIIPS is found to be driven on some other information variables rather than exchange rate change, the ratio of trade to GDP and the ratio of FDI to GDP under 10% significance level. A similar scenario is presented for UK and Sweden regarding the Volatility GIIPS spillover, in which the ratio of the variable trade to GDP and the ratio of FDI to GDP are significant under 5% significance level. Also, the effect of the GIIPS on these two aforementioned countries appear to be positive.

The robust joint Wald test is performed. Results are expounded in Table 5.3.2. The joint Wald test gives further evidence of the significance of the information variables included in the conditional spillover model to explain the mean and volatility spillover from US and GIIPS in the countries under consideration.

To investigate the relevance of the GIIPS and US markets shocks on volatility, the variance ratios of the US and GIIPS volatility in the European country have been computed. Table 5.3.3 provides the summary statistics of the Variance ratios and Figure A.2.5 plots the time-series for the variance ratios.

The figures give a very clear picture of the scenario. The six European equity markets analyzed are highly dependent on the US shocks on volatility. Global factors appear to have relatively more influence than local shocks for the whole sample period, except for the case of the Netherlands and Switzerland. Indeed, in the early 2010, the GIIPS equity market experienced a significant upward trend, which can be directly related with the Eurozone Sovereign Debt Crisis that was taking place in the EMU region. On average, the variance proportion accounted by the US shock in the Netherlands is 0.598 while the average shock by the GIIPS market is just 0.221. However, the US relative importance on the Netherlands return volatility is weakening over time, and balancing.

In Germany, the influence of the US is clearly more significant than the GIIPS stock market on its return volatility. During the whole sample period, the US impact on average corresponds to a ratio of 0.599.

The return volatility in France is heavily driven by US factors, which is in line with the aforementioned results in the Conditional Model. This scenario may have been caused by the increasing degree of integration of the French market with global markets. On average, France accounts 0.602 influence by the US shock, and a very weak ratio of 0.001 of GIIPS influence. Also, pure local shock have an strong impact on the France volatility (0.395).

Furthermore, the three outside Eurozone countries have been meticulously analyzed. United Kingdom and Sweden follow a similar pattern to the one in Germany. The mean of the US variance proportion accounts for 0.578 of the United Kingdom volatility, and 0.539 for the case of Sweden. However, the GIIPS equity market relevance is just a 0.160 value on the United Kingdom market, and 0.170 on the Swedish market.

Switzerland also presents a higher dependence on US shocks than news from the GIIPS equity market. Not only that, the figure shows two significant spikes on the US factors in the beginning of the Subprime Crisis and the Eurozone Sovereign Debt Crisis. Followed by (Liu, 2007) it is interesting to explore the paths of the US and GIIPS Variance Ratios over time by analyzing the fluctuations of the parameters φ and ψ of the conditional model. If we compare the conditional model with the unconditional model, the US Variance ratios are almost invariable, while the GIIPS Variance Ratio have been changed, specially in the case of France. France presents a significant decrease on the US Variance Ratio, which is in line with the ψ parameter.

Table 5.3.1:

Time-Varying Spillover Model Coefficient Estimates
This table displays the market integration variables for each country series under study for the whole sample period. It exhibits three information variables for each US and GIIPS equity markets: Exchange Rate Change, Trade to Gross Domestic Product(GDP) and Foreign Direct Investment (FDI) to Gross Domestic Product (GDP).

		DE	FR	NL	UK	SE	CH
Mean Spillover From US	Constant	-0.534*	0.179	-0.340*	-0.064	0.290	0.104**
		(0.056)	(0.298)	(0.090)	(0.832)	(0.134)	(0.015)
	Exchange Rate Changes	-5.705***	-2.570**	-0.800	-4.000***	0.592	0.760
		(0.000)	(0.014)	(0.651)	(0.004)	(0.691)	(0.448)
	trade/GDP	15.243**	-3.282	6.752**	1.839	-4.341	1.038
		(0.021)	(0.608)	(0.029)	(0.801)	(0.399)	(0.667)
	FDI/GDP	-3.325	-4.520*	-0.092	0.313	2.008**	0.570
		(0.481)	(0.079)	(0.783)	(0.260)	(0.049)	(0.702)
Mean Spillover From GIIPS	Constant	0.159***	0.075	0.074	0.312**	-0.122	-0.007
		(0.000)	(0.438)	(0.684)	(0.015)	(0.417)	(0.965)
	Exchange Rate Changes	-	-	-	-2.037	0.998	1.166
		(-)	(-)	(-)	(0.147)	(0.604)	(0.447)
	trade/GDP	-2.476	-0.986	-0.983	-5.869**	4.936	-0.144
		(0.220)	(0.383)	(0.587)	(0.025)	(0.197)	(0.926)
	FDI/GDP	1.140	3.408	-0.201	-0.243	1.343	3.519
		(0.659)	(0.112)	(0.530)	(0.329)	(0.488)	(0.598)
Volatility Spillover From US	Constant	1.164***	1.159***	1.751***	0.862***	1.013***	0.994***
		(0.000)	(0.000)	(0.000)	(0.002)	(0.000)	(0.000)
	Exchange Rate Changes	0.497	3.777***	4.121***	3.656**	2.155	2.724*
		(0.643)	(0.000)	(0.000)	(0.029)	(0.160)	(0.058)
	trade/GDP	1.089	-1.484	-9.300***	0.229	5.456	-2.597
		(0.821)	(0.799)	(0.000)	(0.971)	(0.134)	(0.372)
	FDI/GDP	4.278	6.813***	0.496	0.462*	2.665**	-2.398
		(0.274)	(0.006)	(0.496)	(0.088)	(0.037)	(0.218)
Volatility Spilover From GIIPS	Constant	0.173	0.544***	0.763***	-0.152	-0.458**	0.334*
		(0.346)	(0.000)	(0.001)	(0.329)	(0.004)	(0.091)
	Exchange Rate Changes	-	-	-	1.603	3.382*	0.670
		(-)	(-)	(-)	(0.393)	(0.083)	(0.709)
	trade/GDP	6.091**	0.980	-1.724	9.091***	27.271***	1.491
		(0.017)	(0.476)	(0.482)	(0.004)	(0.000)	(0.484)
	FDI/GDP	12.380***	14.478***	0.813*	1.708***	-5.778**	-4.368
		(0.000)	(0.000)	(0.052)	(0.000)	(0.029)	(0.601)

Note: p-values are denoted in parentheses. ***,**,* represents the levels of significance at 0.01, 0.05 and 0.10. US, United States; GIIPS, aggregate index Greece, Italy, Ireland, Portugal, Spain; DE, Germany; FR, France; NL, Netherlands; UK, United Kingdom; SE, Sweden; CH, Switzerland.

Table 5.3.2:

Time-Varying Spillover Model Wald Test
This table tests the joint hypothesis of the null hypothesis of no conditional spillover effects from US and GIIPS to each country i for the full sample period.

	Wald$_1$	**Wald$_2$**
DE	24.334***	1767.032***
	(0.002)	(0.000)
FR	7812.134***	1023.570***
	(0.000)	(0.000)
NL	81.939***	1143.725***
	(0.000)	(0.000)
UK	1677.104***	530.17757***
	(0.000)	(0.000)
SE	1656.155***	554.137***
	(0.000)	(0.000)
CH	1127.868***	570.000***
	(0.000)	(0.000)

Note: The test statistic is performed under $\chi^2(6)$ distribution for the EMU countries while $\chi^2(8)$ distribution is used for the non-EMU countries. p-values appear in parentheses. ***, **,* which indicates the level of significance at 0.01, 0.05 and 0.10. US, United States; GIIPS, aggregate index Greece, Italy, Ireland, Portugal, Spain; DE, Germany; FR, France; NL, Netherlands; UK, United Kingdom; SE, Sweden; CH, Switzerland.

Table 5.3.3:

Variance Ratios Summary Statistics
The table below displays the summary statistics of the variance ratios for the time-varying spillover model. The US and GIIPS proportions on the six equity markets are displayed. The data spans from January 2002 to December 2014.

		DE	**FR**	**NL**	**UK**	**SE**	**CH**
US	Mean	0.599	0.602	0.598	0.578	0.539	0.455
	Std. Dev.	0.117	0.127	0.126	0.120	0.124	0.138
GIIPS	Mean	0.225	0.001	0.221	0.160	0.170	0.192
	Std. Dev.	0.095	0.001	0.094	0.090	0.087	0.082
Country i	Mean	0.175	0.395	0.179	0.260	0.290	0.351
	Std. Dev.	0.073	0.128	0.072	0.098	0.111	0.104

US, United States; GIIPS, aggregate index Greece, Italy, Ireland, Portugal, Spain; DE, Germany; FR, France; NL, Netherlands; UK, United Kingdom; SE, Sweden; CH, Switzerland.

6
Conclusion

This research paper explores the relevance of the spillover and volatility effects from US and aggregate GIIPS equity markets to the largest six European equity markets. The empirical methodology used is a three step univariate volatility spillover model followed by Christiansen (2007) and Ng (2000) to analyze the relevance of global shocks (US), regional shocks (GIIPS) and local shocks (own country), among the equity markets under consideration. In fact, I test for mean and volatility spillovers from US and GIIPS markets and explore signs of asymmetry. Extensive prior work reveals that a negative purely idiosyncratic shock accounts for a higher volatility, which subsequently leads to a higher return volatility than a positive shock of equal magnitude.

Evidence shows that both regional and global shocks are relevant for the European equity markets volatility, but global factors tend to have a greater impact. Also, the results point out that for the pre-crisis subsample, there exists strong evidence of both US mean-spillover and volatility-spillover effects, but weak evidence of GIIPS mean-spillover effect is found for the six powerful European countries analyzed. In contrast, in the Subprime crisis sample, the Eurozone countries suffer from a strong GIIPS mean and volatility spillover effects, whereas the null hypothesis of no significant mean spillovers have not been rejected for any country outside the eurozone region. Indeed, a stronger impact of global shocks on outside eurozone markets can be found, whereas the euro area countries show larger effect of regional shocks on their markets. In the study of Eurozone Sovereign Debt Crisis, half of the countries under study show significant US mean and volatility spillovers.

The results suggest the existence of mean asymmetric effects for the three eurozone countries aforementioned. Also, I found investors to react more sharply to US and GIIPS bad news in each individual European market than a positive shock of equal size.

The final section presents the Conditional Spillover model, and results suggest the relevance of the information variables included in the conditional spillover model to explain the mean and volatility spillover from US and GIIPS in the countries under consideration. Examples include the importance of the ratio trade/GDP on mean spillover from US in the EMU countries. Further research urges the analysis of the Contagion and Spillover effect in the new BREXIT scenario, which already presents many additional challenges.

A
Appendix

A.1 Tables

Table A.1.1:

Granger Causality Test
This table shows the Causality test, which have been performed using R-program. The test have been computed with stationary data.

	DE	**FR**	**NL**	**UK**	**SE**	**CH**	**US**	**GIIPS**
DE	N/A	0.430	0.871	0.390	0.020*	0.756	0.238	0.965
FR	0.087*	N/A	0.168	0.632	0.163	0.388	0.099*	0.774
NL	0.512	0.567	N/A	0.295	0.133	0.380	0.094*	0.784
UK	0.134	0.580	0.263	N/A	0.835	0.303	0.041*	0.476
SE	0.252	0.866	0.150	0.835	N/A	0.309	0.361	0.772
CH	0.840	0.561	0.978	0.470	0.255	N/A	0.253	0.544
US	0.101	0.059	0.007*	0.002*	0.004*	0.046	N/A	0.251
GIIPS	0.545	0.630	0.671	0.728	0.243	0.788	0.085*	N/A

Note: p-values are denoted in parentheses. ***,**,* represents the levels of significance at 0.01, 0.05 and 0.10. US, United States; GIIPS, aggregate index Greece, Italy, Ireland, Portugal, Spain; DE, Germany; FR, France; NL, Netherlands; UK, United Kingdom; SE, Sweden; CH, Switzerland.

Table A.1.2:

Information Criteria Optimal Number of Lags
This table displays the Optimal number of lags selected by the Information criterion at 0.005 level.

Lag	AIC	SIC	HQC
0	-44.848	-44.794*	-44.827*
1	-44.939	-44.454	-44.751
2	-45.006*	-44.092	-44.652
3	-44.967	-43.621	-44.446
4	-44.932	-43.156	-44.244
5	-44.868	-42.662	-44.014
6	-44.837	-42.200	-43.815
7	-44.802	-41.734	-43.614
8	-44.729	-41.230	-43.374

* presents the lag order selected by the criterion in the VAR model.

Table A.1.3:

Augmented Dickey-Fuller (ADF) Test

Augmented Dickey-Fuller (ADF) Test				
	Index		**Return**	
Markets	**t-stat**	**p-value**	**t -stat**	**p-value**
DE	-1.012	0.751	-9.634	0.000
FR	-2.154	0.223	-5.636	0.000
NL	-1.931	0.320	-13.650	0.000
UK	-2.038	0.271	-5.906	0.000
SE	-1.229	0.663	-6.269	0.000
CH	-0.828	0.809	-29.103	0.000
US	0.454	0.985	-8.807	0.000
GIIPS	-1.949	0.309	-9.637	0.000

Table A.1.4:

Phillips Perron (PP) Test

Phillips Perron (PP) Test				
	Index		**Return**	
Markets	**t-stat**	**p-value**	**t -stat**	**p-value**
DE	-1.110	0.713	-28.475	0.000
FR	-1.846	0.358	-150.936	0.000
NL	-1.956	0.306	-28.148	0.000
UK	-1.696	0.432	-28.944	0.000
SE	-1.306	0.628	-30.147	0.000
CH	-0.852	0.803	-28.960	0.000
US	0.384	0.982	-27.965	0.000
GIIPS	-1.634	0.464	-27.664	0.000

Table A.1.5:

Autoregressive Conditional Heteroskedasticity (ARCH)Test

ARCH Test								
Markets	**DE**	**FR**	**NL**	**UK**	**SE**	**CH**	**US**	**GIIPS**
F-statistic	20.655	42.610	13.072	7.037	17.053	28.204	50.296	34.692
Prob. F-stat.	0.000	0.000	0.000	0.008	0.000	0.000	0.000	0.000
Obs*R-Squared	20.100	40.195	12.861	6.985	16.681	27.152	46.942	33.092
Prob. Chi-Square	0.000	0.000	0.000	0.008	0.000	0.000	0.000	0.000

The null hypothesis of homoskedasticity is rejected under 0.05 significance level.

Table A.1.6:

White Test

White Test								
Countries	**DE**	**FR**	**NL**	**UK**	**SE**	**CH**	**US**	**GIIPS**
F-statistic	21.790	20.023	8.960	11.220	5.548	16.883	32.386	7.769
Prob. F-stat.	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Obs*R-Squared	94.569	87.899	42.373	52.236	26.878	75.655	59.357	64.242
Prob. Chi-Squared	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

The null hypothesis of homoskedasticity is rejected under 0.05 significance level.

A.2 Figures

Figure A.2.1:

Equity Market Indices
This figure plots the market indices for each individual country. Note: US = United States; GIIPS = aggregate index Greece, Italy, Ireland, Portugal, Spain; DE = Germany; FR = France; NL = Netherlands; UK = United Kingdom; SE = Sweden; CH = Switzerland.

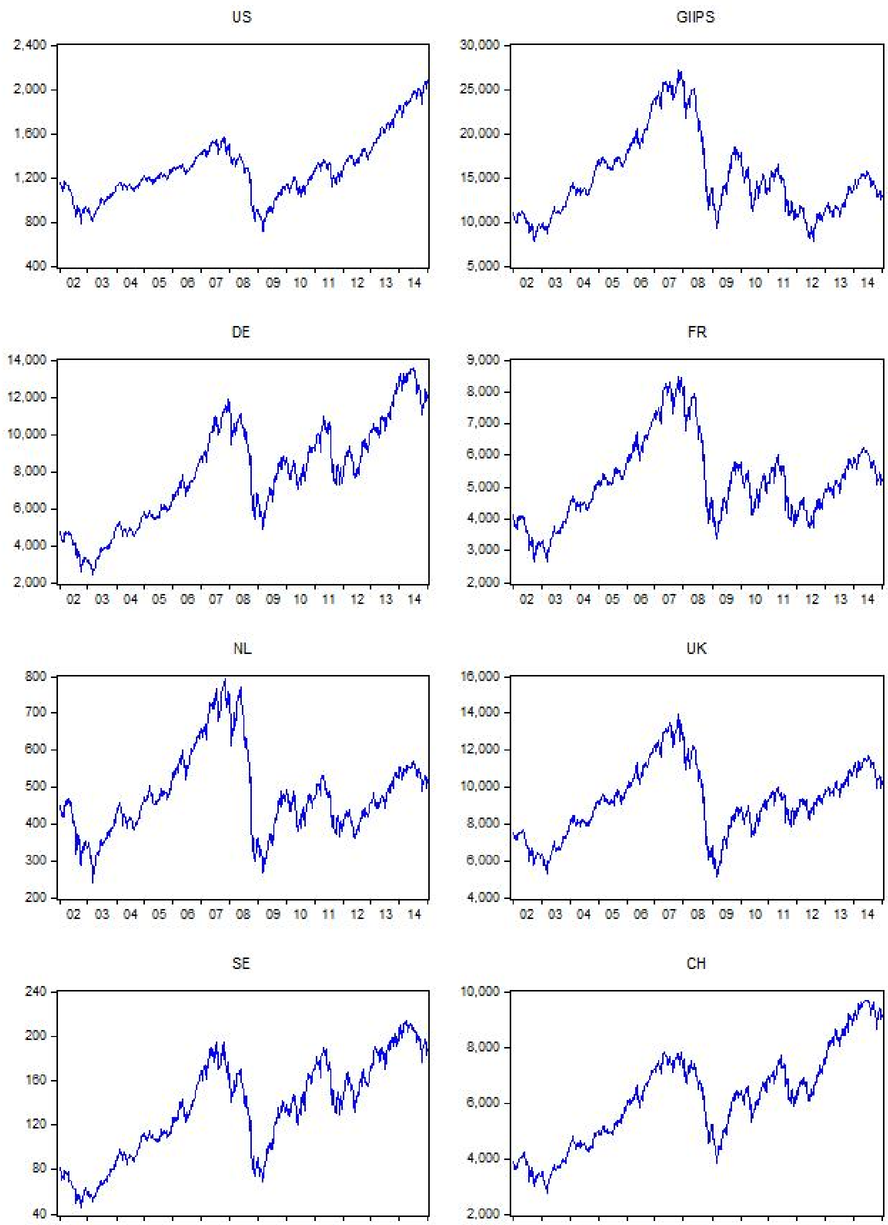


Figure A.2.2:

Return Series of the equity markets indices

This figure illustrates the returns series of the each individual equity market under study.Note: US = United States; GIIPS = aggregate index Greece, Italy, Ireland, Portugal, Spain; DE = Germany; FR = France; NL = Netherlands; UK = United Kingdom; SE = Sweden; CH = Switzerland.

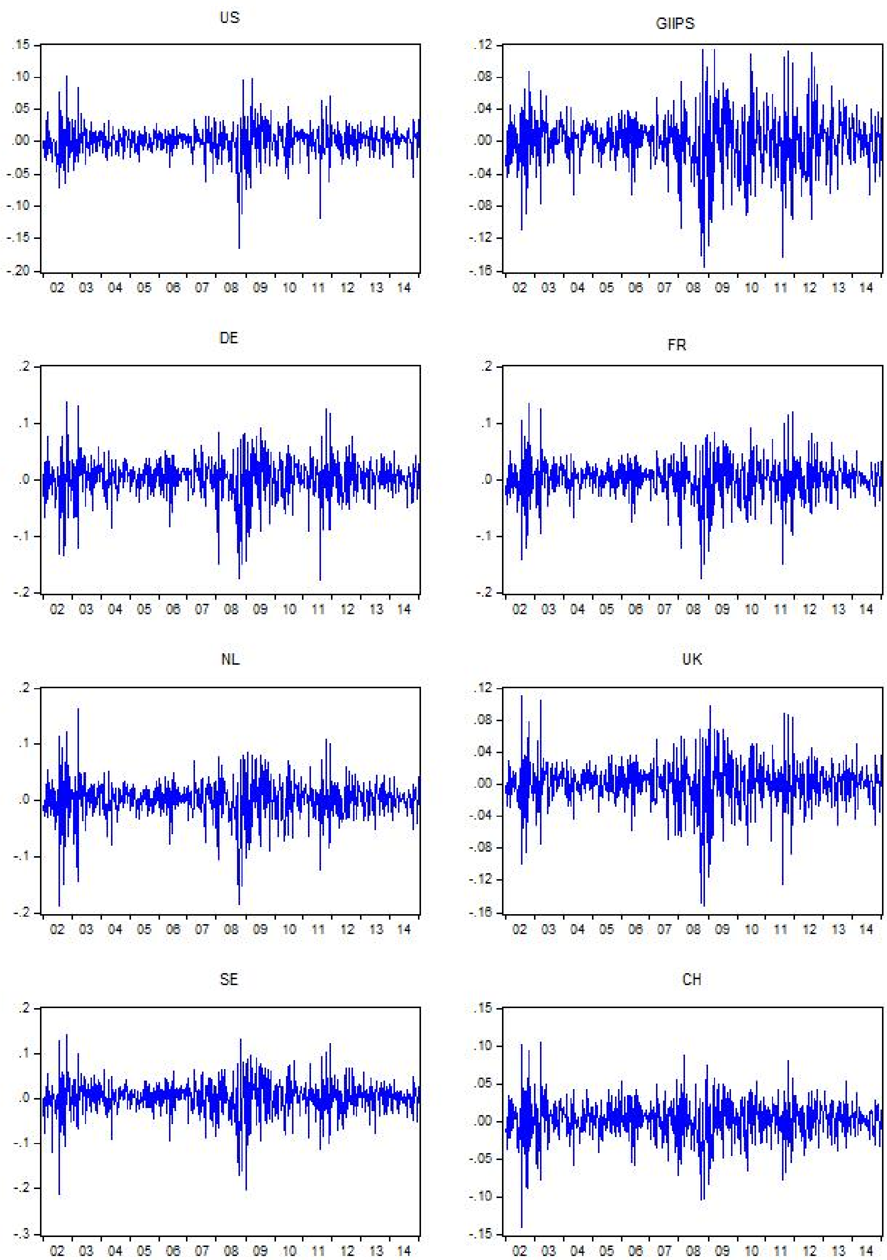


Figure A.2.3:

Squared Returns

The following figure plots the squared returns of the series.

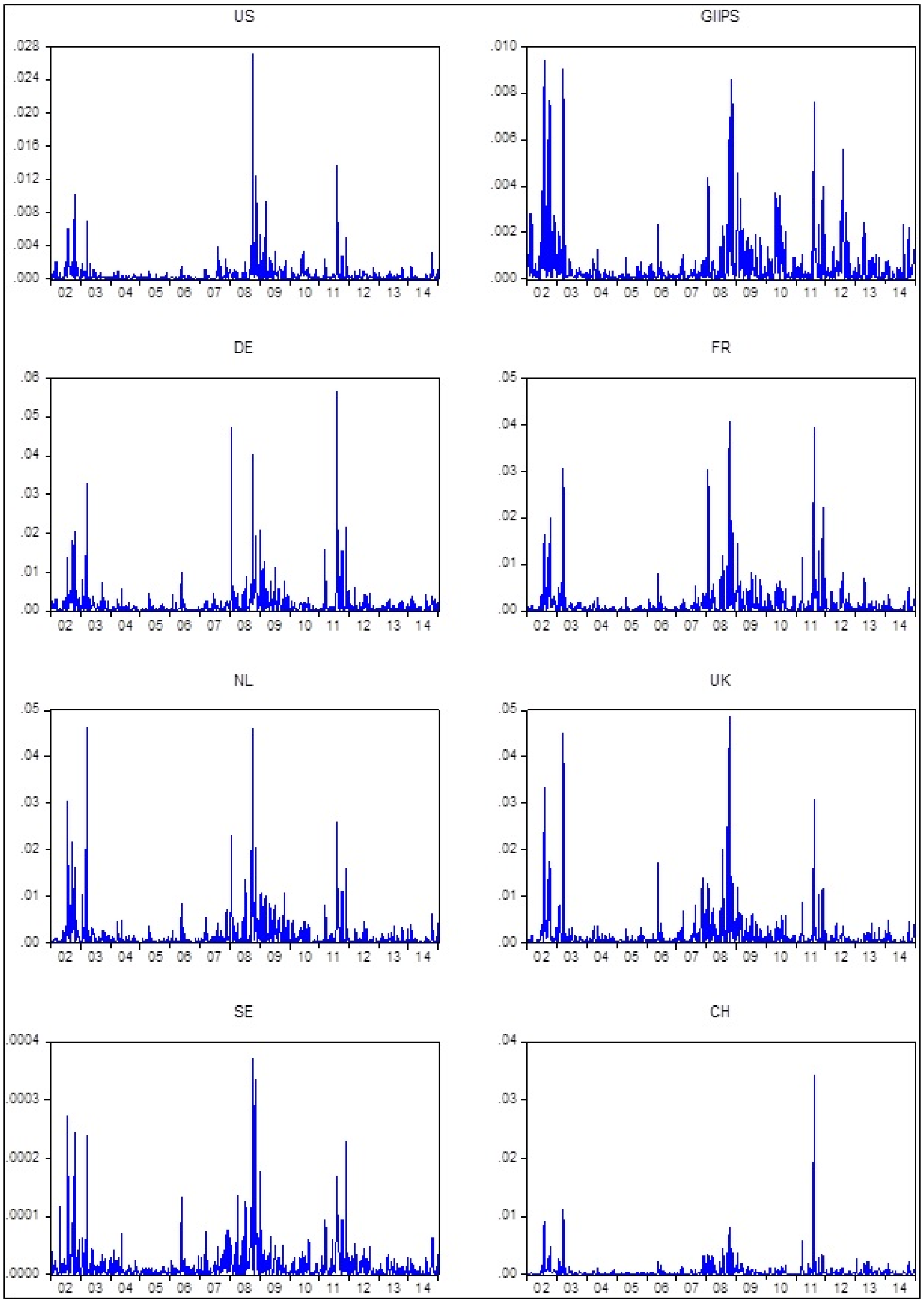
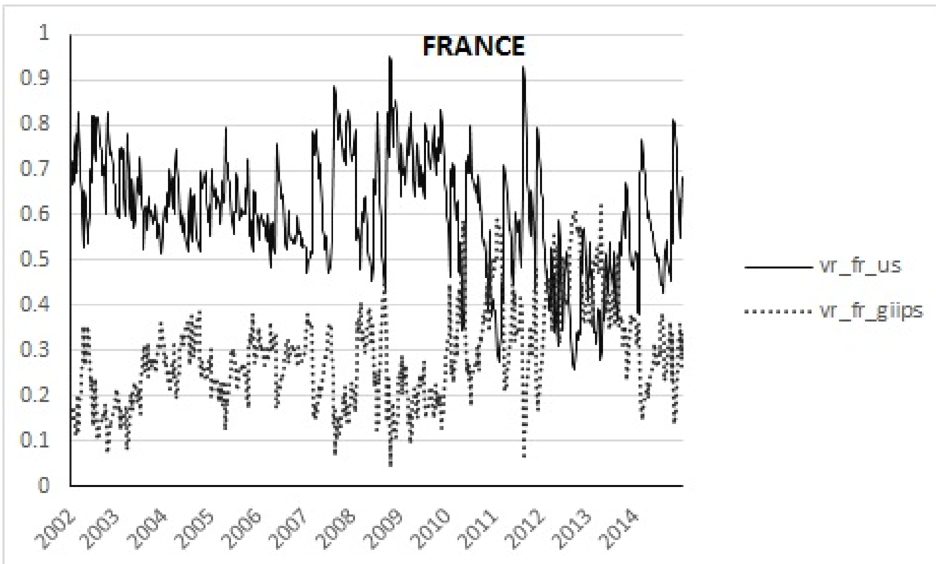


Figure A.2.4:

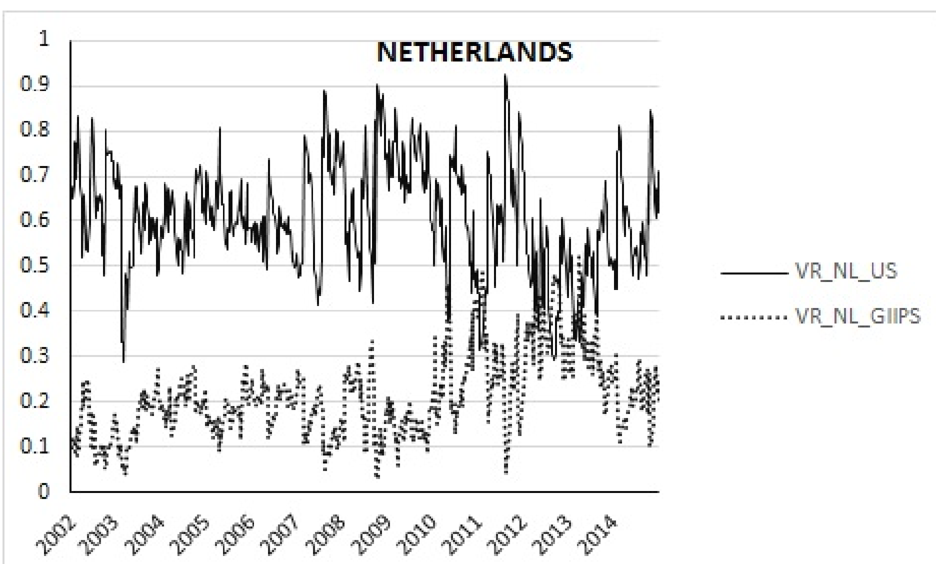
Unconditional Variance spillover model from the US and GIIPS

These figures represent the constant variance spillover effects from the US and GIIPS to regional and local equity markets. The variance spillover estimation follows Eq. 4.11 and Eq 4.12. , which are computed as $(\varphi^2_{i,t-1}\sigma^2_{US,t})$ and $(\gamma^2_{i,t-1}\sigma^2_{GIIPS,t})$. The data spans from January 2002 to December 2014 on a weekly basis, and with a total of 680 observations.

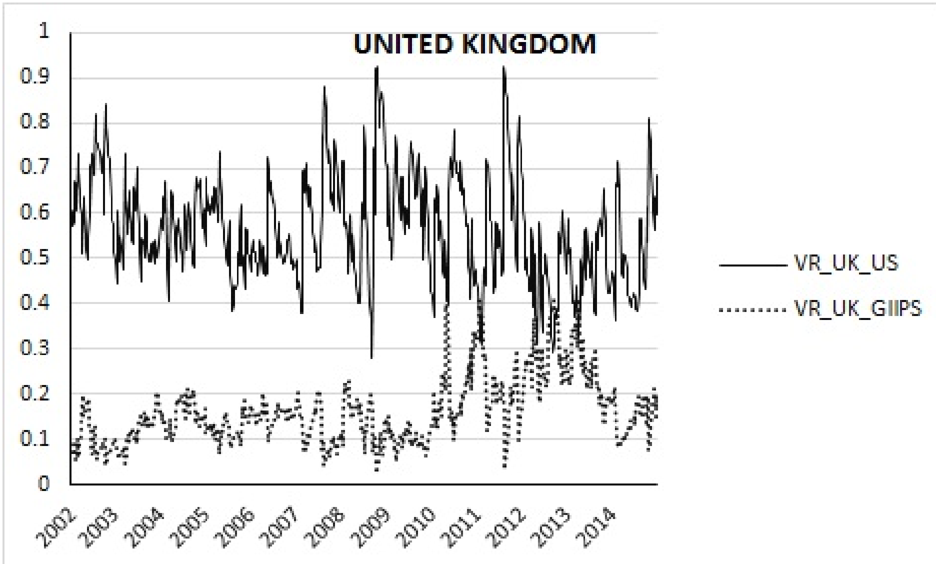
Unconditional Variance Spillover France



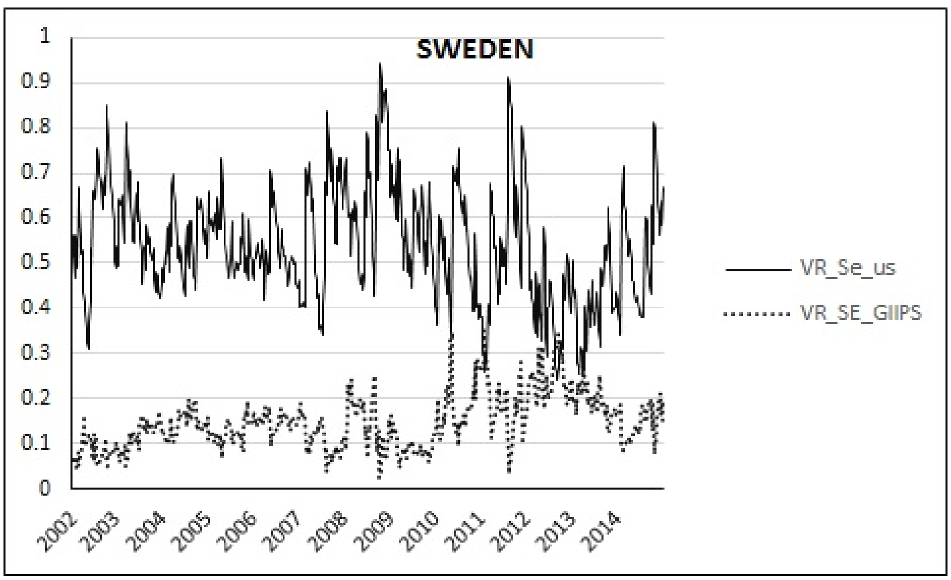
Unconditional Variance Spillover Netherlands



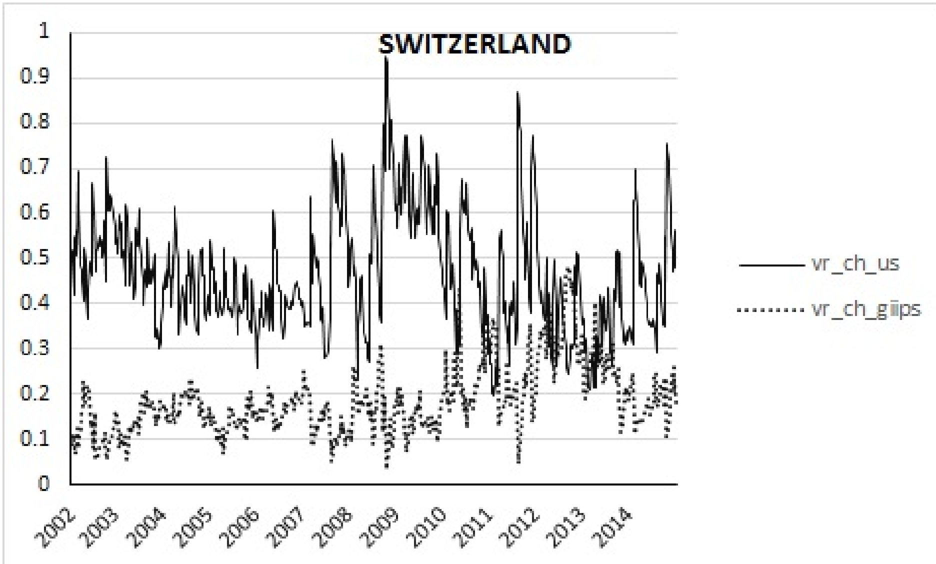
Unconditional Variance Spillover UK



Unconditional Variance Spillover Sweden



Unconditional Variance Spillover Switzerland



Unconditional Variance Spillover Germany

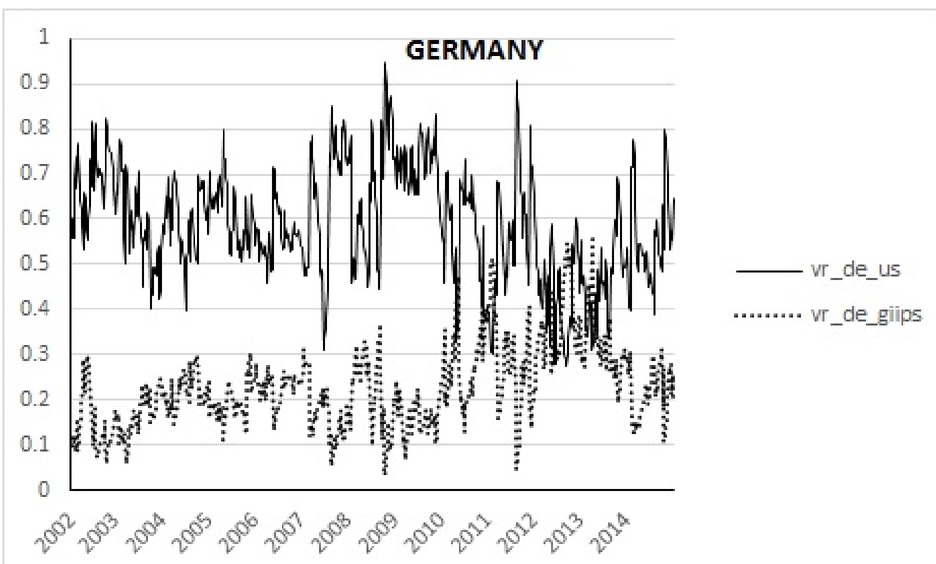
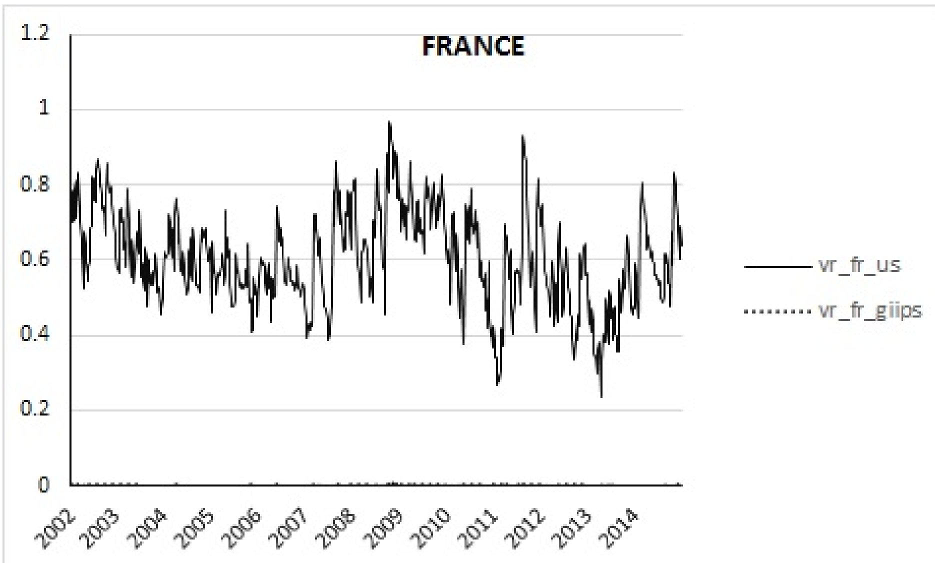


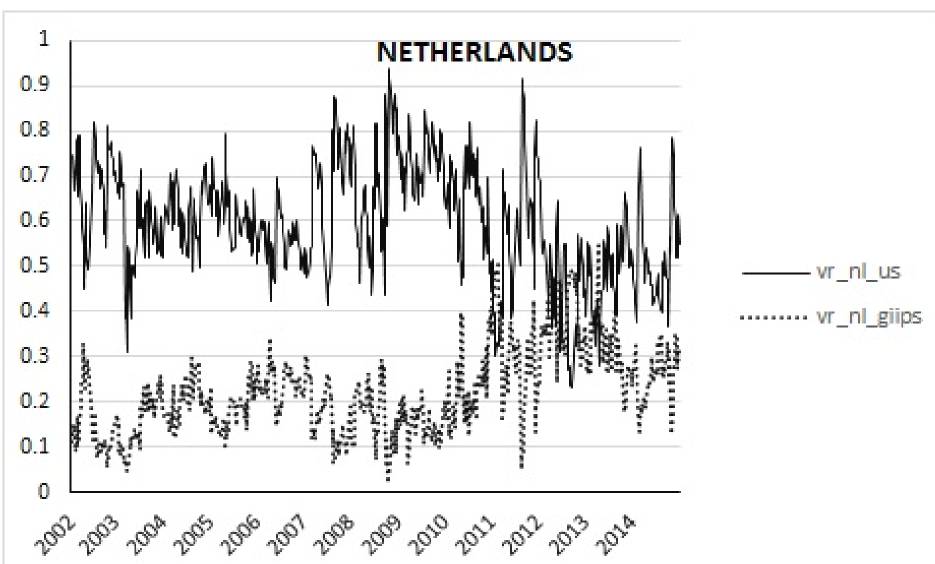
Figure A.2.5:

Variance spillover in the Time-Varying spillover model from the US and GIIPS
These figures represent the constant variance spillover effects from the US and GIIPS to regional and local equity markets. The variance spillover estimation follows Eq. 4.11 and Eq 4.12. , which are computed as $(\varphi^2_{i,t-1}\sigma^2_{US,t})$ and $(\gamma^2_{i,t-1}\sigma^2_{GIIPS,t})$. The data spans from January 2002 to December 2014 on a weekly basis, and with a total of 680 observations.

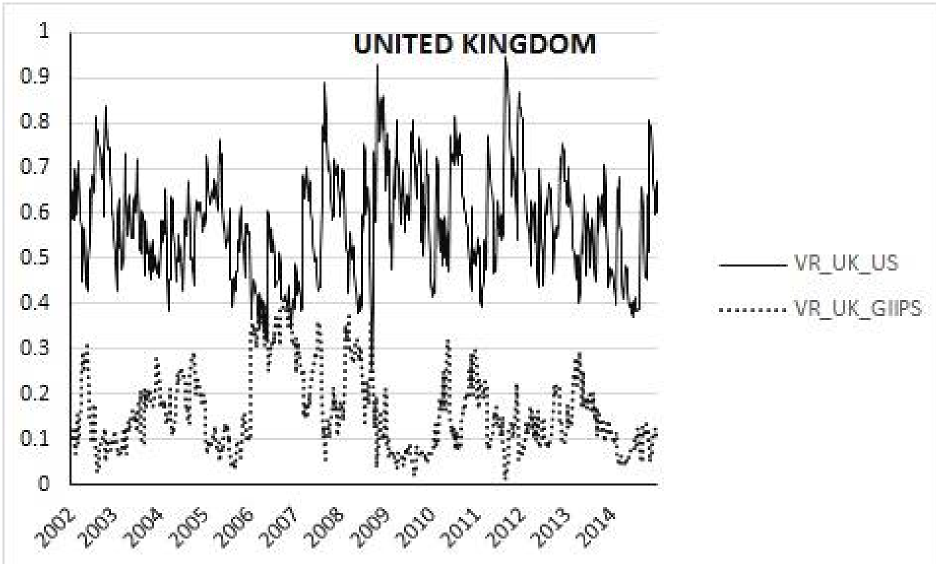
Conditional VR France



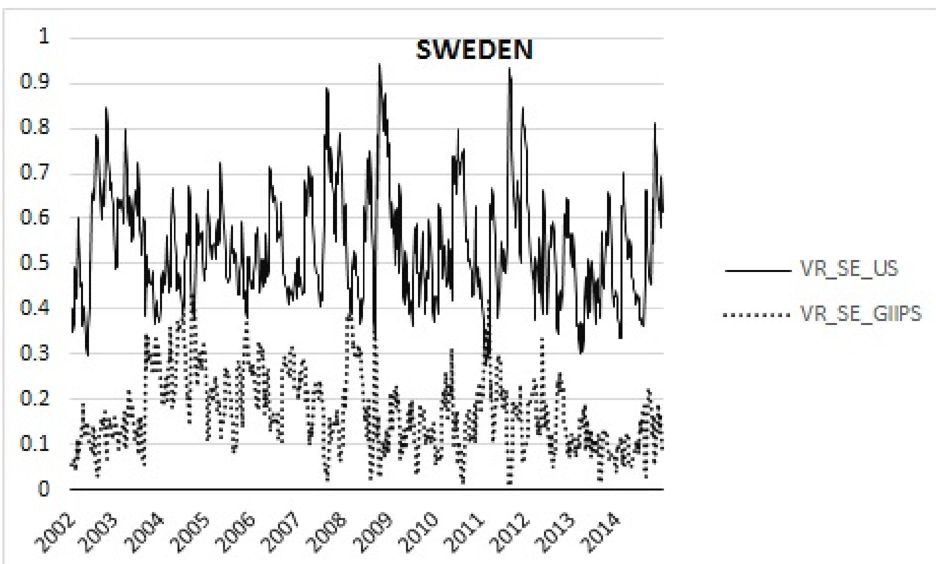
Conditional VR Netherlands



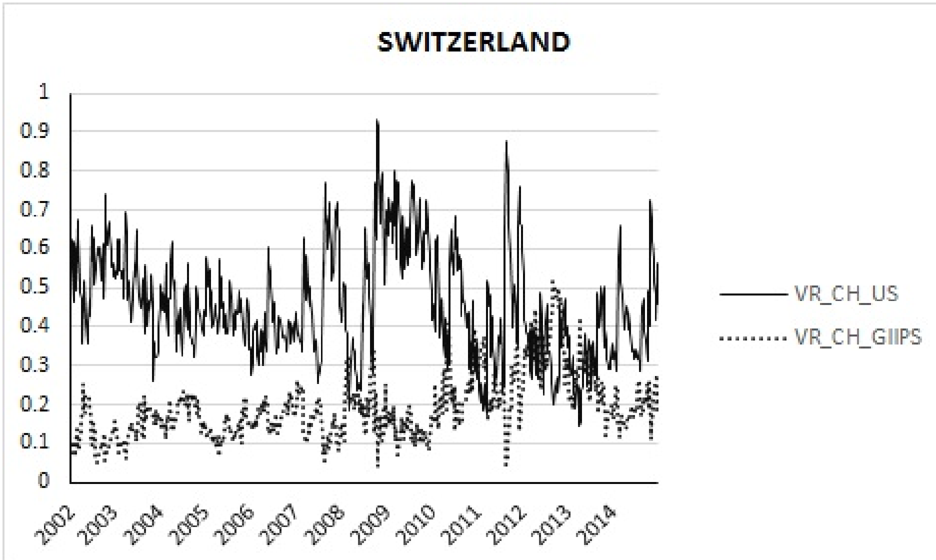
Conditional VR UK



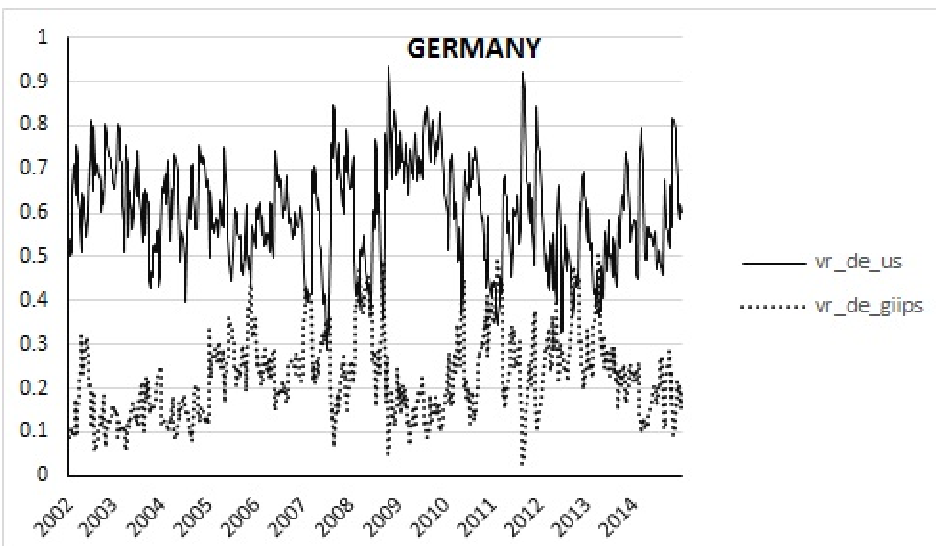
Conditional VR Sweden



Conditional VR Switzerland



Conditional VR Germany



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