JÖNKÖPING UNIVERSITY
International Business School

Title: The statistical relationship between the EUR/USD exchange rate and the Greek, Spanish, and German Stock Market.

MASTER

THESIS WITHIN: Economics

NUMBER OF CREDITS: 15

PROGRAMME OF STUDY: International Financial Analysis

AUTHOR: *Mamalis Spyridon*

TUTOR: *Scott Hacker, Mikaela Backman*

JÖNKÖPING 05.2016

Abstract

There are numerous of papers testing the relationship between the exchange rates and the stock indices of various countries. This paper serves the purpose of a supplementary research testing the causal relationship between the EUR/USD exchange rate and Athens stock index-ASE, EUR/USD exchange rate and Spanish stock index- IBEX35, and EUR/USD exchange rate and German stock index- DAX. ASE is chosen because of the debt crisis in Greece that has had a great impact to the European Union. IBEX35 is used at the models because Spain faced sovereign debt crisis as well. DAX index is used because it represents Europe's strongest economy. Each index is used as a proxy of performance for each economy. The statistical relationships between the variables, are tested by two VAR models.

JEL classification: G150, C32

Key words: Stock Prices, Exchange Rates, Bivariate causality, Greek stock index, Spanish stock index; German stock index

Acknowledgements

I want to express my gratitude to my professor and assistant professor, Scott Hacker and Mikaela Backman respectively for their contribution to this research. Also I want to thank my wife Angie for standing by me, and giving me the incentives to go on.

Contents

.... 1

Abstract 2

Acknowledgements 3

1. Introduction 5

2. Literature Review 7

3. Historical values of the variables under consideration 9

4. Data and Methodology 11

5. Empirical Results 15

  5.1 Information Criteria Optimal lag length selection (ADF-Test) 15

  5.2 Dickey Fuller Test: Checking for Unit Root 15

6. Scatterplots 19

7. VAR models Construction 20

  7.1 Three Bivariate VAR Models 21

  7.2 Four-variable VAR Model 27

8. Granger Causality Discussion 29

  8.1 Granger Causality Test: 3 bivariate model 29

  8.2 Granger Causality Test: 4 Variable-VAR Model 31

  8.3 Granger Causality Summary 32

9. Conclusion 33

References 36

Appendix A. 38

Appendix B. 40

Appendix C. 43

Appendix D. 44

Appendix E. 46

Appendix F. 46

1. Introduction

The Greek debt crisis has been one of the most discussed issues the last five years at the financial markets. It was back on the 23rd of April 2010 that the Greek Prime Minister George Papandreou announced that the country had to be rescued by activating the IMF rescue. The commissioner Rehn verified that the European Union and IMF joint financial support program would be offered to Greece. A program was launched to restore the financial health and stability of the country, which could stop the debt spiral (European Commission, 2010). The Greek debt crisis is very much at the core of the European crisis, as the Greek debt amounted to 329.52 billion euros in 2010 (Statista, 2015). The current public debt to GDP ratio is 177 percent (Wall Street Journal, 2015) making the debt sustainability if not difficult, impossible. The contagion effects of the crisis are known as the situation spread to other countries such as Portugal, Italy, Spain and Cyprus.

This paper attempts to study whether the EUR/USD exchange rate is related in a Granger causal way to the Greek stock index-ASE, Spanish stock index-IBEX35 and German stock index-DAX. It is important to investigate the relationship between the exchange rate and stock prices since both of them influence the economic development of countries. Therefore this paper tests the statistical relationship between the euro currency (using the EUR/USD exchange rate as a proxy) and the indices of two European countries facing sovereign debt problems and one European country that is considered the strongest economy in Europe.

There are two theories that link exchange rates and stock prices. The ''traditional approach'' (also known as ''Goods Market Theory'') argues that currency depreciation results in higher exports and profits that are followed by higher stock prices in the short run. Currency appreciation makes the exporting firm less competitive leading to lower stock prices in the short run. This relationship is attributed to Solnik (1987). The causality runs from the exchange rate to the stock market.

The other theory is the ''portfolio balance approach'' (Frankel (1983)). This theory postulates that foreign capital inflows and outflows occur whenever there is a change in stock prices. If the stock market index increases this will attract foreign investment, foreign capital resulting on higher stock prices. On the other hand if the stock market index decreases this will result in lower corporate wealth and lower demand for money. The lower demand for money is alleviated with lower interest rates and this leads to the outflow of foreign capital that searches for more attractive interest rates elsewhere. Either way causality runs from the stock market to exchange rate.

The EUR/USD exchange rate is used as a proxy of how the overall performance of European Union economy against another similar size economy as the American is doing. The last ten years are used, so five years before the financial crisis and five years following the crisis are considered. The paper addresses EUR/USD exchange rate in relationship to ASE Greek stock index. Moreover the EUR/USD exchange rate statistical relationship to IBEX35 Spanish stock index and DAX- German stock index are considered as a measure of comparison. In order to capture the dynamic relationship between the variables, vector auto regressive (VAR) models are deployed in which all the variables appear as dependent and as independent. The Granger causality discussion is then used to determine the statistical relationship among the variables.

The results are somewhat mixed as to whether stock indexes lead exchange rates or *vice versa* and whether feedback effects exist among the variables. The existence therefore and the degree of causality as well as the direction of causality depends to a great extent to the country under consideration. Each country's economy has unique characteristics, which influence the relationship. To the best of the author's knowledge there is no previous research paper testing the EUR/USD exchange rate statistical relation to the Greek stock index-ASE, Spanish stock index-IBEX35 and German stock index-DAX simultaneously.

Two different type models are formulated to test the statistical relationship among the variables. One four-variable VAR model and three bivariate VAR models. The four variable VAR testing all the variables simultaneously and the three bivariate testing each of the indices to the EUR/USD exchange rate separately. The empirical results are different for the variables under consideration. Specifically the results of the three bivariate VAR models are not exactly the same as the results of the Four-variable VAR model proposing that some of the suggestions (those that differ) should be approached with caution.

To be more precise, at the ''Three bivariate VAR model'' there is sufficient evidence that Greek stock index- ASE Granger causes EUR/USD exchange rate. There is bidirectional Granger causality between Spanish stock index- IBEX35 to EUR/USD exchange rate, since both the p values of the lagged values of IBEX35 and the lagged values of EUR/USD exchange rate are significant. Granger causality is found from DAX to EUR/USD exchange rate. The ''Four-variable VAR model'' retains only the Granger causality running from the Spanish stock index to EUR/USD exchange rate.

The paper is structured as follows. At section 2 is the Literature Review related to previews studies on the statistical relationship between exchanges rates and stock prices or stock indexes as it is the case at this paper. Section 3 has the historic values of the variables under consideration in order to check any trends if present. Section 4 describes the data and methodology used to perform the empirical research. Section 5 follows with the empirical results divided to subsection 5.1 that information criteria are used to check the optimal lag length of the variables, subsection 5.2 covers the Dickey Fuller test checking for the existence of Unit Root; at section 6 the scatterplots for visual inspection of the statistical relationship between the indices and the EUR/USD exchange rate. The VAR model estimations follow at the subsections 7.1 and 7.2. At subsections 8.1 and 8.2 the Granger causality is discussed. The subsection 8.3 provides a Granger causality summary. The conclusion follows at section 9.

2. Literature Review

There is a large number of research available regarding the exchange rate determination. An important contribution has been made by Meese and Rogoff (1983). That paper compares different techniques in terms of predicting and forecasting the exchange rate, employing time series and structural models. Time series models which are of interest to this paper, as well as structural models failed to perform better than the random walk model. Both univariate models and multivariate models were used in their time series section but none of them outperformed the random walk.

There are many research papers that consider the statistical relationship of exchange rates to stock prices using the Granger causality test. The relationship between stock indexes and the exchange rate is of great interest for many academics and professionals since both are very important variables when considering the overall state of the economy. However the existing literature is inconclusive on the relation between exchange rate movements and the stock indices.

Aggarwal (1981) and Dornbusch and Fisher (1980) agree that there is a direct relationship between exchange rate behavior and stock market performance. The theory proposes that a change in a country's exchange rate will affect the country's firm profitability to a lesser or greater extend depending on the sector and the way that the firm operates. For example firms that base their operations mainly on exporting or importing will be subject to greater impact. There is further evidence that a causal relation from the exchange rate to stock price should be expected (Jorion P, 1990). For example currency appreciation may reduce stock prices because it might cause a decrease at the profits of the firm, especially when the firm's profits are mainly export oriented (Jorion P, 1990). A paper by Mukherjee and

Naka (1995) reinforces the aforementioned. The paper tests the relationship between the Japanese stock market and six macroeconomic variables, such as the exchange rate, the money supply, the inflation, the industrial production, the long term government bonds rate and the call money rate. They found a long term equilibrium relationship**.** Abdalla and Murinde (1997) advocate that there exists a causal relationship from the exchange rate to stock price (India, Pakistan, Korea,). Bokhari (2013) in his study found causal relationship from exchange rate to stock price for India.

Abdalla & Murinde (1997) support that there is a causal relationship from the stock price to exchange rate (Philippines). Additionally according to Benjamin Miranda Tabak (2006) there is evidence of a causal relationship from the stock price index to the exchange rate. A decrease at the stock index and consequently at the majority of stock prices will lead investors to seek more attractive investments abroad. As a result the demand for money decreases and this decreases the interest rates. However lower interest rates will strengthen the outflow of money, and therefore will depreciate further the domestic currency. Alternatively higher stock prices will lead to higher demand raising the interest rates and strengthening the domestic currency**.** Likewise there is also evidence that a causal relation from the stock prices to the exchange rate should be expected Ajayi and Mougoue (1996), Ajayi, Friedman and Mehdian (1998), found that the stock prices Granger caused the exchange rate volatility. Ajayi, Friedman and Mehdian found this unidirectional causal relationships in the case of advanced economies. Bokhari (2013) found causality from the stock prices to exchange rates for Pakistan and Sri Lanka. Similarly Stavarek (2004) and Wickremasinghe (2006) argue unidirectional causality, stock prices cause exchange rates.

Bidirectional causality is found as well. According to Ajayi and Mougoue (1996) for the period of April 1985 to August 1991 for eight developed countries (Canada, France, Germany, Italy, Japan, Netherlands, UK, US). An increase in stock price has a negative short-run effect but a positive long-run effect on domestic currency value. Also, currency depreciation has negative effects both in the short-run and the long-run on the stock market. Additionally bidirectional causality between the exchange rate and the stock indices is found by Bokhari (2013) for the period 1997-2010 for Bangladesh and Nepal.

Whilst Bahmani-Oskooee and Sohrabian (1992) find no long run relationship between the exchange rate and the stock price (although bidirectional causality was present for the short run) for United States. Similarly a few years later Nieh and Lee (2001) using daily data from October 1993 to February 1996 they find no significant long-run relationship between stock prices and exchange rates for G-7 countries using both the Engle-Granger and Johansen's cointegration tests. Furthermore, they find ambiguous significant short-run relationships.

There are also papers that do not support any significant causal relation between the exchange rates and the stock prices**,** such as Solnik (1987) and Frank and Young (1972), Ratner (1993), and Ihsan, Baloch and Jan (2015). Below (Table 2.1) follows a summary of previews literature on the exchange rates and Stock Price.

Table 2.1: Previews Literature

Reference	country of study	period	Exchange Rate Granger Causes Stock Price		Stock Price Granger Causes Exchange Rate	
Aggarwal R 1981	USA	1974-1978	Yes		_	
Ajayi R.A., Mogoue M. 1996	Canada,France,Germany, Italy, Japan, Holland,UK,USA	1985-1991	Yes	(long run)	Yes	(long run) +
Ajayi R.A., Mogoue M. 1996	Canada,France,Germany, Italy, Japan, Holland,UK,USA	1985-1991	Yes	(short run)	Yes	(short run) -
Ajayi R.A., Friedman J. & Mehdian S.M 1998	Seven Advanced Economies	1987-1991	No		Yes	
Ajayi R.A., Friedman J. & Mehdian S.M 1998	Indonesia, Phillipines	1987-1991	No		Yes	
Ajayi R.A., Friedman J. & Mehdian S.M 1998	Korea	1987-1991	Yes		No	
Ajayi R.A., Friedman J. & Mehdian S.M 1998	Hong Kong, Singapore, Malaysia, Thailand	1987-1991	No		No	
Ajayi R.A., Friedman J. & Mehdian S.M 1998	Taiwan	1987-1991	Yes		Yes	
Nieh, C., and Lee 2001	France, Germany, USA	1993-1996	No	(long run)	No	(long run)
Nieh, C., and Lee 2001	Canada, Germany, UK	1993-1996	Yes	(short run)	No	
Nieh, C., and Lee 2001	Italy, Japan	1993-1996	No		Yes	(short run)
Bahmani-Oskooee, M.&Sohrabian A 1991	United States	1973-1988	No	(long run)	No	(long run)
Bahmani-Oskooee, M.&Sohrabian A 1992	United States	1973-1988	Yes	(short run)	Yes	(short run)
Mukherjee, T.K., and Naka A 1995	Japan	1971-1990	Yes		Yes	
Franck, P., and Young A 1972	USA		No		No	
Solnic, B 1987	USA,Japan,Germany,UK,France,Canada,Netherlands,Belgiu	1973-1983	_		Yes(insignificant)	
Jorion, P 1990	USA	1971-1987	Yes	(negligible)		
Soenen & Hennigan 1988	USA	1980-1986	Yes		Yes	
Abdalla and Murinde 1997	Pakistan, Korea	1985-1994	Yes		No	
Abdalla and Murinde 1997	India	1985-1994	Yes		No	
Abdalla and Murinde 1997	Phillipines	1985-1994	No		Yes	
Dornbusch R. and Fisher S 1980	Goods Market Approach	1980	Yes		_	
Tabak Miranda Benjamin 2006	Brazil	1994-2002	Yes	(short run)	Yes	(short run)
Tabak Miranda Benjamin 2006	Brazil	1994-2002	No	(long run)	No	(long run)
Ratner 1993	USA	1973-1989	No		_	
Granger et al 2000	South Korea, Phillipines	1986-1998	Yes		No	
Granger et al 2000	Indonesia, Japan	1986-1998	No		No	
Granger et al 2000	Hong Kong,Malaysia,Singapore,Thailand,Taiwan	1986-1998	Yes		Yes	
Yu Quiao 1997	Tokio	1983-1994	Yes		Yes	
Yu Quiao 1997	Singapore	1983-1994	No		No	
Yu Quiao 1997	Hong Kong	1983-1994	Yes		No	
Stavarek 2004	Czech Republic, Hungary, Poland, Slovakia, USA	1993-2003	No		Yes	
Wickremasinghe 2006	Sri Lanka	1986-2004	No		Yes	
Bokhari 2013	Pakistan,Sri Lanka	1997-2010	No		Yes	
Bokhari 2013	India	1997-2010	Yes		No	
Bokhari 2013	Bangladesh, Nepal	1997-2010	Yes		Yes	
Ihsan, Baloch and Jan 2015	Pakistan	2012-2014	No		No	

3. Historical values of the variables under consideration

The EUR/USD exchange rate has experienced a downward trend the last five years (see figure 3.1), starting from November of 2010, just a few months after the Greek Prime Minister Papandreou announced the activation of the IMF rescue mechanism. Since its existence the euro reached the highest level of 1.6038 US dollars in July of 2008 and reached the lowest level of 0.8252 US dollars in October of 2000 (Trading Economics, 2016). The rising concerns over the liquidity of the Greek and the Spanish banks at the 2012 led the exchange rate to fall below 1.21 for the first time in two years. The downward trend continues as the commitments of the countries under financial aid programs are not met. The necessary reforms in Greece are not happening, and the irreversible situation of demographics pose a serious threat not only for Greece but for the rest of the Union as well. As of January 2016 the euro is weak; it is worth 1.08605 US dollars and it is debated if the Union's solidarity is adequate to restore the overall financial stability.

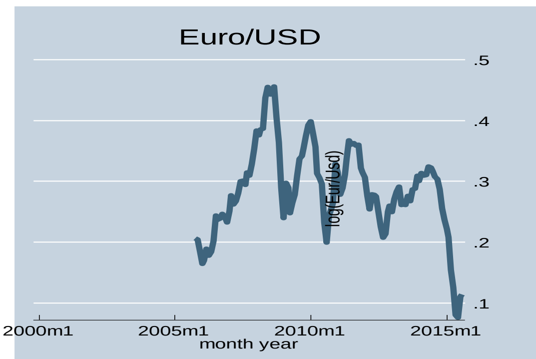


Figure 3.1. Euro/US dollar exchange rate

Figure 3.2. Greek Stock Index-ASE.

The Greek stock market (see figure 3.2) follows a sharp decline (depreciation) starting from July 2008 foretelling the problems that follow. The Greek stock index was 6355.04 in September 1999 whereas it was 631.35 in December of 2015, almost the 1/10th of the Septembers 1999 level. This depreciation depicts the severe consequences of the sovereign debt crisis on the Greek economy.

The Spanish Index-IBEX35 (see figure 3.3) reached the highest level of 15945.70 in November of 2007. Since then there is no clear trend. Actually the graph reminds us of the random walk process. There is a downward movement towards the 6000 level though following the announcement of the rescue loan from Eurozone on 9th of June 2012. On December 31st of 2015 the IBEX35 was at the level of 9555.79.

The German Index-DAX (see figure 3.4) from 2008 has a downward retracement of approximately 50 percent of its previous bounce, probably as a result of the sovereign debt crisis. However as of the beginning of 2010 the trend becomes upward again. The German economy appears strong bypassing the general uncertainty, since the stock index is appreciating.

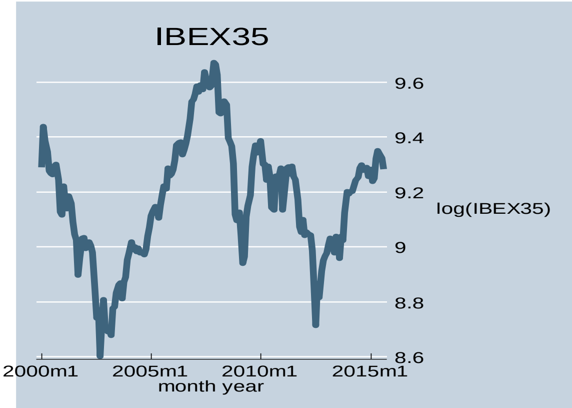


Figure 3.3. Spanish Stock Index-IBEX35

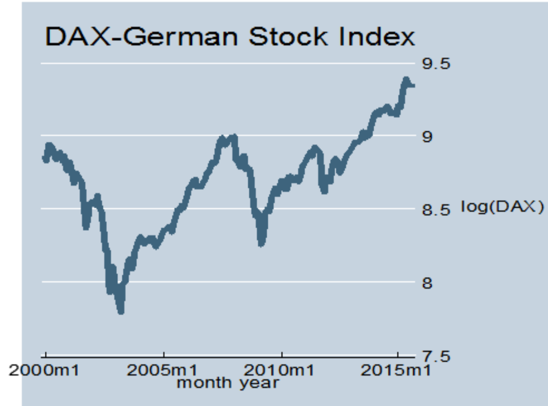


Figure 3.4. German Stock Index-DAX

4. Data and Methodology

In this paper three bivariate VARs are examined along with one four-variable VAR model (The parameters of interest are: the EUR/USD exchange rate, the Athens stock exchange Index-ASE (HELEX), and the IBEX35 Spanish stock index and the German stock index-DAX. All of those parameters are of vital importance for our empirical paper analysis. Therefore a discussion about each one of them follows below.

Because of their strong influence on the current account and other macroeconomic variables exchange rates are among the most important prices in an open economy (Krugman, 2011). Also the exchange rates are of great importance since importers, exporters, tourists as well as governments, investment banks and hedge funds buy and sell currencies in the foreign exchange market (Reilly & Norton 2003). This market has been of growing importance due to globalization and the free trans-border exchange of goods and services, and due to its growing familiarity to investors and speculators. (The modern foreign exchange market as it is known today has been formed during the 1970's. In 1971 the Bretton Woods agreement came to an end, and the dollar should no longer be denominated in gold. The currencies became free floating, and this is the beginning of the foreign exchange market, as we know it today.) The foreign exchange market is tremendously liquid and large sums of money are traded on a daily basis. An indication of the aforementioned liquidity of this market is the $5.3 trillion average turnover on a daily basis on April 2013 while the global goods trade amounted only to $18.5 trillion turnover for all of 2013 (*Deutsche Bundesbank 2013, UNCTAD 2015*). In this paper the EUR/USD exchange rate is at the core of the research since euro is the currency for the countries under consideration (Greece, Spain and Germany). The dollar (USD) is used at the pair since we pick another reserve currency that shares many common characteristics with euro.

The Athens Stock Exchange (ASE) was founded back in 1876. The privatization of the stock exchange started at 1997 to 1999. Nowadays the private company Hellenic Exchanges founded in 2000 is responsible for the operation of stock exchange and the major shareholder.

The third variable is Spanish stock index-IBEX35. IBEX35 was inaugurated in 1992. It consists of the 35 companies with the highest traded volume in euros over the last six months, however there are also some other prerequisites of inclusion at this index, such as the number of traded days during those six months and the average of the flee float market cap is at least the 0.3 percent of the total market cap of the index. IBEX is a very important variable for the models as Spain is another country that faces sovereign debt crisis and it has a much larger economy than the Greek.

The DAX Index is used as a proxy of German economy performance. DAX represents the major 30 companies in German Economy. It was created in 1988 with a base index value of 1000. The importance of the DAX Index is verified by the fact that it represents 75 percent of total market capitalization traded in Frankfurt's stock exchange.

The data we use are acquired from finance.yahoo.com and the www.oanda.com. The data regarding the stock indexes were extracted from Yahoo Finance, whereas Oanda provided the historical exchange rates.

Monthly data are used for the analysis in this paper for all the variables. Monthly data are used since it provides not only a short run insight but also captures a more macroeconomic relationship than daily data. The time span of data used is from 31st of December 1999 for ASE (Athens Stock Index), IBEX35 (Spanish Index) and DAX (German Stock Index) until the 2nd of June 2015. The time span included for the exchange rate starts five years later from the 1st of September 2005, until the 2nd of June 2015.

The Vector autoregression (VAR) model is used at the paper. In finance as in many other applications, we may be concerned with the relationship between two or more variables. A bivariate VAR (1) example follows (equation 4.1):

$$(4.1) \quad \hat{X}_t = \alpha X_{t-1} + \beta Y_{t-1}$$

$$\hat{Y}_t = \gamma X_{t-1} + \delta Y_{t-1}$$

The above process may be written in a matrix format with X_t and Y_t forming a vector:

$$\begin{bmatrix} X_t \\ Y_t \end{bmatrix} = \begin{bmatrix} \alpha & \beta \\ \gamma & \delta \end{bmatrix} * \begin{bmatrix} X_{t-1} \\ Y_{t-1} \end{bmatrix}$$

Since one lagged value is included it is a VAR (1) model. This is a bivariate VAR model since it is formulated by two variables (X_t and Y_t). Multivariate VARs may include more variables.

Basically: i.) A bivariate VAR model is created to test If there is a Granger causal relation between the Greek Stock Index-ASE and the EUR/USD exchange rate. ii.) Another bivariate VAR model is developed to check if there is Granger causality between the Spanish stock index-IBEX35 and EUR/USD exchange rate. iii.) A third bivariate VAR model is formed to test Granger causality between exchange rate and German stock index- DAX. iv.) The results for each bivariate model are presented to come up with some conclusions about the dynamics of the relationships. v.) In order to test the robustness of the three bivariate VAR models and due to globalization and interconnectedness of national economies, another ''four-variable VAR model'' is formulated. That model tests for Granger causality among the EUR/USD exchange rate, the ASE-Athens stock index, the IBEX35-Spanish stock index and the DAX-German stock index, and additionally the ''four-variable VAR model'' tests the potential statistical interdependence between the Indices. The four-variable VAR model comes as a supplementary model that makes the analysis more complete.

The first step is to choose the optimal lag length for each variable for unit root testing using the Augmented Dickey Fuller (ADF) test. The tools used for the length determination are the information criteria AIC, BIC, HQIC. The Akaike's Information Criterion (AIC) information criterion imposes a penalty for adding regressors to the model:

$$\text{Ln AIC} = \left(\frac{2k}{n}\right) + \ln\left(\frac{RSS}{n}\right)$$

The ln AIC is the natural log of AIC and the 2k/n is the penalty factor. Specifically k is the number of regressors and n is the number of the observations. Similar in spirit to the AIC criterion is the Bayesian information criterion (BIC) also known as Schwarz's criterion (SIC):

$$\text{Ln BIC} = \frac{k}{n}\ \ln n + \ln\left(\frac{RSS}{n}\right)$$

The [(k/n)* ln*n*] is the penalty factor this time. The BIC criterion is considered stricter than AIC criterion. The third criterion the Hannan Quinn information criterion is an alternative to the two aforementioned criteria:

$$\text{Ln HQIC} = \frac{2k}{n}\ \ln(\ln(n)) + \ln\left(\frac{RSS}{n}\right)$$

The penalty factor for additional regressors is (2k/n)*ln (ln (*n*)). After choosing the optimal lag length for each variable, the second step is to conduct unit root tests for every variable separately. It is necessary to check for stationarity, and the ADF test is employed for that purpose. All the variables are found to be stationary in first difference.

The third step is to use scatterplots for visual inspection of the relation between the variables. In this case between EUR/USD and ASE, EUR/USD and IBEX35, EUR/USD and DAX.

The fourth step is the development of the desired VAR models. The first step is repeated once more in order this time to find the optimal lag length for each of the three bivariate VAR models and the four-variable VAR model. This step is of crucial importance and special precaution is used. Therefore the combined results of more than one information criterion are employed. The three bivariate VAR models are used in order to capture the dynamic relationship between the EUR/USD exchange rate and Greek stock index-ASE, the EUR/USD exchange rate and the Spanish stock exchange Ibex35, and the EUR/USD exchange rate and the German Stock Index-DAX. The four-variable VAR model is used in order to check the relationship of the EUR/USD exchange rate to the indices. Information criteria dictate the optimal lag length for all of the VAR models. We estimate the parameters of the models, taking into consideration that the magnitude of the coefficients cannot be interpreted as in standard univariate equations *(Gujarati, 2003)*. Nevertheless, we are interested in the sign of the coefficients as well as their statistical significance.

The fifth step is to discuss Granger causality based on the results for both models. Standard regression analysis deals with the dependence of one variable (regressor) on other variables (regressands) but it does not prove causality among them. The Granger causality test is widely used to consider causality relationships, and their direction. The Granger causality test may have four possible outcomes: 1) unidirectional Granger causality from the Y variable on X with the lagged values of Y providing forecasting information for X, 2) unidirectional Granger causality from X variable on Y, with the lagged values of X providing forecasting information for Y, 3) bidirectional Granger causality so that the lagged values of Y help predict X and the lagged values of X help predict Y, or 4) no Granger causality with neither the lagged values of Y helping in predicting X, nor the lagged values of X helping in predicting Y.

The Granger causality test is very sensitive to the number of lags included, and the results may be misleading if the optimal number of lags is not chosen. That is why the information criteria by Akaike (AIC), Schwarz (SIC), and Hannan Quin (HQIC) are used combined to determine the number of lags to be included in order to define the appropriate VARs as already mentioned.

5. Empirical Results

The statistical software Stata 12 is used to proceed to the empirical results. The following steps are of major importance for our data analysis: (1) the information criteria dictate the number of lags that is appropriate for each of the variables to include in the ADF test. (2) The Augmented Dickey Fuller test is then used to check for stationarity of the variables under consideration. (3) Scatterplots are inspected. (4) VAR models are formulated. (5) Granger causality is discussed, and (6) Granger causality results are summarized.

5.1 Information Criteria Optimal lag length selection (ADF-Test)

The information criteria are applied in two cases. First we use information criteria to choose the optimal lag length of each variable to apply the Augmented Dickey Fuller test. Also the information criteria are applied to choose the optimal lag length for each of the three bivariate VAR Models and the optimal lag length for the ''four-variable VAR model''. According to the information criteria the EUR/USD variable has as an optimal lag length of 4. Also the information criteria dictate as the optimal lag length for ASE the 4th lag[1]. Moreover the information criteria dictate as the optimal lag length for IBEX35 and DAX the 1st[2]. The above criteria are used when applying the Augmented Dickey Fuller test. When considering the ''four-variable VAR model'' and the ''three bivariate VAR model'' the optimal lag length becomes the 1st for both models (after differencing to induce stationarity)[3].

5.2 Dickey Fuller Test: Checking for Unit Root

The Dickey Fuller test is applied in order to check if there is any unit root (Gujarati and Porter). The null hypothesis states that there is at least one unit root (H_0) on the contrary the alternative hypothesis (H_α) states that there is no unit root: $\Delta E_t=\gamma E_{t-1}+u_{t.}$

H_0: $\gamma=0$. Then the series contains at least one unit root.
H_α: $\gamma < 0$. Then there is no unit root.

Applying Augmented Dickey Fuller test for EUR/USD is found that there is a unit root. The variable is stationary at the first difference therefore it is integrated of first order I (1). Below the graph (see figure 5.2.1) presents the logged variable EUR/USD before the first difference and on graph (see figure 5.2.2)

[1] Optimal lag length ASE, Appendix A
[2] Optimal lag length IBEX35, DAX, Appendix A
[3] Optimal lag length ''Three Bivariate VARs Model'' and ''Four-variable VAR model'', Appendix A

after taking the first difference. The horizontal axis represents time and the vertical the exchange rate.

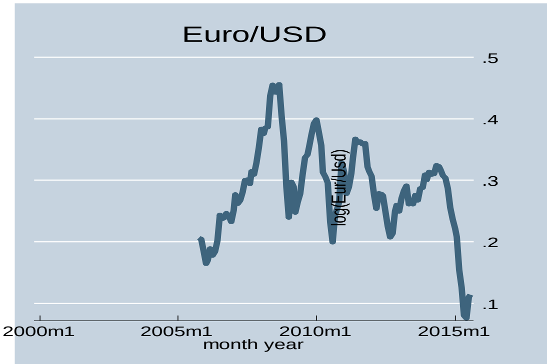


Figure 5.2.1: Logged EUR/USD exchange rate

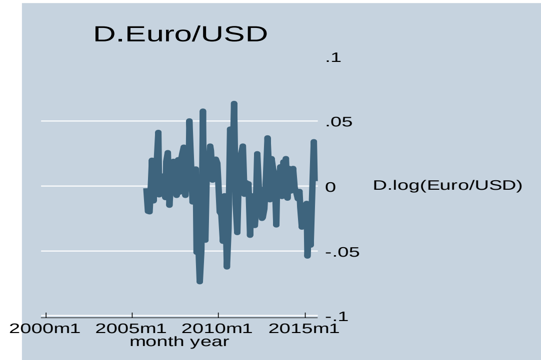


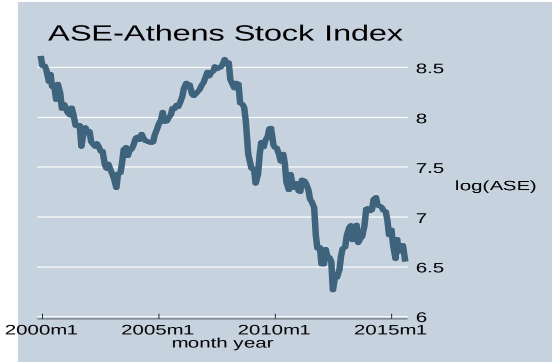
Figure 5.2.2: Change in Logged EUR/USD exchange rate

[2]For detailed information criteria test see Appendix A

The exchange rate is a random walk process (see figure 5.2.1.), since it is not mean reverting and its variance is not steady. Dickey Fuller Test verifies the above since the absolute value of τ statistic does not exceed the critical values so the null hypothesis of unit root (γ=0) cannot be rejected[4]. However after taking the first difference (see figure 5.2.2), it becomes stationary since it is mean reverting resembling to white noise process. The absolute τ value is significant, suggesting that the null hypothesis should be rejected[5].

The same way the Dickey Fuller test for unit root is applied at ASE. The Dickey Fuller test suggests that the series are not stationary since the absolute value of τ statistic is less than all critical values at all levels of significance[6]. We found that ASE is integrated of first order I (1)[7] so that it is difference stationary. The aforementioned is verified when the series are differenced the absolute value of τ (tau) statistic is greater than all the critical values at all levels of significance. Below the same graphs are presented for the other variable under consideration ASE-Athens stock exchange. As in the case of EUR/USD the ASE has two completely different graphs. Figure 5.2.3 depicts the ASE closing price while Figure 5.2.4 represents the ASE closing price after being differenced to get rid of integration. As it is the case at the previews figures the horizontal axis stands for time, whereas the vertical for the variable under consideration.

[4] For summarized ADF test see Appendix B, Table 2.
[5] For summarized ADF test see Appendix B, Table 3.
[6] For summarized ADF test see Appendix B, Table 4.
[7] For summarized ADF test see Appendix B, Table 5.



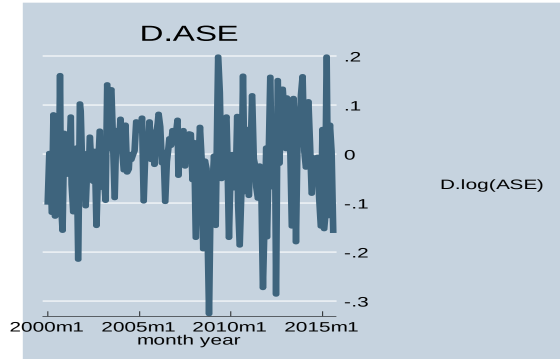
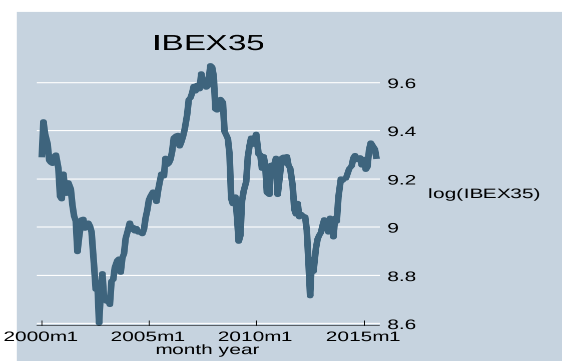


Figure 5.2.3: Logged ASE-Athens Stock Index

Figure 5.2.4: Change in Logged ASE-Athens Stock Index

Figure 5.2.3 is a random walk process. On the other hand figures 5.2.4 shows that the target of stationarity is achieved after 1st differencing, since mean reversion is present and the variance is relatively steady.

As above applying the Augmented Dickey Fuller test to the variable IBEX (noted as sclose at the appendix). The test result shows that it is integrated of first order I (1), since the null hypothesis is not rejected immediately but at the first difference. The absolute value of τ statistic is less than all the critical values at all levels of significance before being differenced so the unit root null hypothesis (γ=0) cannot be rejected[8]. After taking the first difference the absolute value of the τ statistic is greater than all the critical values at all levels of significance therefore the null is rejected and the series become stationary[9]. Figure 5.2.5 depicts the IBEX35 variable before being differenced. The Figure 5.2.6 depicts the variable after being differenced. Once more at figure 5.2.6 the variable is mean reverting, stationary.



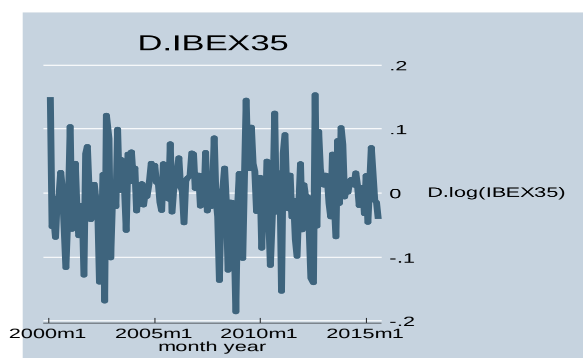


Figure 5.2.5: Logged IBEX35- Spanish Stock Index

Figure 5.2.6: Change in Logged IBEX35- Spanish Stock Index

[8] For summarized ADF test see Appendix B, Table 6.
[9] For summarized ADF test see Appendix B, Table 7.

The same way the Dickey Fuller test for unit root is applied at DAX. The test result shows that it is integrated of first order I (1), since the null hypothesis is not rejected immediately but at the first difference. The absolute value of τ statistic is less than all the critical values at all levels of significance before being differenced so the Unit Root null hypothesis (γ=0) cannot be rejected[10]. Taking the first difference the absolute value of the τ statistic is greater than all the critical values at all levels of significance therefore the null is rejected and the series become stationary[11]. Figure 5.2.7 depicts the DAX variable before being differenced. The Figure 5.2.8 depicts the variable after being differenced. At figure 5.2.8 the variable is mean reverting, stationary.

Figure 5.2.7: Logged DAX- German Stock Index

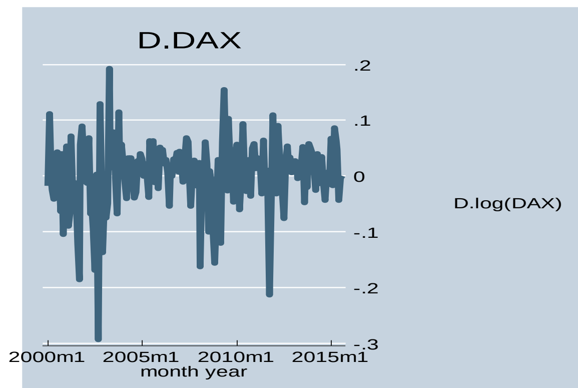


Figure 5.2.8: Change in Logged DAX- German Stock Index

All of the above tests are used to give an idea of how each of the variables under consideration behaves. Similar tests were performed for each one of the three bivariate VAR models and for the four-variable VAR model as well, the results show integration of first order I (1). Stationarity is induced when taking the first differences. Having induced stationarity the information criteria dictate as optimal lag length in all of the cases the 1st.

[10] For summarized ADF test see Appendix B, Table 8.
[11] For summarized ADF test see Appendix B, Table 9.

6. Scatterplots

The visual inspection through the use of scatterplots is used as well. Scatterplots help us reveal whether there is any pattern in the relationship between the variables. The first scatterplot (see figure 6.1) considered is the one depicting the EUR/USD and the ASE (Athens-stock-index-XAA-close). Later on the second scatterplot (see figure 6.2) under consideration is the relation of EUR/USD against the Spanish stock exchange index (IBEX). The third scatterplot (see figure 6.3) depicts the relationship of the EUR/USD exchange rate against the lagged value of the DAX-German stock index. The visual inspection provides a great insight for the relationship between the variables and contributes to the analysis of research data.

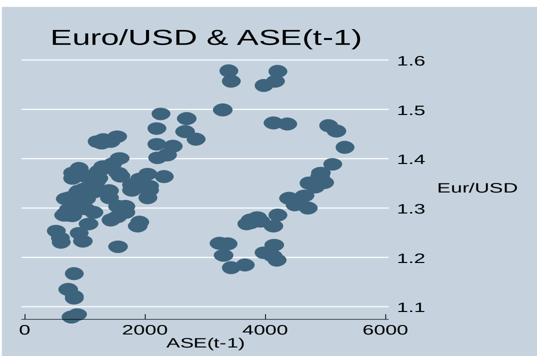


Figure 6.1: Scatterplot EUR/USD values, lagged values of ASE

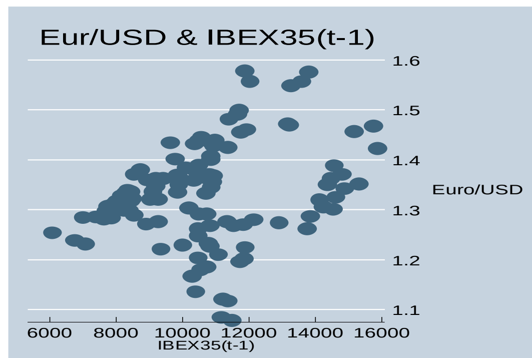


Figure 6.2: Scatterplot EUR/USD values, lagged values IBEX

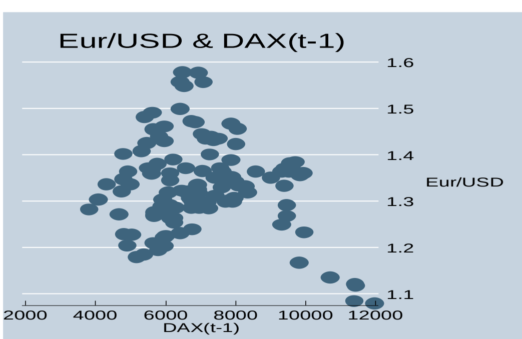


Figure 6.3: Scatterplot EUR/USD values, lagged values DAX.

There is a similar trend obvious in both of the first two scatterplots and they seem to follow a similar pattern. It seems that the pair EUR/USD has a positive correlation to ASE and IBEX35 as well. A strong euro is followed by a rise at the Stock Indexes, whereas the week euro is followed by a fall on the Stock Indexes. At the beginning both variables rise together but in about the middle of each of the scatterplots both variables fall together (years 2008-2009, sovereign debt crisis). This is due to the European debt crisis that took place since the end of 2009 and became obvious for the weaker member states such as Greece, Italy, Spain, and Portugal. Though the financial markets act as a foreteller and the downtrend started from 2008. The weaker of them in financial terms is Greece that under the threat of default and imposing questions about the solidarity of the European Union caused the euro to weaken and created problems in the form of contagion to other member states as well. The possibility of a defaulting European country reinforced uncertainty and led to higher borrowing costs for the other already in trouble countries. The Greek 10 year bond borrowing cost (yield) reached 42 percent on March 2012 the same year the Spanish 10 year bond borrowing (yield) cost reached 7.73 percent on July (Bloomberg, 2016). The impact of Greece has been very important in Europe the last years that is why as stated earlier the Greek Index-ASE is considered in this research. Spain has been one of the member states having financial problems as well and it is therefore used in the research as a comparison measure to the Greek impact.

At the third scatterplot EUR/USD exchange rate has a positive relationship to DAX though not that lasting as with ASE and IBEX. This positive relationship turns into a negative one later on. German Economy has been growing the last 10 years except the year 2009[12]. German Stock Index has had a growing trend the last years (see figure 6.3) disregarding the strong or weak euro, the extrovert economy and the positive balance of trade minimized the impact of the crisis to a great extent. On the other hand the Greek stock index-ASE and Spanish stock index-IBEX35 that face sovereign debt crisis during those years have similar patterns against EUR/USD exchange rate. That is why instead of including as proxies only the stock indices of the ''troubled'' economies, the stock index of the strongest economy in Europe is also included as a measure of comparison between a healthy economy and economies in trouble.

7. VAR models Construction

In economics it is common to have models that some variables are not only explaining the dependent variables, but they are also explained by the variables that they are used to determine. In that case, models of simultaneous equations appear (Asteriou, 2007). Those are an n-equation, n variable linear

[12] Graph of GDP growth rate, Appendix C.

models in which each variable is determined by its lagged values and the current and lagged values of the other variables. According to Sims (1980) all those variables should be treated symmetrically and as endogenous. Each equation in its general reduced form has the same set of regressors which leads to the development of VAR models. All the VAR models we construct are 1st order VARs since one lag is proposed by the selection criteria (AIC, SBIC, HQIC).

7.1 Three Bivariate VAR Models

In this section the two models are formed. In both models we check for heteroscedasticity at the error terms. The Breusch Pagan test is employed for that purpose. The results for the heteroscedasticity tests propose that we cannot reject its presence[13]. In most of the cases heteroscedasticity is absent. Nevertheless in order to be more conservative the robust standard errors are used to account for the presence of heteroscedasticity. (The VAR models formed provide the coefficients necessary to determine whether the variables are positively or negatively related. The Granger causality discussion that follows in sections 8.1 and 8.2 does not provide any information regarding the positive or negative nature of this relation. Instead it tests only the presence or not of causality.)

According to ADF (subsection 5.2) test results all the variables become stationary after taking their first differences. Therefore the series are differenced to get rid of integration of order one. Also as it is the case in financial data logged variables are used to estimate the percentage changes. The first bivariate VAR (equation 7.1.1) explains current exchange rate (E) in terms of the lagged Greek stock index (XG_{t-1}) and the lagged values of EUR/USD exchange rate (E_{t-1}), and the current Greek stock index (XG) in terms of the lagged Greek stock index (XG_{t-1}) and the lagged exchange rate (E_{t-1})[14]:

$$7.1.1 \quad \begin{bmatrix} \Delta LnE_t \\ \Delta LnXG_t \end{bmatrix} = \begin{bmatrix} \delta_{eg} \\ \delta_{ge} \end{bmatrix} + \begin{bmatrix} \varphi_{1eg} & \varphi_{2eg} \\ \varphi_{1ge} & \varphi_{2ge} \end{bmatrix} * \begin{bmatrix} \Delta LnE_{t-1} \\ \Delta LnXG_{t-1} \end{bmatrix} + \begin{bmatrix} U_{teg} \\ U_{tge} \end{bmatrix}$$

(EUR/USD exchange rate=E, Greek stock index= XG, intercept=δ, ϕ= coefficients, Δ= Delta stands for the first difference, Ln=log.)

The second bivariate VAR (equation 7.1.2) explains the current value of the exchange rate (E) in terms of the lagged value of the exchange rate (E_{t-1}) and the lagged value of the Spanish stock index (XS_{t-1}),

[13] Heteroscedasticity Breusch Pagan tests, Appendix D.
[14] All the variables considered are differenced (to induce stationarity), and logged. That holds for all the VARs under consideration. (equations 7.1.1, 7.1.2 and 7.1.3)

and the current value of Spanish stock index (XS) in terms of its own lagged value (XS_{t-1}) and the lagged value of the EUR/USD exchange rate (E_{t-1})[15].

7.1.2 $$\begin{bmatrix} \Delta LnE_t \\ \Delta LnXS_t \end{bmatrix} = \begin{bmatrix} \delta_{es} \\ \delta_{se} \end{bmatrix} + \begin{bmatrix} \varphi_{1es} & \varphi_{2es} \\ \varphi_{1se} & \varphi_{2se} \end{bmatrix} * \begin{bmatrix} \Delta LnE_{t-1} \\ \Delta LnXS_{t-1} \end{bmatrix} + \begin{bmatrix} U_{tes} \\ U_{tse} \end{bmatrix}$$

(EUR/USD exchange rate=E, Spanish stock index-iIBEX35= XS, intercept=δ, ϕ= coefficients, Δ= Delta stands for the first difference, Ln=log.)

The third bivariate VAR model (equation 7.1.3) explains the current value of the exchange rate (E) in terms of its own lagged value (E_{t-1}) and the lagged value of the German stock index (DAX_{t-1}). Similarly it explains the current values of German stock index (DAX) in terms of its own lagged values and the lagged values of the exchange rate (E_{t-1}).

7.1.3 $$\begin{bmatrix} \Delta LnE_t \\ \Delta LnDAX_t \end{bmatrix} = \begin{bmatrix} \delta_{ed} \\ \delta_{de} \end{bmatrix} + \begin{bmatrix} \varphi_{1ed} & \varphi_{2ed} \\ \varphi_{1de} & \varphi_{2de} \end{bmatrix} * \begin{bmatrix} \Delta LnE_{t-1} \\ \Delta LnDAX_{t-1} \end{bmatrix} + \begin{bmatrix} U_{ted} \\ U_{tde} \end{bmatrix}$$

(EUR/USD exchange rate=E, German stock Index-DAX= DAX, intercept=δ, ϕ= coefficients, Δ= Delta stands for the first difference, Ln=log.)

The results found from running the three bivariate VAR models are summarized below (table: 7.1). There are three columns one for each of the three bivariate VAR models. Each of the columns has the two dependent variables of the VAR model. The table has also one row for each of the lagged independent variables, the rows represent the independent variables:

[15] All the variables considered are differenced (to induce stationarity), and logged. That holds for all the VARs under consideration. (equations 7.1.1, 7.1.2 and 7.1.3)

Table 7.1: Summarized Results for the three bivariate models						
	ASE		IBEX35		DAX	
Variables	(ΔLnXGt)	(ΔLnEt)	(ΔLnXSt)	(ΔLnEt)	(ΔLnDAXt)	(ΔLnEt)
(ΔLnXGt-1) (p-value)	0.169 (0.110)	0.075*** (0.005)				
(ΔLnXSt-1) (p-value)			0.152 (0.173)	0.136*** (0.000)		
(ΔLnDAXt-1) (p-value)					0.192** (0.035)	0.115*** (0.003)
(ΔLnEt-1) (p-value)	-0.713 (0.114)	0.187* (0.086)	-0.520* (0.076)	0.210** (0.037)	-0.297 (0.144)	0.254*** (0.003)
Constant (p-value)	-0.012 (0.187)	0.000 (0.891)	-0.000 (0.962)	-0.001 (0.751)	0.006 (0.256)	-0.001 (0.513)
Observations	117	117	117	117	117	117

p-values, *** p<0.01, ** p<0.05, * p<0.1 Notations: EUR/USD=E, Greek Stock Index= XG, Spanish Stock Index-IBEX35= XS, German Stock Index- DAX=DAX, intercept=constant. D= Stands for the first difference.

The Results of the ''Three Bivariate VAR Model'' are:

i) $\Delta LnE_t = 0.187\ \Delta LnE_{t-1} + 0.075\ \Delta LnXG_{t-1} + U_{teg}$

$\Delta LnXG_t = -0.012 - 0.713\ \Delta LnE_{t-1} + 0.169\ \Delta LnXG_{t-1} + U_{tge}$

ii) $\Delta LnXS_t = -\ 0.520\ \Delta LnE_{t-1} + 0.152\ \Delta LnXS_{t-1} + U_{tse}$

$\Delta LnE_t = -0.001 + 0.210\ \Delta LnE_{t-1} + 0.136\ \Delta LnXS_{t-1} + U_{tes}$

iii) $\Delta LnE_t = -0.001 + 0.254\ \Delta LnE_{t-1} + 0.115\ \Delta LnDAX_{t-1} + U_{ted}$

$\Delta LnDAX_t = 0.006 - 0.297\ \Delta LnE_{t-1} + 0.192\ \Delta LnDAX_{t-1} + U_{tde}$

Above appear the results of running in Stata software the three bivariate VAR models under consideration. Looking at the each of the bivariate VAR models, the magnitude and the significance of the coefficient are important[16], the results suggest that:

i) The lagged value of the EUR/USD-(E) exchange rate coefficient on the ASE-Athens Stock Index (XG) is close to significant at the level of 10 percent since the p value is 0.11. There is a negative relationship between those variables. Therefore an increase in EUR/USD by say 1 percent, will be followed next

[16] The significance because it is related to the precision of the estimate, and the magnitude because it is the size of the effect (how big the coefficient is).

month (all else equal, holding all the other variables constant[17]) by a 0.713 percent decrease in ASE-Athens Stock Index. ii) The lagged value of ASE-Greek stock index coefficient on the EUR/USD exchange rate is significant at the level of 1 percent. There is a positive relationship between these variables. Therefore an increase in ASE by 1 percent will be followed next month (all else equal, holding all the other variables constant) by a 0.075 percent increase in the exchange rate EUR/USD. Thereby the Euro which is the base currency in this pair will appreciate against the US Dollar (quote currency) by 0.075 percent.

The second bivariate VAR model has as dependent variable the differenced closing prices of IBEX35-XS and independent its lagged values and the lagged values of the other variable under consideration the exchange rate EUR/USD-E. It also has a dependent variable the closing prices of the exchange rate EUR/USD-E and independent its lagged values as well as the independent lagged values of IBEX35-XS. iii.) The lagged value of EUR/USD coefficient on the Spanish Index-IBEX35 is significant at the level of 10 percent. There is a negative relationship between those variables. An appreciation of euro by 1 percent against the dollar is followed by a decrease in IBEX35 by 0.52 percent next month. iv.) The lagged value of IBEX35-Spanish stock index coefficient on the EUR/USD exchange rate is significant at the level of 1 percent (the estimate is considered very precise). There is a positive relationship between those variables. An increase in IBEX35 by 1 percent will be followed by an increase in the exchange rate by 0.136 percent next month (the coefficient's magnitude is not negligible). Therefore Spanish economy has more impact on euro than Greek. The euro appreciates when IBEX appreciates and it depreciates when IBEX depreciates by about the double magnitude in comparison to the Greek impact (0.136 vs 0.0713). This is rational since the impact from the Spanish economy on euro is expected to be greater than the impact of Greece, due to the Spanish economy magnitude which is more than six times larger (in terms of GDP).

The third bivariate model has as independent variable the differenced closing prices of DAX Index and independent its lagged values and the lagged values of exchange rate EUR/USD-E. Likewise the closing prices of exchange rate EUR/USD-E as ''dependent variable'' and ''independent'' its lagged values and the lagged values of DAX Index. v.) The lagged value of EUR/USD coefficient on DAX Index is close to

[17] Holding all other variables constant is a hypothetical assumption, (since VARs are dynamic, from a practical point of view it is impossible to change one predictor while holding all others fixed), and it is used for the sake of interpreting the VAR coefficients (the hypothetical impact they have on the ''independent variable'').

significant at 10 percent. Since the p value is small but not small enough to reject the null hypothesis, we may conclude that there might exist a negative relationship between those variables but the coefficient estimate is not that precise, since the precision threshold is marginally lower. If the exchange rate increases by 1 percent then the DAX decreases by 0.297. vi.) The lagged value of DAX Index coefficient on EUR/USD exchange rate is significant at 1 percent. Since the result is significant at this level the coefficient estimate is very accurate. A change of 1 percent at the lagged value of DAX will be followed by a change of 0.115 percent on exchange rate (Holding the all else equal assumption).

In all bivariate models there is a consideration of the impact the past values of the variables have on their contemporary values. We consider only the first lag period (1 month) as it was the case so far since only this lag provides significant results. Always, having the all else equal condition in mind[18].
The lagged values of ASE and DAX on their next month values are insignificant at the level of 10 percent for ASE and significant at 5 percent for DAX. A change of 1 percent in previews month's values will be followed by a change of 0.169 percent for ASE (although this estimate is not very accurate due to insignificance) and 0.192 percent change for DAX (more accurate than the previews estimate). In other words the past values explain through the next month values changes by the aforementioned percentages. (Again the all else equal assumption is a prerequisite)
viii.) The lagged values of IBEX35 coefficient are not significant for IBEX35's next period values.
ix.) The lagged values of exchange rate coefficient on their next month values are all significant at the level of 10 percent. The lagged values have a positive relationship to the next month's values. A 1 percent change of the euro against the dollar one month ago, should be followed by 0.187 change in its value next month according to the first bivariate model (exchange rate, ASE). A change of 1 percent of the euro against dollar should be followed by 0.210 change in its value next month according to the second bivariate model (exchange rate, IBEX35). Also at the third Bivariate VAR Model (the on including DAX Index) a change of 1 percent of the EUR/USD exchange rate one month ago will provide feedback of 0.254 percent for the value of the exchange rate one month later. (All else equal, holding all the other variables constant).

[18] Holding all other variables constant is a hypothetical assumption, (since VARs are dynamic, from a practical point of view it is impossible to change one predictor while holding all others fixed), and it is used for the sake of interpreting the VAR coefficients (the hypothetical impact they have on the ''independent variable'').

To make clear some of the economic implications that the results propose, the positive relation between the exchange rate and the lagged values of ASE, shows that the two variables move together. An increase ASE will have positive impact on the exchange rate moving the euro higher. However a higher euro means weaker exports. Because of that imports are becoming cheaper. A stronger ASE may be the result of financial reforms, depicting the country's financial performance to some extent. Of course there is a tradeoff here of pros and cons, but still the cons are more in the case of weaker euro. Greece is a country with negative trade balance 27 billion euros for 2014 *(OECD 2016)*. A depreciation of 1 percent in euro against dollar one lag before increases the ASE=Athens Greek Stock Market, the magnitude of that increase is 0.713 percent. (Which is not negligible...). The aforementioned reinforces the belief that exports become stronger. At least 47 percent of the Greek exports are to non-European countries according OEC (Observatory of Economic Complexity, 2016), therefore the weaker the euro the greater the purchasing power of the non-European countries. A decrease in the past values of ASE-Athens Stock Index should have a negative impact at the exchange rate, resulting in a weaker euro. Weaker euro for Greece means more tourism. Tourism is very important for Greece and it accounts for 70 percent of its ''exports''. Tourism is price sensitive and one to three visitors in Greece travels from outside the euro area. The ASE Index is positively related to its past values, so that an increase will be most probably followed by a subsequent increase, and a decrease by a subsequent decrease.

Regarding the second bivariate model and the case of Spain, an increase in the lagged values of the IBEX35 will have a positive impact on the exchange rate. Spain as well as Greece have a negative balance of trade and a strong euro does not help to increase the exports. For the same reason the imports have become cheaper but imports is not what those two countries need (since both have negative balance of trade)[19]. IBEX35 may increase because of positive developments of the Spanish economy though. Again there are pros and cons. The balance of trade for Spain was negative 33 billion euros for 2014 *(OECD 2016).* A depreciation 1 percent of euro against the dollar one lag before has positive impact on the IBEX-35 (0.520 percent, which is not small) and the Spanish exports. The 33 percent of the Spanish export are outside the European Union. Comparing the Spanish Stock Increase of 0.520 percent for a 1 percent decrease in euro, it makes sense to be less in percentage terms than the Athens Stock Index increase due to 1 percent decrease in euro since the second country has about

[19] Balance of Trade Chart, Appendix C.

half of total exports (47 percent) outside euro area whereas the first has about a third (33 percent) of total exports outside euro area, according to OEC -Observatory of Economic Complexity (2016). There is a positive relationship between IBEX-35 and its first lagged value. Also the exchange rate has a positive relationship to its first lagged value.

All of the assumptions made so far rely on the all else equal condition. The step followed after the VAR results is the Granger Causality discussion that gives the guidelines of the statistical relationship among the variables without the ‘’all else equal assumption’’ as a prerequisite and without definition in terms of positive or negative correlation.

7.2 Four-variable VAR Model

Since all the variables are I (1) we include their first differences in the VAR model. Also as it is the case in economics logged variables are used to estimate the percentage changes. Thus we have the VAR in Ln differences:

$$7.2.\quad \begin{bmatrix} \Delta LnE_t \\ \Delta LnXG_t \\ \Delta LnXS_t \\ \Delta LnXD_t \end{bmatrix} = \begin{bmatrix} \delta_e \\ \delta_g \\ \delta_s \\ \delta_d \end{bmatrix} + \begin{bmatrix} \varphi_{1e} & \varphi_{2e} & \varphi_{3e} & \varphi_{4e} \\ \varphi_{1g} & \varphi_{2g} & \varphi_{3g} & \varphi_{4g} \\ \varphi_{1s} & \varphi_{2s} & \varphi_{3s} & \varphi_{4s} \\ \varphi_{1d} & \varphi_{2d} & \varphi_{3d} & \varphi_{4d} \end{bmatrix} * \begin{bmatrix} \Delta LnE_{t-1} \\ \Delta LnXG_{t-1} \\ \Delta LnXS_{t-1} \\ \Delta LnXD_{t-1} \end{bmatrix} + \begin{bmatrix} U_{te} \\ U_{tg} \\ U_{ts} \\ U_{td} \end{bmatrix}$$

Notations: EUR/USD=E, Greek Stock Index= XG, Spanish Stock Index-IBEX35= XS, German Stock Index-DAX= XD, intercept=δ. Δ= Delta stands for the first difference.

Below (table 7.2) the VAR estimation results follow. At this table the notation is similar to the one referred at part 7.1 of the paper, this notation is used for the sake of simplicity. However in order to visualize the results of the four variable VAR created above in a more interactive way, additional information regarding the notation is provided below the table.

Table 7.2 : Four-variable VAR Model results				
Variables	Exchange rate (ΔLnE_t)	ASE ($\Delta LnXG_t$)	IBEX35 ($\Delta LnXS_t$)	DAX ($\Delta LnDAX_t$)
(ΔLnE_{t-1})	0.194*	-0.659	-0.461	-0.361
(p-value)	(0.071)	(0.126)	(0.129)	(0.176)
($\Delta LnXG_{t-1}$)	0.023	-0.180	-0.079	-0.041
(p-value)	(0.502)	(0.226)	(0.365)	(0.604)
($\Delta LnXS_{t-1}$)	0.097*	0.619**	0.213	0.294*
(p-value)	(0.062)	(0.017)	(0.253)	(0.066)
($\Delta LnDAX_{t-1}$)	0.020	0.172	0.048	0.026
(p-value)	(0.712)	(0.505)	(0.752)	(0.836)
Constant	-0.001	-0.017*	-0.002	0.006
(p-value)	(0.810)	(0.051)	(0.784)	(0.237)
Observations	117	117	117	117

*** p<0.01, ** p<0.05, * p<0.1

All the variables are in first differenced algorithms, P Value in parenthesis
Notations: EUR/USD=E, ASE-Greek Stock Index= XG, Spanish Stock Index-IBEX35= XS, intercept= constant.

The Results of the ''Four-variable VAR model'' are:

i.) $\Delta LnE_t = -0.001 + 0.194\ \Delta LnE_{t-1} + 0.023\ \Delta LnXG_{t-1} + 0.097\ \Delta LnXS_{t-1} + 0.020\ \Delta LnDAX_{t-1} + U_{te}$

ii.) $\Delta LnXG_t = -0.017 - 0.659\ \Delta LnE_{t-1} - 0.180\ \Delta LnXG_{t-1} + 0.619\ \Delta LnXS_{t-1} + 0.172\ \Delta LnDAX_{t-1} + U_{tg}$

iii.) $\Delta LnXS_t = -0.002 - 0.461\ \Delta LnE_{t-1} - 0.079\ \Delta LnXG_{t-1} + 0.213\ \Delta LnXS_{t-1} + 0.048\ \Delta LnDAX_{t-1} + U_{ts}$

iv.) $\Delta LnDAX_t = 0.006 - 0.361\ \Delta LnE_{t-1} - 0.041\ \Delta LnXG_{t-1} + 0.294\ \Delta LnXS_{t-1} + 0.026\ \Delta LnDAX_{t-1} + U_{td}$

According to the first time series equation the coefficient of the lagged Exchange rate (ΔLnE_{t-1}) is significant at 10 percent, suggesting that a change of 1 percent at the lagged value of the EUR/USD will be followed by a change of 0.194 percent at the next value of EUR/USD (all else equal). Also the lagged value of IBEX35 ($\Delta LnXS_{t-1}$) has a coefficient of 0.097 significant at 10 percent, indicating that a 1 percent change in lagged IBEX ($\Delta LnXS_{t-1}$) should be followed by 0.097 percent change in Exchange rate (ΔLnE_t) (all else equal).

The second equation results suggest a significant coefficient (at 5 percent) of the lagged IBEX35 ($\Delta LnXS_{t-1}$). Therefore a change of lagged IBEX35 ($\Delta LnXS_{t-1}$) by 1 percent should be followed by a change of 0.619 percent at the next period value of ASE ($\Delta LnXG_t$). Except that the value of the intercept is significant at 5 percent.

The third equation results do not suggest any significant relationship among the variables.

The fourth equation has only one significant coefficient (at 10 percent) the one of the lagged of IBEX35. Consequently a change of the lagged value of IBEX35 ($\Delta LnXS_{t-1}$) by 1 percent should be followed one period later by a change of 0.294 percent at the value of DAX Stock Index ($\Delta LnDAX_t$).

Also, although the lagged value of exchange rate (ΔLnE_{t-1}) is not significant (posing accuracy questions) for the Indices the p value found is close to 10 percent significance level and it is 12.6 percent, 12.9 percent and 17.6 percent, for ASE, IBEX35 and DAX respectively.(those p values could be considered as marginally significant).

The coefficients of the VAR models are only an approximation and a general idea based on all else equal assumption. Due to the theoretical nature of the coefficients, we should not elaborate more. Therefore as stated at the section 7.1 the Granger causality discussion should be used to shed light to the relationship among the variables, at least in terms of causality.

Since the sample size is not large enough to use the asymptotic χ^2 distribution, the t statistic (p value) provides more accurate results for the Granger causality test.

8. Granger Causality Discussion

8.1 Granger Causality Test: 3 bivariate model

The Granger causality Test is used to determine whether the lagged values of an explanatory variable provide feedback for the dependent variable (Granger, C.W.J, 1969).

The null hypothesis is that all coefficients of lagged variables are equal to zero, rejecting the null hypothesis would imply that a causal effect from the lagged values to the left-hand side variable cannot be rejected. The null hypothesis for the sake of notation is quoted as H_0. In the model, one lag is used in each equation. The null hypothesis testing for Granger causality running from ASE-Greek stock index (XG) to EUR/USD exchange rate (E) is tested by:

Null hypothesis H_0: $\Delta LnXG_{t-1}=0$

The coefficient estimates for $\Delta LnXG_{t-1}$ (lagged value of ASE-Greek stock index) is significantly different than zero. The result is significant at 1 percent, it has a low p value (0.005). Hence the lagged value of Greek stock index, Granger causes the next period's value of the EUR/USD exchange rate.

An identical test is constructed to test the Granger causality from EU/USD to the ASE (XG). This time the null hypothesis tests whether $\Delta LnE_{t-1}=0$. The result is not significant at the level of 10 percent, the p value is 0.114. Although the null hypothesis of no causality cannot be rejected, the p value is close to significant. However without a lenient approach the first bivariate VAR (variables: EUR/USD exchange rate, and XG-Greek stock index) shows unidirectional causality from the Greek stock index to exchange rate and not vice versa (though as already mentioned the result could be considered close to bidirectional).

Similarly for the second bivariate model under consideration the null hypothesis testing Granger causality from IBEX35 (XS) to exchange rate (E) is testing whether $\Delta LnXS_{t-1}=0$. The coefficient estimates for $\Delta LnXS_{t-1}$ (lagged value of Spanish stock index) is significantly different than zero. So the Spanish stock index-IBEX35 Granger causes the EUR/USD exchange rate, it provides feedback for the next period's value of exchange rate. The p value is significant at 1 percent. The null of $\Delta LnE_{t-1}=0$ is tested as well. The result show that EUR/USD exchange rate (E) Granger causes the Spanish stock index-IBEX35 (XS). The result is significant at the level of 10 percent. Therefore regarding the second bivariate VAR (variables: EUR/USD, IBEX35) there is a bidirectional causality.

The third bivariate model under consideration is testing granger causality from DAX (DAX) to exchange rate (E) and vice versa. The null of $\Delta LnDAX_{t-1}=0$ is tested. The result is significant at the level of 1 percent. So the lagged values of DAX provide significant feedback for the next period's values of EUR/USD exchange rate. The opposite direction Granger causality is tested for the null of $\Delta LnE_{t-1}=0$. The Granger causality test result shows that the EUR/USD exchange rate does not Granger cause the DAX-German stock index. The result is insignificant at the level of 10 percent (p value=0.144). Therefore regarding the third bivariate VAR model there is a unidirectional causality running from the DAX index to the exchange rate and not vice versa.

To sum up, bidirectional Causality is present at the second bivariate model above (EUR/USD and IBEX35-XS). This bidirectional Causality is in conjunction to previews research by Ajayi and Mogoue (1996) ,Ajayi, Friedman & Mehdian (1998) research for Taiwan, Bahmani-Oskooee & Sohrabian (1992) for United States, Mukherjee T.K. and Naka 1995 paper for Japan, Soenen & Hennigan (1988, United States), Tabak Miranda Benjamin (2006, Brazil) and Granger et al. (2000, Hong Kong, Malaysia, Singapore, Thailand, Taiwan).

On the other hand, the results suggest one way Granger causality (unidirectional causality) for the second the third bivariate VAR. The lagged values of ASE Granger cause next period's values of EUR/USD exchange rate however the lagged values of EUR/USD exchange rate do not Granger cause the next period's values of ASE-Greek stock index. Additionally, the lagged value of the DAX Granger causes Exchange rate. The Exchange rate does not Granger cause the DAX Index. The results of the first and the third bivariate model are in conjunction to previews studies, Ajayi R.A. and & Mehdian (1998) research for Phillipines and Indonesia, Nieh & Lee (2001) for Japan and Italy, Solnic (1987) and Abdalla & Murinde (1997) for Phillipines all of them found unidirectional causality from Stock Price to Exchange rates.

8.2 Granger Causality Test: 4 Variable-VAR Model

The null hypothesis for the sake of notation is quoted as H_0 .In this model, one lag is used in each equation. The null hypothesis for the specification of the Exchange rate is the following:

Null hypothesis H_0: ϕ_{ie}[20]= 0

Except its own lagged value only the lagged value of IBEX35-Spanish stock index (ΔXS_{t-1}) provides feedback for the exchange rate (E). Therefore Spanish index Granger causes EUR/USD exchange rate. No causality is found running from ASE or DAX to EUR/USD exchange rate. Also no causality is found from EUR/USD exchange rate to ASE and DAX.

[20] The i= 1…4. Refer to page 28, 7.2 matrix format equation. (Lagged Exchange Rate=1, lagged ASE-Greek index=2, lagged IBEX35-Spanish index=3, lagged DAX-German index.)

8.3 Granger Causality Summary

The Granger Causality results suggest that the results of the first ''Three Bivariate VAR Model'' causality results are different from the second ''Four-variable VAR model'', however a great part of the causality results is the same in both tests, If there were not the close to significant p values. The models are reinforcing the belief that causality actually exists. Since the results change at the second model this proposes that the statistical relationships seem to be a little more complicated and the results should be approached with caution.

However, a very important result is that both models dictate Causality running from IBEX35 Stock Index (XS) to EUR/USD Exchange rate (E). Furthermore, the three bivariate VAR models suggest unilateral Causality running from ASE Stock Index (XG) to EUR/USD exchange rate and unilateral Granger causality running from DAX-German stock index to EUR/USD exchange rate (E). Whereas the ''Four-variable VAR model finds no other Granger causality except that running from the IBEX35-Spanish index to the EUR/USD exchange rate (E). Table 8.3 summarizes the results.

Table 8.3: Granger Causality Summary

Granger Causality Indices vs EUR/USD Exchange rate	ASE-Exchange rate (ΔLnXGt) (ΔLnEt)	IBEX35-Exchange rate (ΔLnXSt) (ΔLnEt)	DAX-Exchange rate (ΔLnDAXt) (ΔLnEt)
Bivariate Models 10percent significance	→	← →	→
Four-variable VAR model 10percent significance		→	

The arrows from the left hand side to the right hand side above show that Granger causality is running from the stock indices to the eur/usd exchange rate. The arrow from the right hand side to the left hand side shows that causality is running from the eur/usd exchange rate to the index.

The Granger causality does change from the one model to the other, the relationship that remains ''intact'' is the unilateral between the Spanish Stock Index-XS and the EUR/USD exchange rate.

Noteworthy is that in almost all of the cases considered the exchange rate does not Granger cause Stock Indices. The only exception comes when considering Granger causality from EUR/USD exchange rate to IBEX35-Spanish index at the three Bivariate VAR models where the p value is significant (p value=0.076). Most of the times when considering Granger causality from exchange rate to Stock Indices the results are not significant but close to significant, indicating that there might be causality but the p value is not small enough to support this. The vast majority of previews papers supports the existence of such causality running from exchange rates to stock indices. (Aggarwal 1981, Ajayi 1996, Bahmani-Oskooee 1992, Mukherjee 1995, Soenen & Hennigan 1988, Abdalla & Murinde 1997, Dornbusch & Fisher 1980). Both ''Three Bivariate VAR Models'' and ''Four-variable VAR Model'' reinforce the belief of Causality from Spanish index to EUR/USD exchange rate.

The four-variable VAR model does not provide significant results. This may be due to multicollinearity. Multicollinearity tests are performed[21]. The tests indicate the presence of moderate multicollinearity which could be the reason of the insignificant results found at the four-variable VAR model. The F test shows that the null hypothesis of zero coefficients for all the variables simultaneously is rejected at 1% significance level[22]. The result supports that there is significant feedback provided by the right hand side variables of the four variable model, as soon as we consider them together. Therefore this reinforces the belief of multicollinearity and the results of both models should be treated with caution.

Next the table 8.4 follows for informational purposes and just for understanding the dynamics. Table 8.4 depicts the statistical relationships among the Indices. That specific output comes from the four-variable VAR model. The Spanish Stock Index- XS Granger causes ASE-XG and German Stock Market-DAX. The results show that IBEX35 has the strongest influence among the variables under consideration.

Table 8.4: Causality among the Indices

Granger Causality	ASE-IBEX35		ASE-DAX		IBEX35-DAX	
Among Indices	($DLnXG_t$)	($DLnXS_t$)	($DLnXG_t$)	($DLnDAX_t$)	($DLnXS_t$)	($DLnDAX_t$)
Four-variable VAR model 10 percent significance	←		_		→	

The arrow from the left hand side to the right hand side shows Granger causality running from the Spanish index to the German. The Arrow from the right hand side to the left hand side depicts Granger causality running from the Spanish stock index to the Greek stock index-ASE.

9. Conclusion

The Greek debt crisis and its effects on the European Union is the main reason for conducting this research. The purpose of the paper is to analyze the relationship between the EUR/USD exchange rate and the lagged values of ASE-Athens Stock Index, as well as the relationship to the opposite direction

[21] Multicollinearity test results Appendix E
[22] Appendix F, F test.

meaning the lagged values of EUR/USD to ASE-Athens Stock Index. Similarly as a measure of comparison the IBEX35-Spanish Stock Index and DAX-German Stock Index are employed, to check their statistical relationship to EUR/USD.

To serve the purpose of checking the statistical relationship of the variables under consideration three Bivariate VAR models are created, one for each country. In order to provide supplementary results to the Bivariate VAR Models a four-variable VAR model is formulated.

The Granger causality test results for the first bivariate show that there is Granger causality from Greek stock market-ASE to the next period value of the EUR/USD exchange rate which is significant at the level of 1 percent. On the other hand the null hypothesis of no causality running from the EUR/USD exchange rate to the Greek stock index cannot be rejected, however the result is close to significant (p value=0.114).

Bidirectional causality is found for the second bivariate VAR model. The Granger causality test results for the second bivariate show that there is Granger causality from the Spanish stock index-IBEX to the next period value of the EUR/USD exchange rate which is significant at the level of 1 percent. Similarly there is Granger causality from the EUR/USD exchange rate to the Spanish index at the 10 percent level of significance.

Unidirectional Granger causality is found between the DAX-German stock index and the EUR/USD exchange rate. Specifically the Granger causality runs from DAX to EUR/USD exchange rate and the result is significant at 1 percent level of significance. Whereas the null hypothesis of zero coefficient cannot be rejected when considering the converse, since the result is insignificant at the level of 10 percent (p value= 0.144).

The ''Four-variable VAR model'' results show Granger causality running from the Spanish stock index-IBEX35 to the EUR/USD exchange rate. All the other Granger tests between the indices and EUR/USD exchange rate are insignificant. However it is worth mentioning, that as it was the case for the ''Three bivariate VAR models'' the Granger causality running from EUR/USD exchange rate to the indices is close to significant. (The p values are close to the significance threshold of 10 percent).

Spain seems to have more impact on exchange rate than Greece. This is rational since its economy is seven times larger in terms of GDP than the Greek. Another reason is that the markets have already accounted for the worst case scenario for Greece and the impact of the country developments or failures is much less than the impact of larger economies (since Greece represents less than 2 percent of the European economy).

Regarding the method used, taking the first difference to induce stationarity to the variables, means that some information is lost in the long run. This issue is addressed by Toda-Yamamoto test, Hacker and Hatemi (2003) agree that the test is attractive due to its simple application, the absence of pre-testing distortions and its basis on the standard asymptotical distribution irrespective of the cointegrating properties and the number of unit roots of the data. Another possible option to improve the accuracy and the validity of the test results is to increase the sample size in order to decrease the standard errors, and produce more accurate parameter estimates (remedy for multicollinearity).

To sum up, the results propose significant relationships, especially strong relationship is present when considering Granger causality running from IBEX35 Stock Index to EUR/USD Exchange rate, since both models suggest it. Unidirectional causality running from Indices to exchange rate is in conjunction with previews papers from Ajayi , Friedman & Mehdian (1998) for Indonesia and Phillipines, Nieh and Lee (2001) for Italy and Japan, Abdalla and Murinde (1997) for Phillipines, Stavarek (2004) for Czech Republic, Hungary, Poland, Slovakia and USA, Wickremasinghe (2006) for Sri Lanka, and Bokhari (2013) for Pakistan.

Equally important finding is that the EUR/USD exchange rate in the vast majority of the tests has close to significant results (we could suspect the moderate presence of multicollinearity to responsible for not rejecting the null). However the p value dictates that only the Spanish index is influenced by exchange rate on the bivariate VAR model, that finding corroborates the previews studies from Aggarwal (1981) for USA, Ajayi, Friedman and Mehdian (1998) for Korea, Nieh and Lee (2001) for Canada, Germany and UK, Granger et al (2000) for South Korea and Philippines, and Yu Quiao (1997) for Hong Kong, Abdalla and Murinde (1997) for Pakistan, Korea and India.

The Bidirectional Granger causality found at the second bivariate VAR model (EUR/USD, IBEX35) corroborates the previews studies from Ajayi & Mogoue (1996), Ajayi R.A. ,Friedman and Mehdian (1998) for Taiwan, Mukherjee and Naka (1995) for Japan , Soenen and Hennigan (1988) for United States and Quiao (1997) for Japan and Bokhari (2013) for Bangladesh and Nepal.

References

Abdalla, I.S.A., and Murinde, V. (1997).Exchange rate and stock prices interactions in emerging financial markets: evidence on India, Korea, Pakistan and the Philippines. *Applied Financial Economics*, volume 7, 25-35.

Aggarwal, R., (1981). Exchange rates and Stock Prices: A study of the US capital market under floating exchange rates. *Akron business economic review*. 7-12.

Ajayi R.A., Mougoue M. (1996) .On the dynamic relation between stock prices and exchange rates. *Journal of Financial Research*, 19, 193-207.

Ajayi R.A., Friedman J. and Mehdian S.M. (1998). On the Relationship between Stock Returns and Exchange rates: Tests of Granger Causality. *Global Finance Journal*, 9(2), pp. 241-251.

Asteriou, D., Hall, S., G., (2007). *Econometrics: A Modern Approach.* London: Palgrave Macmillan. 279.

Bahmani-Oskooee, M., Sohrabian A., (1992*). Stock Prices and the Effective Exchange rate of the Dollar*. Applied Economics. 459-464.

Bloomberg. (2016). *Greece Govt Bond 10 Year Acting as Benchmark.* Retrieved March 19, 2015, from: http://www.bloomberg.com/quote/GGGB10YR:IND

Bokhani, H., (2013). Social Relationship between Exchange Rate and Stock Prices, a case on SAARC economies. *Academy of Contemporary Research Journal, 2,* 175-181.

Deutsche Bundesbank. (n.d). *Turnover in German foreign exchange trading falls short of global trend*. Retrieved January 10, 2015, from: https://www.bundesbank.de/Redaktion/EN/Topics/2013/2013_09_10_foreign_exchange.html?nn=151264

Dornbusch, R., and Fisher, S., (1980). Exchange rates and the Current Account*. American Economic Review*, 70, No. 5, 547-644.

Frank, P., and Young A. (1972). Stock Price Reaction of Multinational Firms to Exchange Realignments*. Financial Management*. 66-73

Frankel, J. A., (1983). *"Monetary and Portfolio-Balance Models of Exchange Rate Determination".* In Bhandar, J. S. and Putman, B. H., ed. Economic Interdependence and Flexible Exchange Rates (Mass.: The MIT Press). 84-115.

Gujarati, Porter. (2009). *Basic Econometrics International 5th edition*. New York: McGraw-Hill/Irwin; 789p.

Hacker, S., Hatemi, J., (2003). *Tests for Causality between Integrated Variables Using Asymptotic and Bootstrap Distributions*. (Lund University Department of Statistics Research paper No 2003:02). Lund: Lund University Department of Statistics

Ihsan, A., Baloch, Q.B., Jan, S.K., (n.d). Relationship between Exchange Rate and Stock Market Index: Evidence from Pakistani Stock Market. *Abasyn Journal of Social Sciences*, 8, 17-34.

Jorion, P., (1990). The exchange rates exposure of US. Multinationals*. Journal of Business* 63; 331-345.

Krugman, P., (2011). *International Economics Theory & Policy*. 9th edition. United States of America: Prentice Hall; 320.

Meese R., A., Rogoff, K., (1983). *Empirical Exchange rate Models of the Seventies*. Do they fit out of Sample? .North Holland Publishing Company; 3-24.

Mukherjee, T.K., and Naka A. (1995). Dynamic Relations between Macroeconomic Variables and the Japanese Stock Market: An Application of a Vector Error Correction Model. *Journal of Financial Research*, Vol. 18, No.2, 223.

Nicita, Al. (2015). *Key Statistics and Trend in International Trade*. Geneva*: UNCTAD (United Nations Conference & Development)*; 1.

Nieh, C., Lee, C. (2001). Dynamic relationship between stock prices and exchange rates for G7 countries. *Quarterly Review of Economics and Finance 41*; 477-490.

Observatory of Economic Complexity. *''Country: Spain, Visualizations''*. [WWW] OEC. Available from: http://atlas.media.mit.edu/en/profile/country/esp/ (Accessed January 2016)

OECD, Organization for Economic Cooperation and Development. (n.d). *International Trade Balance*. Retrieved January 05, 2015, from: http://stats.oecd.org/index.aspx?queryid=166

Ratner, M., (1993). A Cointegration Test of Impact of Foreign Exchange Rates on U.S. Stock Market Prices. *Global Finance Journal*, 4, 93-101.

Rehn Commissioner (2010, April). *Statement by Commissioner Rehn on Greece*. Retrieved November 16, 2015, from: http://ec.europa.eu/economy_finance/articles/eu_economic_situation/2010-04-29-statement-commissioner-rehn-on-greece_en.htm).

Reilly, F.,Norton, E., A., (2003). *Investments* (6th ed.). Canada: Thomson & South-western. 428.

Sims, C., (1980). Macroeconomics and Reality. *Econometrica,* 48, 1-48.

Solnik, B., (1987*).*Using Financial Prices to Test Exchange rate Models- A Note. *Journal of Finance*. 42, 141-149p.

Statista. *Greece: National Debt from 2002 to 2020 (in billion euros)*. Retrieved September 15, 2015, from: http://www.statista.com/statistics/270409/national-debt-of-greece/

Stavarek, D., (2004): Stock Prices and Exchange rates in the EU and the USA: Evidence of their Mutual Interactions. Published in: Finance a úvěr - *Czech Journal of Economics and Finance* , Vol. 55, No. 3-4 (2005): pp. 141-161.

Tabak M., B., (2006). *The Dynamic Relationship between Stock Prices and Exchange rates (evidence for Brazil)*. Banco de Brazil. 3-4.

Trading Economics. *Greece Stock Market ASE*. Retrieved January 5, 2016, from http://www.tradingeconomics.com/greece/stock-market

Wall Street Journal. *The Numbers: Greece's Debt*. Retrieved July 30, 2015, from: http://blogs.wsj.com/briefly/2015/07/03/greeces-debt-the-numbers/

Wickremasinghe, G., (2011*).*The Sri Lankan stock market and the macro economy: an empirical investigation*. Studies in Economics and Finance*, Vol. 28,179 – 195.

Yu, Q., (1997*).* Experience in Leading East Asian Financial Center Tokyo, Hong Kong and Singapore*. Singapore Economic Review*, 41, 47-56.

The citation methods used at this paper are according the APA (Harvard) system of referencing, for books, journals, online sources etc.

Appendix A.

Optimal lag length selection Logged Eur/Usd								
lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	138.292				0.005377	-2.378	-236.382	-236.382
1	264,824	253,06	1	0	0,000606	-4,57085	-4,55148	-4,52312
2	271,519	13,39	1	0	0,000549	-4,6699	-4,64083	-4,59829
3	271,543	0,04663	1	0,829	0,000558	-4,65291	-4,61416	-4,55744
4	274,794	6,5033	1	0,011	0,000537	-4,69207	-4,64363	-4,57273

Optimal lag length selection Logged ASE-Athens Stock Index								
lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	-163,853				0,334796	1,78219	1,78925	1,7996
1	183,426	694,56	1	0	0,008236	-1,96136	-1,94725	-1,92655
2	183,726	0,59933	1	0,439	0,008299	-1,95379	-1,93263	-1,90157
3	183,73	0,00852	1	0,926	0,008388	-1,94303	-1,91481	-1,8734
4	189,204	10,947	1	0,001	0,007992	-1,99139	-1,95612	-1,90435

Optimal lag length selection Logged IBEX35- Spanish Stock Index

lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	12,104				0,51893	-0,1207	-0,11361	-0,10322
1	264,053	503,9	1	0	0,003392	-2,8484	-2,83424	-2,81346
2	264,673	1,2409	1	0,265	0,003406	-2,84428	-2,82303	-2,79186
3	264,82	0,29384	1	0,588	0,003438	-2,835	-2,80668	-2,76511
4	265,845	2,0495	1	0,152	0,003437	-2,83527	-2,79986	-2,74791

Optimal lag length selection Logged German Stock Index-DAX								
lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	-56,176				0,10864	0,61812	0,625175	0,635528
1	249,137	610,63*	1	0,000	0,00404*	-2,67175*	-2,65764*	-2,63694*
2	250,042	1,810	1	0,179	0,00405	-2,67072	-2,64956	-2,61850
3	250,140	0,196	1	0,658	0,00409	-2,66097	-2,63275	-2,59134
4	251,257	2,234	1	0,135	0,00409	-2,66224	-2,62697	-2,57520

Optimal lag length selection for the first bivariate model EUR/USD to ASE-Athens Stock Index both logged.

lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	27,6284				0,002195	-0,44571	-0,42634	-0,39797
1	384,809	714,36	4	0	4,70E-06	-6,58799	-6,52986	-6,44478
2	395,483	21,347	4	0	4,20E-06	-6,70405	-6,60716	-6,46536
3	397,346	3,7275	4	0,444	4,40E-06	-6,66689	-6,53126	-6,33273
4	403,427	12,162	4	0,016	4,20E-06	-6,70308	-6,52869	-6,27344

Optimal lag length selection for the first bivariate model EUR/USD to ASE-Greek Stock Index both differenced (to induce stationarity) and logged.

lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	372,056				5.2e-06	-6,492	-6,473	-6,444
1	385,781	27	4	0,000	4.4e-06*	-6,66282*	-6,60437*	-6,51881*
2	386,737	1,913	4	0,752	4.6e-06	-6,609	-6,512	-6,369
3	392,850	12,227*	4	0,016	4.5e-06	-6,647	-6,510	-6,310
4	393,203	0,706	4	0,951	4.7e-06	-6,583	-6,407	-6,150

Optimal lag length selection for the second bivariate model EUR/USD to IBEX35-Spanish Stock Index both logged.

lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	159,957				0,00022	-2,74708	-2,7277	-2,69934
1	438,662	557,41	4	0	1,90E-06	-7,52456	-7,46643	-7,38135
2	450,878	24,431	4	0	1,60E-06	-7,66744	-7,57056	-7,42875
3	453,289	4,8219	4	0,306	1,60E-06	-7,6398	-7,50417	-7,30564
4	458,076	9,5749	4	0,048	1,60E-06	-7,6535	-7,47911	-7,22386

Optimal lag length selection for the second bivariate model EUR/USD to IBEX35-Spanish Stock Index both differenced (to induce stationarity) and logged.

lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	425,115				2.0e-06	-7,423	-7,404	-7,375
1	441,230	32,229*	4	0,000	1.7e-06*	-7,63561*	-7,57717*	-7,4916*
2	442,383	2,306	4	0,680	1.7e-06	-7,586	-7,488	-7,346
3	445,352	5,938	4	0,204	1.8e-06	-7,568	-7,431	-7,232
4	445,575	0,446	4	0,979	1.9e-06	-7,501	-7,326	-7,069

Optimal lag length selection for the third bivariate model EUR/USD to DAX-German Stock Index both logged.

lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	148,423				0,000	-2,546	-2,527	-2,498
1	443,422	590	4	0,000	1.7e-06	-7,607	-7,549	-7,464
2	454,797	22,750	4	0,000	1.5e-06	-7,736	-7,63871*	-7,49691*
3	459,246	8,899	4	0,064	1.5e-06	-7,743	-7,608	-7,409
4	464,230	9,967*	4	0,041	1.5e-06*	-7,76051*	-7,586	-7,331

Optimal lag length selection for the third bivariate model EUR/USD to DAX-German Stock Index both differenced (to induce stationarity) and logged.

lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	432,788				1.8e-06	-7,558	-7,538	-7,510
1	444,613	23,649*	4	0,000	1.6e-06*	-7,69496*	-7,63652*	-7,55095*
2	446,736	4,247	4	0,374	1.6e-06	-7,662	-7,565	-7,422
3	448,679	3,885	4	0,422	1.7e-06	-7,626	-7,490	-7,290
4	451,210	5,063	4	0,281	1.7e-06	-7,600	-7,425	-7,168

Optimal lag length selection ''Four Variables VAR Model'' (all the variables logged and differenced)								
lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	790,267				1.2e-11	-13,794	-13,7552*	-13,6981*
1	814,879	49,225*	16	0.000	1.0e-11*	-13,945*	-13,7504*	-13,4652*
2	824,195	18,6320	16	0,2880	1.2e-11	-13,828	-13,477	-12,964
3	834,366	20,3420	16	0,2050	1.3e-11	-13,726	-13,219	-12,478
4	843,804	18,8760	16	0,2750	1.5e-11	-13,611	-12,948	-11,979

Appendix B.

Table 1.

Variable	lags	ADF-Statistic	p-value
logged ASE_(lclose)	4	-1.004	0.7520
differenced logged ASE_(dlclose)	1	-9.349	0.0000
logged IBEX35_(lsclose)	1	-2.034	0.2718
differenced logged IBEX35_(dlsclose)	1	-9.857	0.0000
logged EUR/USD_(leusd)	4	-3.049	0.1190
differenced logged EUR/USD_(dleusd)	1	-6.890	0.0000
logged DAX_(ldax)	1	-0.778	0.8254
differenced logged DAX_(dldax)	1	-9.584	0.0000

MacKinnon approximate p-value for Z(t).

Table 2. Logged Exchange rate Unit Root Test (at the 4th lag)

Augmented Dickey-Fuller test for Unit Root				
	Test Statistic	1percent Crit.Value	5percent Crit.Value	10percent Crit.Value
Z(t)	-3.049	-4.035	-3.448	-3.148

MacKinnon approximate p-value for Z(t) = 0.1190

Table 3. First Differenced Logged Exchange rate Unit Root Test

Augmented Dickey-Fuller test for Unit Root				
	Test Statistic	1percent Crit.Value	5percent Crit.Value	10percent Crit.Value
Z(t)	-6.890	-3.505	-2.889	-2.579

MacKinnon approximate p-value for Z(t) = 0.0000

Table 4. Logged ASE Unit Root Test (at the 4th lag)

Augmented Dickey-Fuller test for Unit Root				
	Test Statistic	1percent Crit.Value	5percent Crit.Value	10percent Crit.Value
Z(t)	-1.004	-3.482	-2.884	-2.574

MacKinnon approximate p-value for Z(t) = 0.7519

Table 5. First Differenced ASE Unit Root Test

Augmented Dickey-Fuller test for Unit Root				
	Test Statistic	1percent Crit.Value	5percent Crit.Value	10percent Crit.Value
Z(t)	-9.349	-3.481	-2.884	-2.574

MacKinnon approximate p-value for Z(t) = 0.0000

Table 6. Logged IBEX35 Unit Root Test (at 1st lag)

Augmented Dickey-Fuller test for Unit Root				
	Test Statistic	1percent Crit.Value	5percent Crit.Value	10percent Crit.Value
Z(t)	-2.034	-3.481	-2.884	-2.574

MacKinnon approximate p-value for Z(t) = 0.2718

Table 7. First Differenced Logged IBEX35 Unit Root Test

Augmented Dickey-Fuller test for Unit Root				
	Test Statistic	1percent Crit.Value	5percent Crit.Value	10percent Crit.Value
Z(t)	-9.857	-3.482	-2.884	-2.574

MacKinnon approximate p-value for Z(t) = 0.0000

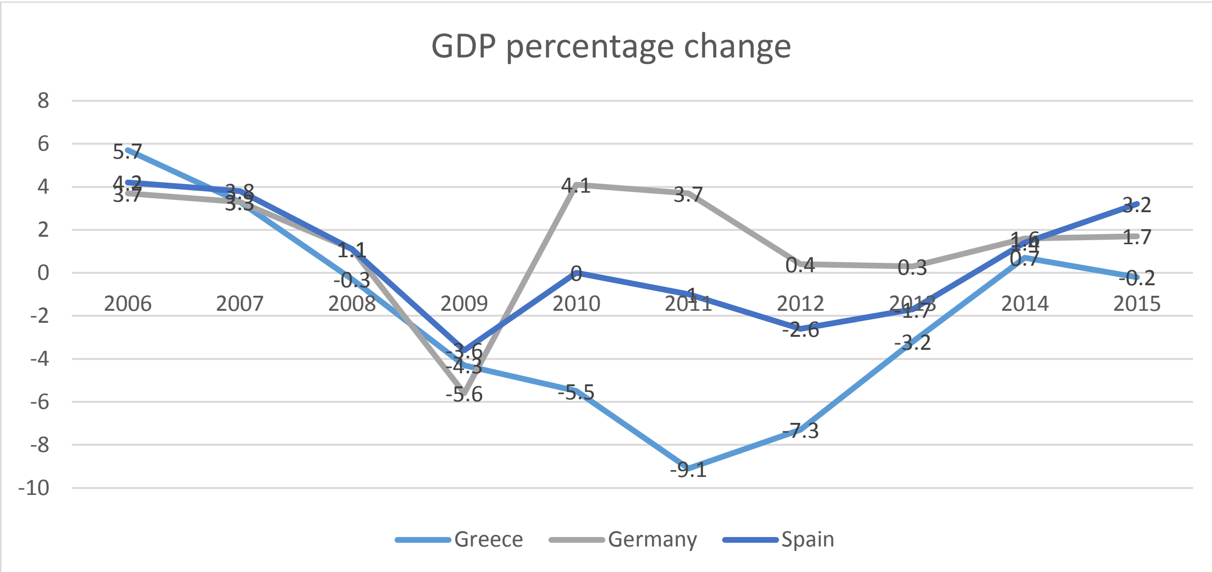
Table 8.Logged DAX Unit Root Test (at 1^{st} lag)

Augmented Dickey-Fuller test for Unit Root				
	Test Statistic	1% Crit.Value	5% Crit.Value	10% Crit.Value
Z(t)	-0.778	-3.481	-2.884	-2.574
MacKinnon approximate p-value for Z(t) = 0.8254				

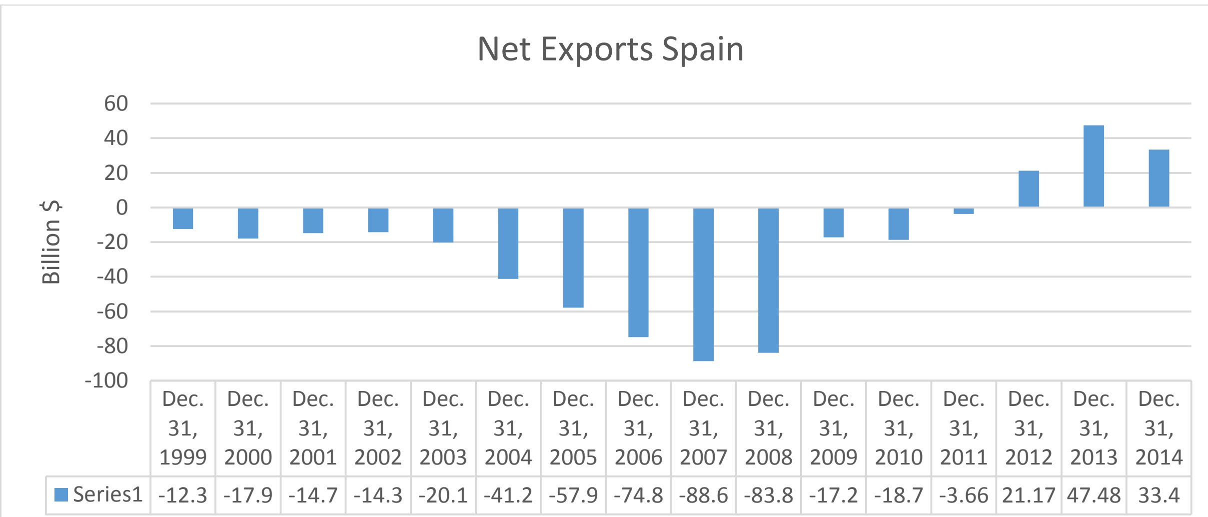
Table 9. First Differenced Logged DAX Unit Root Test

Augmented Dickey-Fuller test for Unit Root				
	Test Statistic	1% Crit.Value	5% Crit.Value	10% Crit.Value
Z(t)	-9.584	-3.481	-2.884	-2.574
MacKinnon approximate p-value for Z(t) = 0.0000				

Appendix C.



	Dec. 31, 1999	Dec. 31, 2000	Dec. 31, 2001	Dec. 31, 2002	Dec. 31, 2003	Dec. 31, 2004	Dec. 31, 2005	Dec. 31, 2006	Dec. 31, 2007	Dec. 31, 2008	Dec. 31, 2009	Dec. 31, 2010	Dec. 31, 2011	Dec. 31, 2012	Dec. 31, 2013	Dec. 31, 2014
Series1	15.69	5.25	34.41	90.97	91.80	142.0	144.7	159.0	228.0	224.0	169.0	177.0	181.0	208.0	217.0	248.0



Appendix D.

Ho: Homoscedasticity

Ha: Heteroscedasticity

P value <10percent (0.10), Null hypothesis (Ho) is rejected.

Four-variable VAR model (''Independent Variable'' Exchange rate_EUR/USD)

Breusch-Pagan / Cook-Weisberg test for heteroskedasticity Ho: Constant variance Variables: fitted values of dleusd
chi2(1) = 2.21
Prob > chi2 = 0.1370

Four-variable VAR model (''Independent Variable'' German Stock Index-DAX)

Breusch-Pagan / Cook-Weisberg test for heteroskedasticity Ho: Constant variance Variables: fitted values of dldax
chi2(1) = 2.88
Prob > chi2 = 0.0897

Four-variable VAR model (''Independent Variable'' Greek Stock Index-ASE)

Breusch-Pagan / Cook-Weisberg test for heteroskedasticity Ho: Constant variance Variables: fitted values of dlclose
chi2(1) = 0.16
Prob > chi2 = 0.6856

Four-variable VAR model (''Independent Variable'' Spanish Stock Index- IBEX35)

Breusch-Pagan / Cook-Weisberg test for heteroskedasticity Ho: Constant variance Variables: fitted values of dlsclose
chi2(1) = 0.01
Prob > chi2 = 0.9122

First Bivariate Model (EUR/USD, ASE) Heteroskedasticity Tests:

Breusch-Pagan / Cook-Weisberg test for heteroskedasticity Ho: Constant variance Variables: fitted values of dleusd
chi2(1) = 5.37
Prob > chi2 = 0.0205

Breusch-Pagan / Cook-Weisberg test for heteroskedasticity Ho: Constant variance Variables: fitted values of dlclose
chi2(1) = 2.70
Prob > chi2 = 0.1006

Second Bivariate Model (EUR/USD, IBEX35) Heteroskedasticity Tests:

Breusch-Pagan / Cook-Weisberg test for heteroskedasticity
Ho: Constant variance
Variables: fitted values of dleusd
chi2(1) = 2.01
Prob > chi2 = 0.1560

Breusch-Pagan / Cook-Weisberg test for heteroskedasticity
Ho: Constant variance
Variables: fitted values of dlsclose
chi2(1) = 0.07
Prob > chi2 = 0.7859

Third Bivariate Model (EUR/USD, DAX) Heteroskedasticity Tests:

Breusch-Pagan / Cook-Weisberg test for heteroskedasticity
Ho: Constant variance
Variables: fitted values of dleusd
chi2(1) = 4.38
Prob > chi2 = 0.0363

Breusch-Pagan / Cook-Weisberg test for heteroskedasticity
Ho: Constant variance
Variables: fitted values of dldax
chi2(1) = 1.33
Prob > chi2 = 0.2482

Appendix E.

Multicollinearity Test Results

Variable	VIF	1/VIF
ldlsclose	2.70	0.369729
ldlclose	2.67	0.373872
ldldax	2.10	0.477096
ldleusd	1.16	0.859682
Mean VIF	2.16	

Appendix F.

F Test-Overall coefficients significance Test

Four-variable VAR model

F(4, 112)	7.10
Prob > F	0