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THE INFLUENCE OF UNCERTAINTY ON MARKET EFFICIENCY: EVIDENCE FROM SELECTED EUROPEAN FINANCIAL MARKETS[3]

The purpose of this study is to determine if the capital markets of fourteen European countries are efficient or not. Additionally, we examine the impact of VIX and GEPU returns on the market efficiency of the analyzed capital markets. We apply the Augmented Dickey-Fuller (ADF) test and Threshold GARCH (TGARCH) Model. The period under examination is 2003-2016. Our results show that the explored European markets are highly integrated, and in the context of the Efficient Market Hypothesis (EMH), a division along the line of the developed-developing market has been revealed. The Bulgarian capital market shows a strong degree of integration with the other explored economies in the conditions of EMH. The efficiency of the explored markets is improved by adding to the model VIX and GEPU returns. We prove that diversification can be achieved based on emerging markets of the EU Member States. Prolonged periods of low volatility can further reduce correlations, encouraging further risk-taking.
Keywords: Efficient Market Hypothesis; VIX; GEPU; capital markets volatility; financial crisis
JEL: C22; G01; G14; G15; G32

1. Introduction

According to financial risk management theories, the efficient market hypothesis (EMH) is of primary importance because it can be considered as an element in building an Early Warning System for an upcoming financial crisis. After the global financial crisis of 2008, the following question was raised: „Do unusual levels of financial market volatility imply an increased likelihood of a subsequent financial crisis?“ (Danielsson, Valenzuela, Zer, 2016).

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Volatility is important for option traders because it affects options prices. Generally, higher volatility makes options more valuable, and vice versa.

There are two types of volatility: realized and implied. Realized volatility reflects the historical price and fluctuations of the asset. Implied volatility is always forward-looking. It is the expected volatility from now until the option's expiration. The volatility index (VIX) is one of the most popular measurement tools for stock market volatility. VIX measures the 30-day volatility implied by the S&P 500 stock index option prices. Market risk can be low when volatility is low. However, low volatility could be a catalyst for market participants to take on more risk, making the financial system more fragile. This is defined as a phenomenon known as the instability/volatility paradox (volatility paradox).

The financial crisis has created big volatility in the stock prices that induces a restriction in the reflection of full information. Therefore, this situation is a challenge for Efficient Market Hypothesis. According to Efficient Market Hypothesis (EMH), stock prices should always show a full reflection of all available and relevant information and follow a random walk process. Undoubtedly, the global financial crisis of 2008 has affected the efficiency of the capital markets in Europe and the USA.

Efficient Market Hypothesis (EMH) was developed independently by Paul A. Samuelson and Eugene F. Fama in the 1960s. Also, Fama (1965) defined three forms of the informational efficiency of the capital market: weak-form (future prices of the financial assets cannot be estimated using the past values), semi-strong form (current prices reflect all the public information available about the assets), and strong form (current prices reflect all public and non-public information about the assets). In the EMH, one of the important and crucial dogmas is the idea about the information efficiency of the markets. It assumed that the market prices quickly reflect all available information. According to the information efficiency, the market prices are unpredictable and follow a random walk while all information is reflected in the prices. The most common violation of the EMH is that of its weak form, namely that future prices of the financial assets cannot be estimated using the past values.

The main aim of this article is to examine the market efficiency of CAC 40 (France), DAX (Germany), FTSE 100 (The United Kingdom), BEL 20 (Belgium), WIG (Poland), BUX (Hungary), PX (Czech Republic), SOFIX (Bulgaria), BET (Romania), ATHEX20 (Greece), PSI-20 (Portugal), ISEQ-20 (Ireland), IBEX35 (Spain) and Italy (FTSE MIB) on the one hand and the impact of VIX and GEPU returns on the market efficiency of these capital markets on the other hand. The object of the study is the group of fourteen European capital markets – France, Germany, The United Kingdom, Belgium, Poland), Hungary, Czech Republic, Bulgaria, Romania, Greece, Portugal, Ireland, Spain and Italy. The subject of our study is the market efficiency of CAC 40 (France), DAX (Germany), FTSE 100 (The United Kingdom), BEL 20 (Belgium), WIG (Poland), BUX (Hungary), PX (Czech Republic), SOFIX (Bulgaria), BET (Romania), ATHEX20 (Greece), PSI-20 (Portugal), ISEQ-20 (Ireland), IBEX35 (Spain) and Italy (FTSE MIB) considering also the impact of VIX and GEPU returns on the market efficiency of these capital markets. The analyzed period is 2003-2016. We apply the Augmented Dickey-Fuller (ADF) test to estimate the stationary of the examined variables. To test if the capital markets are efficient or not, we apply the Threshold GARCH (TGARCH) Model.

Our results show that the explored European markets are highly integrated, and in the context of the EMH, a division along the line of the developed-developing market has been revealed. The efficiency of the explored markets is improved by adding to the model VIX and GEPU returns. We prove that diversification can be achieved based on emerging markets of EU Member States. Our research study could provide useful and important information for investors on these capital markets. Additionally, our study is relevant for all key players in the capital markets. Prolonged periods of low volatility can further reduce correlations, encouraging further risk-taking. This pro-cyclical behaviour increases investors' risk of losing a systematic shock as volatility jumps and asset-return correlations return to historical levels. Low volatility, corresponding to deteriorating market performance, can directly affect market risk. During such a period, investors underestimate the likelihood of a possible upcoming jump in volatility and financial distress. As far as we know, this is the first research that estimates the simultaneous influence of GEPU and VIX on the market efficiency of the European markets. Estimating the influence, we prove that the expected volatility is an objective assessment of the actual volatility of the return, and therefore, during a market turmoil, VIX is likely to react hastily, which in turn corresponds to investor nervousness and brings potential profits to the options seller.

2. Literature Review

Matteo and Gunardi (2018) study some of the most important market anomalies in France, Germany, Italy, and Spain stock exchange indexes in the first decade of the new millennium (2001-2010) by using statistical methods: the GARCH model and the OLS regression. The analysis doesn't show strong proof of comprehensive Calendar Anomalies and some of these effects are country-specific. Cristi and Cosmin (2018) intend to identify the main studies in the literature that has as the main objective the analysis of the integration of financial systems. The results of the studies are heterogeneous – on the one hand, integration of financial systems is indicated, and, on the other hand, a high degree of heterogeneity is integrated. Also, the recent studies prove that financial markets show a strong correlation between them by applying the methods and models of modern financial technologies and financial deregulation (Jebran et al., 2017; Okičić, 2015; Baumöhl et al., 2018; Huo and Ahmed, 2017; Panda et al., 2019; BenSaïda et al., 2018).

Simeonov (2020) makes a comprehensive stock profile for four of the most popular East Asian stock exchanges-Tokyo, Hong Kong, Taiwan, and Shanghai, for the period 2007-2019. Simeonov (2020) concludes that the global financial crisis of 2008 has a significant and lasting negative impact only on the price component of the stock exchange profiles, while the stock exchange activity of the studied exchanges remains completely unaffected. Simeonov and Peneva (2020) conclude that the investment activity of the Athens Stock Exchange and that of the Bulgarian Stock Exchange experienced a significant decline in the years after the 2008 crisis, with some of the measures showing a variable improvement from 2016 on. What is more, all initial and analytical indicators of stock exchange activity are shown a dozen times a better activity on the Greek Stock Exchange. Viewed and calculated as investors' activity average per capita, the differences across all measures are significantly smaller.

Armeanu and Cioaca (2014) test the EMH in the case of Romania for the period from 2002 to 2014 using four methods, including the GARCH model. They find out that the Romanian capital market is not weak-form efficient. Dragota and Oprea (2014) test the Romanian stock market's informational efficiency and they establish that the predictability of returns suggests that the Romanian stock market has a low level of efficiency. Furthermore, the impact of new information is more intense before and after its release.

Zdravkovski (2016) examines the impact of the 2008 financial crisis on the interconnection among the SEE stock markets (Macedonian, Croatian, Slovenian, Serbian, and Bulgarian) and he finds out no evidence of cointegration between studied markets during the pre- and post-crisis periods. However, during the 2008 financial crisis, the empirical findings support the existence of three cointegration vectors. This means that the recent global financial crisis and the subsequent euro crisis strengthened the connection between the investigated stock markets. Furthermore, the analysis reveals that during periods of financial turmoil, the Macedonian stock market is positively and actively influenced by the Croatian and Serbian markets. A significant implication of these results is that the integration between SEE stock markets tends to alter over time, particularly during stages of financial disturbances.

Joldes (2019) investigates the volatility of daily returns in the Romanian stock market over the period from January 2005 to December 2017. The conditional volatility for the daily return series shows clear evidence of volatility shifting over the period. In the course of the examination, we discovered that there is a great influence of international stock markets on the capital market operations in Romania.

Chiang (2019) examines the efficient market hypothesis by applying monthly data for 15 international equity markets. With the exceptions of Canada and the US, the null for the absence of autocorrelations of stock returns is rejected for 13 out of 15 markets. The evidence also rejects the independence of market volatility correlations. The null for testing the absence of correlations between stock returns and lagged news measured by lagged economic policy uncertainty (EPU) is rejected for all markets under investigation. The evidence indicates that a change of lagged EPUs positively predicts conditional variance.

Yeap and Gan (2017) propose the conceptual framework of stock market efficiency in economic uncertainty. According to the authors, the economic uncertainty, can be categorized into exchange rate uncertainty, monetary policy uncertainty (namely, interest rate uncertainty, money supply uncertainty), inflation uncertainty, and output uncertainty, and is associated with the stock market efficiency. They prove that economic uncertainty contains useful information and is important in determining the stock market efficiency and could promote better efficiency in stock market.

Ruan (2018) explores the influence of market volatility (VIX index) on the stock market and then empirically analyses the stock index data of several countries. The empirical results show that the VIX index has a significant impact on the linkage between stock markets. The VIX index is easy and more intuitive to obtain, providing another way for the dynamic linkage research between the market, which can provide investors with some guidance and advice when conducting financial activities such as diversification.

Traykov et al. (2018) apply the comparative analysis in the continuing quest to find and adapt better practices for management risk, which leads to increased profits and competitiveness of firms. We showed a good and easy risk management using R Language, which can be useful for a happy and successful career. Trenchev et al. (2019) claim that using 3D modelling is an important tool in teaching students to find alternative solutions for different issues. This technology can be used also in the field of financial markets.

3. Methodology and Data

In this study, we explore fourteen EU Member States (France, Germany, The United Kingdom, Poland, Hungary, Czech Republic, Belgium, Bulgaria, Romania, Greece, Portugal, Ireland, Spain, Italy). The variables that we use, represent the capital market indexes for the following countries: France (CAC 40), Germany (DAX), The United Kingdom (FTSE 100), Belgium (BEL 20), Poland (WIG), Hungary (BUX), Czech Republic (PX), Bulgaria (SOFIX), Romania (BET), Greece (ATHEX20), Portugal (PSI-20), Ireland (ISEQ-20), Spain (IBEX35) and Italy (FTSE MIB). We choose the EU countries listed above based on the following criteria: countries with a developed capital market, the values of which CDS during the crisis of 2008 has not to suffer significant changes (UK, Germany, France, and Belgium, Poland, Hungary, Czech Republic); countries with relatively developing capital markets (emerging markets), which CDS spreads grow immediately after the crisis, but their values gradually decrease during the debt crisis (Bulgaria, Romania); countries with emerging capital markets which CDS spread reaches peak values – “problem countries” (distressed countries) (Greece, Portugal, Ireland, Italy, and Spain). A country’s index data is obtained from the internet sources of their capital markets. The data is with monthly frequency. The explored period is March 2003 – June 2016.

We use Global Economic Policy Uncertainty Index (GEPU). The GEPU Index is a GDP-weighted average of national EPU indices for 21 countries: Australia, Brazil, Canada, Chile, China, Colombia, France, Germany, Greece, India, Ireland, Italy, Japan, Mexico, the Netherlands, Russia, South Korea, Spain, Sweden, the United Kingdom, and the United States. Each national EPU index reflects the relative frequency of own-country newspaper articles that contain a trio of terms about the economy (E), policy (P), and uncertainty (U). In other words, each monthly national EPU index value is proportional to the share of own-country newspaper articles that discuss economic policy uncertainty in that month.

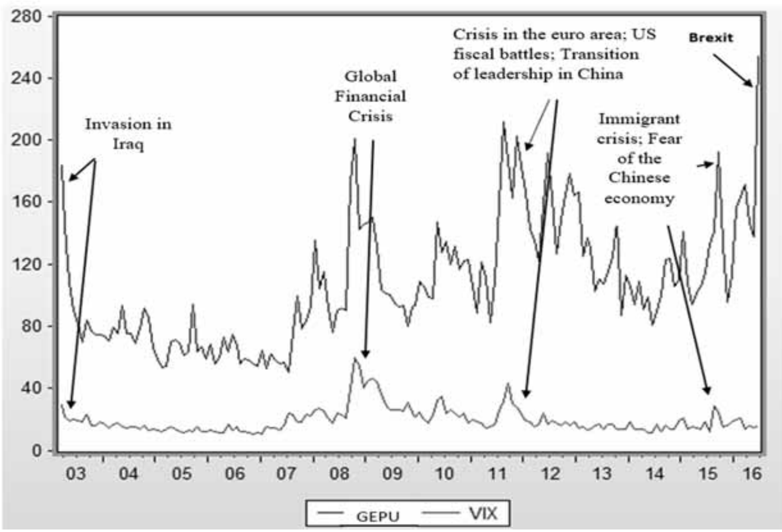
The volatility index (VIX) is a popular measure of the stock market’s expectation of volatility based on S&P 500 index options. It is calculated and disseminated on a real-time basis by the CBOE (Chicago Board Options Exchange) and is often referred to as the fear index or fear gauge. Low VIX values do not necessarily indicate that there is impending financial stress. A high level of VIX suggests more fear. Volatility is often measured as the standard deviation of historical returns and it is used as a proxy for risk (Markowitz, 1952).

In 1993 Chicago Board Options Exchange (CBOE) introduced the volatility index, also known as VIX. After the recent 2008 financial crisis, financial media regularly report on VIX dynamics along with stock market indices dynamics. Whaley (1993) suggests that the VIX provided a “reliable estimate of expected short-term market volatility. Additionally, Whaley (2009) argues that the main attraction was its forward-looking nature, “measuring volatility that investors expect to see”. We can assume that VIX is the investors’ sentiment index and it is the barometer of future stock market risk. In general, VIX is constructed using observed option prices. The market participant buys call/put options to hedge/trade the volatility, and the same observed option price is used to derive VIX in real-time (Shaikh and Padhi, 2015). Additionally, Whaley (2000) points out that a high level of VIX is observed due to the high degree of market turmoil.

We divide the explored period into two sub-periods: Period 1 – crisis period (March 2003 – September 2011) and Period 2 (September 2011 – June 2016). The division above was made based on the peak values of VIX and GEPU in 2011, which were significantly higher than in 2008. The division above was made based on the peak values of VIX and GEPU in 2011, which was higher than in 2008 (GEPU) or almost equal to the level in 2008 (VIX). The dynamic of the explored indexes of uncertainty is exposed in Graph 1.

Graph 1

Dynamics of GEPU and VIX for the period 2003-2016



Source: Authors' estimation, based on the data from https://ww2.cboe.com/products/vix-index-volatility/vix-options-and-futures/vix-index/vix-historical-data and https://www.policyuncertainty.com/global_monthly.html.

GEPU index rapidly increases as a response to the US invasion of Iraq in 2003; the global financial crisis of 2008; the European migrant crisis and fear about China's economy at the end of 2015; and The Brexit referendum in June 2016. GEPU fluctuates around consistently high levels from mid-2011 until the beginning of 2013. This period is characterized by recurring debt and banking crises in the Eurozone, intense battles over fiscal and health policy in the United States, and the transition to General leadership in China. The average value of GEPU index is 60% higher during the period July 2011 – August 2016 than in the previous fourteen years period. What is more, the average value of GEPU index in July 2011 is 22 percent higher than in 2008-2009, when policymakers faced the worst economic crisis since the Great Depression of the 1930s. These results suggest that policy-related issues have become a major source of economic uncertainty in recent years.

Graph 1 shows two high values for VIX, coinciding with the mortgage crisis in 2008, and instability in the US in 2011. VIX dynamics present cyclical periods of small and large changes with irregular intervals. Sudden upward spikes of VIX are followed by a relatively slow return to the average value. Low values of VIX do not necessarily mean that severe financial stress is unlikely to occur.

We can make two important remarks here. First, there is historically a strong relationship between the two variables – GEPU and VIX. Second, the dynamics of GEPU and VIX are not synchronized for the period 2013-2016. Graph 1 can be used to target the vulnerability of capital markets, given that based on such measures, capital markets do not reflect deteriorating conditions.

The data used in this study is the following: monthly values of the studied stock indices, VIX, GEPU for the period 03.03.2003 – 01.07.2016 and we calculate the return of these variables:

$$r_t = \ln\left(\frac{P_t}{P_{t-1}}\right) \tag{1}$$

Where:

r_t - the return of the explored variable at time t;

PI_t – the value of the variable at time t;

PI_{t-1} - the value of the variable at time t-1.

We apply the ADF test to estimate stationarity. We prove that all variables are stationary in the form dlog (x) i.e. variables were integrated of order 1.

- **Argument Dickey-Fuller Test**

The Augmented Dickey-Fuller (ADF) test constructs a parametric correction for higher-order correlation by assuming that the y series follows an AR (p) process and adding p lagged difference terms of the dependent variable y to the right-hand side of the test regression:

$$\Delta y_t = \alpha y_{t-1} + x_t^{'}\delta + \beta_1 \Delta y_{t-1} + \beta_2 \Delta y_{t-2} + ... + \beta_p \Delta y_{t-p} + \nu_t \tag{2}$$

- **The Threshold GARCH (TGARCH) Model**

TARCH or Threshold ARCH and Threshold GARCH were introduced independently by Zakoïan (1994) and Glosten, Jaganathan, and Runkle (1993). The generalized specification for the conditional variance is given by:

$$\sigma_t^2 = \omega + \sum_{j=1}^{q} \beta_j \sigma_{t-j}^2 + \sum_{i=1}^{p} \alpha_i \varepsilon_{t-i}^2 + \sum_{k=1}^{r} \gamma_k \varepsilon_{t-k}^2 I_{t-k} \tag{3}$$

where $I_t = 1$ if $\varepsilon_t < 0$ and 0 otherwise.

In this model, good news, $\varepsilon_{t-i} > 0$, and bad news $\varepsilon_{t-i} < 0$, have differential effects on the conditional variance; good news has an impact on α_i, while bad news has an impact $\alpha_i + \gamma_i$. If $\gamma_i > 0$ bad news increases volatility, and we say that there is a *leverage effect* for the i-th order. If $\gamma_i \neq 0$, the news impact is asymmetric.

We use TGARCH(p,q) for testing the market efficiency of the examined capital markets and the impact of VIX and GEPU returns on the market efficiency. The selection of values p and q for used models is based on testing different combinations of values by applying the Likelihood ratio hypothesis test (LRHT) and Akaike information criteria (AIC) test. The output combinations of parameters p and q are determined by the maximum value of 2 for both parameters and thus tested are the following combinations: (1,1), (2,1), (1,2), and (2,2). We have tested the following distributions: Normal (Gaussian), Student's t, Generalized Error, Student's t with fixed df and GED with fixed parameter. The selection procedure tries to find a combination of the two parameters that leads to more successful modelling of the studied data. The appropriate model has been chosen for each index.

Table 1

The most appropriate TGARCH model for the study of individual stock indices in the analyzed periods

Indices	Period 1 – crisis period (March 2003-September 2011)	Period 2 (September 2011-June 2016)
CAC 40	TGARCH(2,1)- t	TGARCH(2,1)- t
DAX	TGARCH(2,2)- t	TGARCH(2,1)- t
FTSE 100	TGARCH(1,1)- t	TGARCH(1,2)- t
BEL 20	TGARCH(2,1)- t	TGARCH(2,2)- t
WIG	TGARCH(2,1)- t	TGARCH(2,1)- t
PX	TGARCH(1,2)- t	TGARCH(2,2)- t
BUX	TGARCH(1,1)- t	TGARCH(1,1)- t
SOFIX	TGARCH(1,1)- t	TGARCH(2,1)- t
BET	TGARCH(2,1)- t	TGARCH(2,2)- t
ATHEX20	TGARCH(1,2)- t	TGARCH(1,2)- t
PSI-20	TGARCH(1,1)- t	TGARCH(1,1)- t
ISEQ-20	TGARCH(2,1)- t	TGARCH(1,1)- t
IBEX35	TGARCH(2,2)- t	TGARCH(2,1)- t
FTSE MIB	TGARCH(2,1)- t	TGARCH(2,1)- t

Source: Authors' Calculations.

We can represent the return model as follows:

$$Y_t = C + \phi_1 Y_{t-1} + \varepsilon_t + \phi_2 X_{t-n} \tag{4}$$

Where:

C – regression constant;

Y_{t-1} – the return of the index in time $t-1$;

ϕ_1 и ϕ_2 – regression coefficients;

X_{t-n} – the return of VIX index and GEPU in measurement $t-n$

Information efficiency as an indicator will be measured by the value of the coefficient of persistence, which determines the impact of disturbances of previous periods on volatility in the research period. High values of this coefficient indicate low information efficiency, which is expressed in the slower inclusion of information in the market and vice versa at low values of this coefficient.

4. Results

4.1. Analysis of the coefficient of persistence

The assumption that there is a leverage effect (Black, 1976) in stock markets indicates a tendency for changes in the price of financial assets, and these changes are negatively correlated with changes in the volatility of the same assets.

Our analysis of the values of coefficients of persistence is based on the Efficient Market Hypothesis (EMH) assumptions, namely: low coefficients of persistence indicate a high degree of information efficiency. Thus, a lower coefficient of persistence values confirms the weak form of EMH. Based on the following researches, we accept that the mean values of the coefficient of persistence are a reliable measure of efficiency: Simeonov (2015), Tsenkov and Georgieva (2016), Abonongo et al. (2016).

We can separate the examined indices into two groups according to the values of the coefficient of persistence for period 1. To examine the market efficiency, we have calculated an average arithmetic value of the coefficients of the persistence of all the studied indices for the crisis period 1. In our case, it has a value of 0.91:

- Indices with relatively high market efficiency (the value of their coefficient of persistence is below 0.91);
- Indices with relatively low market efficiency (the value of their coefficient of persistence is higher than 0.91).

The first group contains the following indices – DAX, FTSE 100, IBEX 35, ATHEX, BEL 20, WIG, PX, BET, and PSI 20 indices with coefficients of persistence below 0.91 (Table 2). To put it another way, the indices from the first group are relatively highly efficient. These results show that there is a decrease in the impact of market shocks on volatility dynamics.

The second group includes CAC 40, BUX, ISEQ-20, SOFIX, and FTSE MIB which coefficients of persistence are higher than 0.91 (Table 2). What is more, these indices above are with relatively low market efficiency. The higher value of coefficients of persistence represents the change in the response of shocks to volatility persistence, which implies that the response of volatility increases with time.

In summary, it should be noted that the capital markets of Germany, France, The United Kingdom, Poland, the Czech Republic, Spain, Greece, Belgium, Romania, and Portugal are relatively informationally efficient. The most efficient is the Greek capital market with the coefficient of persistence (0.804904). The positive statistically significant values of leverage coefficients are in the range between 0.113571 (PX) and 0.280531 (WIG).

Table 2

The indices with relatively high market efficiency and their coefficients of persistence below 0,91 and leverage coefficients for period 1

Index	Coefficient of persistence < 0.91	Leverage coefficient
DAX	0.853706	0.220670*
FTSE 100	0.842815	0.238910*
WIG	0.873201	0.280531*
PX	0.892861	0.113571*
IBEX 35	0.865174	-0.156829
ATHEX	0.804904	0.183728
BEL 20	0.888098	-0.439441
BET	0.854704	0.261555**
PSI 20	0.883428	-0.069209
CAC 40	0.903009	0.149206*

*Notes: *, ** denote statistical significance at the 1% and 5% respectively.*
Source: Author's Calculations.

Table 3 presents the values of the coefficient of persistence and leverage coefficient for the capital markets with relatively low market efficiency for crisis period 1. We can conclude that Bulgarian, Italian, and Irish capital markets are relatively informationally inefficient markets compared to the other examined markets. Also, we register the highest value of the coefficient of persistence for the Irish index (1.100299). Leverage coefficients are positive and statistically significant for ISEQ-20.

Table 3

The indices with relatively low market efficiency and their coefficients of persistence higher than 0.91 and leverage coefficients for period 1

Index	Coefficient of persistence > 0.91	Leverage coefficient
ISEQ-20	1.100299	0.502254**
SOFIX	0.981382	-0.026806
FTSE MIB	1.003057	0.340572
BUX	0.993480	0.102803

*Notes: *, ** denote statistical significance at the 1% and 5% respectively.*
Source: Authors' Calculations.

Similarly, we can separate the examined indices into two groups according to the values of the coefficient of persistence for period 2. Again, to examine the market efficiency, we have calculated an average arithmetic value of the coefficients of the persistence of all the studied indices for the post-crisis period 2. In this case, it has a value of 0.93:

- Indices with relatively high market efficiency (the value of their coefficient of persistence is below 0.93);
- Indices with relatively low market efficiency (the value of their coefficient of persistence is higher than 0.93).

Based on the results presented in Table 4, we prove that most of the studied stock indices are efficient considering their coefficients of persistence which are below 0.93. It should be noted that despite the increase in the number of efficient capital markets with a lower coefficient of persistence for period 2 compared to period 1, the average value of the coefficient of persistence for period 1 is lower than the average value of the coefficient of persistence for period 2.

Table 4

The indices with relatively high market efficiency and their coefficients of persistence below 0.93 and leverage coefficients for period 2

Index	Coefficient of persistence < 0.93	Growth rate	Leverage coefficient
BEL 20	0.887135	-0,11%	-0.428131
BET	0.850104	-0,54%	0.310524**
CAC 40	0.890612	-1,37%	0.130323**
DAX	0.808175	-5,33%	0.200558**
FTSE 100	0.853702	1,29%	0.214602**
IBEX 35	0.873406	0,95%	-0.160335**
PSI 20	0.890351	0,78%	-0.070425
SOFIX	0.882015	-10,12%	-0.072651
WIG	0.862835	-1.18%	0.213501*
PX	0.923518	3.43%	0.116802*

*Notes: *, ** denote statistical significance at the 1% and 5% respectively.*
Source: Authors' Calculations.

Comparing the results for both periods, we prove that the developed capital markets are efficient – DAX, CAC 40, FTSE 100, BEL 20, WIG and PX. These results may be explained by the high integration of these financial markets. We observe the lowest value of the coefficient of persistence in the German DAX. This may be explained by the good performing of Germany after the financial crisis. This is proved by the income per capita growth, which corresponds with growth in employment.

The different performance of the financial markets of Poland, Hungary and the Czech Republic may be explained with the difference in the privatization process of these countries resulted in significant changes in their stock market structures. While Hungary remained completely stable in terms of the number of stocks listed, Poland maintained an upward trend and the Czech Republic a declining trend. The relative abruptness of the Czech Republic privatization process led to many newly-listed companies gradually fading from the scene (Corredor et al., 2015).

Despite the proven improvement in the market efficiency of the Bulgarian SOFIX during period 1 and period 2, the main shortcomings of the Bulgarian capital market continue to be related to low liquidity, a small volume of freely traded shares, high transaction costs, limited internet trading and small retail investors. Low liquidity is a major drawback of the capital market in Bulgaria. It is due to the small volume of freely traded shares, as well as the outflow of foreign investors from the Bulgarian capital market during the financial and economic crisis. The limitations that operate at the institutional level are related to the lack of a functioning clearing system, without which the development of the derivative market in Bulgaria cannot take place, the large differences of the Bulgarian capital market compared to developed European capital markets, lack of political will for change, etc. The impact of problematic factors, such as high levels of corruption, limited access to finance and the low efficiency of institutions, on market efficiency can also be taken into account here.

Despite the undeniable and indisputable progress and development of the Romanian capital market and the improvement of its efficiency considering period 1 and period 2 factors such as the slow and unfinished privatization process, weak interest from foreign investors, low liquidity trading have a negative impact on the market efficiency of this stock exchange.

Comparing the efficiency of the emerging markets (Bulgarian and Romania) between period 1 and period 2, we observe a higher level of information efficiency during the crisis period (period 1) because these markets follow the negative market news that leads to long-term market trends.

We register positive statistically significant values for leverage coefficient of BET, CAC 40, DAX, FTSE 100, WIG, and PX and only the leverage coefficient of Spanish index IBEX 35 is with a negative value (-0.160335).

Table 5

The indices with relatively low market efficiency and their coefficients of persistence higher than 0.93 and leverage coefficients for period 2

Index	Coefficient of persistence > 0.93	Growth rate	Leverage coefficient
ATHEX	1.218971	51,44%	0.174261
ISEQ-20	1.093603	-0,61%	0.523026**
FTSE MIB	1.012835	0,97%	0.385705
BUX	0.983568	-1%	0.253826*

*Notes: *, ** denote statistical significance at 1% and 5% respectively.*
Source: Authors' Calculations.

We can conclude that Greek, Italian, Hungarian, and Irish capital markets are relatively informationally inefficient markets compared to the other examined markets.

The most inefficient capital market in the group is the Greek market, with a coefficient of persistence (1.218971). Probably the main reason for the market inefficiency of the Greek stock exchange is the fact that at the end of 2009, the Greek economy was facing one of the most severe crises due to a combination of international and domestic factors. Some of these factors are related to the Greek state budget, which is poorly structured and balanced, with a high annual deficit. To finance this deficit, Greece is forced to regularly assume new government debt, and thus the country's net debt is constantly increasing. The sovereign debt crisis, in turn, lowers the country's credit rating, and it is deprived of access to cheap capital resources on the free financial market, which in turn further aggravates the situation and Greece is unable to finance its budget deficit, which inevitably affects and on market efficiency.

We observe high levels of inefficiency in Irish and Italian stock markets. These results assume that the investors do not have the same levels of information to predict future returns, which lead to problems of asymmetric information in these financial markets. Besides the inefficient capital markets, during the explored period, these countries are characterized by high current account and budget deficits, high levels of unemployment which may be considered as a result of slow output realization. The financial markets of the aforementioned countries are highly influenced by the solvency problems. Actually, we proved that during the explored periods, some of the financial markets from the PIIGS are considered as efficient and others as inefficient, these results prove that despite considering this group of countries as homogenous, there are differences that may be based on the regime on public expenditures, tax revenues.

We register two statistically significant leverage coefficients (ISEQ-20 – 0.523026 and BUX – 0.253826).

It can be assumed that during period 1 and period 2 for the inefficient markets, new information has a strong impact on volatility (see the values of the leverage coefficient in tables 3 and 5), but this influence is significant for a small group of markets which is proved by the results of the statistical significance of the leverage coefficients. Here, it should be clarified that the leverage ratio in the BUX registered a strong positive significant value for period 2, which shows that market news leads to a significant reduction of volatility, marking the presence of a strong negative trend, further strengthened by short-term market news.

4.2. Analysis of the change of coefficient of persistence considering the impact of VIX and GEPU returns

The validity of efficient market prices is challenged by the lack of information, the lack of knowledge, and the lack of experience. Under the market uncertainty theorem, market behaviour is interpreted with reference to market prices and market uncertainty (Slovik, 2011). This is the main reason that we explore the relationship between the market uncertainty theorem and the EMH in the context of revealing the impact of GEPU and VIX on the coefficients of persistence.

Based on the results of the AIC test for the whole period under examination, presented in Table 6 we can conclude the following:

- If the AIC for the model with VIX is lower than the base model, then we conclude that the uncertainty measure matter. Including in the model of stock returns the VIX and GEPU returns, it increases the explanatory power of the model. The only exception is the Belgian stock index BEL 20. To sum up, information influences from VIX and GEPU returns affect the returns of the studied stock indices to the extent that they are explanatory variables, which leads to a significant improvement in the explanatory power of econometric models covering the returns from the studied European stock indices for the period 2003-2016.
- Registering identical results as a manifestation of the use of returns from VIX and GEPU as an explanatory variable concerning stock indices leads to the conclusion that there is a common mechanism for reflecting the information influences of these indicators. This reconfirms the results of Danielsson, Valenzuela, Zer (2016). They also prove that volatility causes financial stress in stock markets.

Table 6

The change of coefficient of persistence considering the impact of VIX and GEPU returns for the whole period under examination

Index	Coefficient of persistence	With VIX	With GEPU
ATHEX	1.838203	1.723665	1.588395
AIC	-7.497055	-6.100906	-6.101060
BET	0.895839	0.986595	0.895683
AIC	-2.402907	-2.242266	-2.362008
BEL 20	1.015379	1.015724	1.016758
AIC	-5.913716	-5.921241	-5.908017
CAC	0.828806	0.762835	0.817735
AIC	-3.358353	-3.874047	-3.460944
DAX	0.666247	0.657432	0.573075
AIC	-3.121344	-3.127424	-3.156653
FTSE 100	0.756942	0.886743	0.756297
AIC	-3.875027	-3.340955	-3.875625
IBEX 35	0.795043	0.790578	0.845945
AIC	-3.139067	-3.458924	-3.179145
ISEQ-20	0.942459	0.865063	0.655654
AIC	-3.102656	-3.395003	-3.458247
PSI 20	0.863198	0.842642	0.841712
AIC	-3.724335	-3.701927	-3.788168
SOFIX	0.849258	0.894234	0.892531
AIC	-2.577884	-2.479014	-2.675238
FTSE MIB	0.951364	0.938610	0.918452
AIC	-4.81427	-4.903557	-5.622138
WIG	0.783280	0.762830	0.768290
AIC	-3.26801	-3.15728	-3.06258
PX	0.798361	0.792146	0.772835
AIC	-4.28153	-4.03861	-3.81650
BUX	0.903541	0.900341	0.883508
AIC	-5.28161	-5.01461	-2.93816

Notes: AIC – Akaike Information Criterion
Source: Author's Calculations.

The results for the change in the values of the coefficient of persistence are presented in Table 6. We can assume that adding the VIX and GEPU returns in the model of stock returns leads to an increase in its information efficiency, except for the Belgian stock index BEL 20. Based on the results, we show that uncertainty influences stock prices and that corresponds to an influence on the stock market efficiency. These results prove the conclusions of Yeap and Gan (2017). The dynamics of the VIX have a stronger impact on the volatility and return of CAC and IBEX 35, rather than the on other stock indexes. When we include GEPU return in the TGARCH model, the values of coefficient of persistence decrease for the stock indices ATHEX, BET, DAX, FTSE 100, ISEQ-20, PSI20, SOFIX, WIG, PX, BUX and FTSE MIB. We consider this as evidence of the presence of information impact of GEPU and its rapid absorption in the values of the above indices, since the decrease in the coefficient of persistence is a consequence of increased information efficiency, i.e. accelerated inclusion of new information in the index values.

Considering the results presented in Tables 7 and 8, we find out that the use in the model of ATHEX, BEL 20, FTSE 100, IBEX 35, ISEQ-20, DAX, CAC 40, SOFIX, reflecting the return of VIX and GEPU leads to the more significant increase in its explanatory power in period 1 than in period 2. We can summarize that in Period 1, which is the crisis period, the information influences of VIX and GEPU have such an impact on stock indices, that explanatory variables are leading to an improvement in their efficiency.

Table 7

The change of coefficient of persistence considering the impact of VIX and GEPU returns for period 1

Index	Coefficient of persistence	With VIX	With GEPU
ATHEX	0.804904	0.803271	0.800196
AIC	-2.059136	-2.264831	-2.984650
BET	0.854704	0.958594	0.874634
AIC	-1.937541	-1.96005	-1.987346
BEL 20	0.881098	0.825405	0.809295
AIC	-5.342185	-5.441273	-5.540523
CAC	0.903009	0.943559	0.822287
AIC	-3.399026	-3.257475	-3.416777
DAX	0.853709	0.807655	0.873401
AIC	-3.052084	-3.062769	-3.043736
FTSE 100	0.842815	0.803913	0.783805
AIC	-3.814811	-4.308056	-3.837846
IBEX 35	0.865174	0.816519	0.831486
AIC	-2.973561	-3.333096	-3.201461
ISEQ-20	1.100299	0.980888	0.882468
AIC	-2.917598	-3.000664	-3.173071
PSI 20	0.883428	0.920016	0.933585
AIC	-3.222176	-3.143341	-3.196074
SOFIX	0.981382	0.996802	0.980602
AIC	-2.176525	-1.999665	-2.248392
FTSE MIB	1.003057	1.003084	1.012864
AIC	-4.182465	-4.182454	-4.248315
WIG	0.873201	0.852813	0.872651
AIC	-3.97051	-3.02810	-3.26502
PX	0.892861	0.882857	0.852802
AIC	-6.21357	-6.03581	-5.28136
BUX	0.993480	1.280275	1.357601
AIC	-5.88214	-6.28351	-6.73405

Source: Authors' Calculations.

We observe a decrease in the values of coefficient of persistence by adding VIX and GEPU return in the model for ATHEX, BEL 20, FTSE 100, IBEX 35, WIG, PX and ISEQ-20 in period 1. We register a decrease in the values of coefficient of persistence due to the influence of VIX and GEPU for BET, DAX, IBEX 35, FTSE MIB for period 2 (2011-2016), which is characterized by more pronounced "bottoms" of volatility.

Table 8
The change of coefficient of persistence considering the impact of VIX and GEPU returns for period 2

Index	Coefficient of persistence	With VIX	With GEPU
ATHEX	1.218917	1.219361	1.028031
AIC	-5.083261	-5.014328	-5.213681
BET	0.850101	0.823671	0.834672
AIC	-4.810352	-4.990235	-4.853468
BEL 20	0.887135	0.903261	0.928034
AIC	-3.281745	-3.257025	-2.890352
CAC	0.890612	0.873025	0.894231
AIC	-6.380253	-7.873261	-6.320421
DAX	0.808175	0.793265	0.801365
AIC	-3.263451	-3.482731	-3.203216
FTSE 100	0.853702	0.832472	0.862041
AIC	-3.817266	-4.028351	-3.528031
IBEX 35	0.873406	0.870324	0.854281
AIC	-2.356710	-2.356931	-2.568903
ISEQ-20	1.093603	1.203805	0.983416
AIC	-5.680341	-4.890454	-5.936028
PSI 20	0.890351	0.892165	0.873571
AIC	-9.110412	-9.035724	-9.281435
SOFIX	0.882015	0.870451	0.932816
AIC	-2.961531	-3.210814	-2.713852
FTSE MIB	1.012835	1.002148	0.983251
AIC	-2.280415	-2.351826	-4.218351
WIG	0.862835	0.860520	0.782135
AIC	-3.35016	-3.28019	-3.02145
PX	0.923518	0.883528	0.892831
AIC	-4.28351	-3.61871	-3.89281
BUX	0.983568	1.093417	1.283506
AIC	-3.88415	-4.28573	-4.61058

Source: Authors' Calculations.

5. Conclusion

The explored European markets are highly integrated, and in the context of the EMH, a division along the line of the developed-developing market has been proven. The relative efficiency of the developed economies during the examined period has been established. The Bulgarian capital market shows a strong degree of integration with the other explored economies in the conditions of EMH. In summary, the capital markets of Germany, The United Kingdom, Poland, the Czech Republic, Spain, Greece, Belgium, Romania and Portugal are relatively informationally efficient for period 1 in terms of the weak form of EMH. The most efficient one in the group is the Greek capital market for period 1. We can conclude that French, Bulgarian, Italian, and Irish capital markets are relatively informationally inefficient markets compared to the other examined markets during period 1. In period 2, the number of efficient financial markets has increased. Additionally, only Greek, Italian, Hungarian, and Irish capital markets are relatively informationally inefficient markets in period 2. We may recommend active portfolio management for the less efficient markets and passive portfolio management in the efficient financial European markets.

There was a deterioration in market efficiency during the period with low levels of volatility compared to period 1. Analyzing the results of the market efficiency study, using the market dynamics of the indices of the EU countries, it can be concluded that regional diversification is possible and feasible. Diversification can be achieved based on emerging markets of EU Member States. After all the above, we can add that during period 2, which includes the sovereign debt crisis, the behaviour of examined indices is characterized by synchronicity and homogeneity. We can assume that this increased degree of synchronicity and integration is one of the reasons for the severe effects of the debt crisis on their economies.

The efficiency of the studied markets is improved by adding to the model VIX and GEPU returns. This trend is most pronounced during period 1. We also register an improvement in the explanatory power of the model. It is also proven that the expected volatility is an objective assessment of the actual volatility of the return and therefore, during a market turmoil VIX is likely to react hastily, which in turn corresponds to investor nervousness and brings potential profits to the options seller. We prove that uncertainty, represented by VIX and GEPU, contains useful information for a bunch of decision-makers about the conclusion that uncertainty is important in determining the stock market performance.

Prolonged periods of low volatility can further reduce correlations, encouraging further risk-taking. This pro-cyclical behaviour increases investors' risk of losing a systematic shock as volatility jumps and asset-return correlations return to historical levels. Low volatility, corresponding to deteriorating market performance, can directly affect market risk. During such a period, investors underestimate the likelihood of a possible upcoming jump in volatility and financial distress.

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APPENDIX 1

Unit Root Results

Null Hypothesis: D(ATHEX) has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic – based on SIC, maxlag=13)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-10.95154	0.0000
Test critical values:	1% level	-3.471987	
	5% level	-2.879727	
	10% level	-2.576546	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(ATHEX,2)
Method: Least Squares
Sample (adjusted): 3 160
Included observations: 158 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(ATHEX(-1))	-0.865276	0.079010	-10.95154	0.0000
C	1.064082	6.053694	0.175774	0.8607

R-squared	0.434652	Mean dependent var	-0.573369
Adjusted R-squared	0.431028	SD dependent var	100.8489
SE of regression	76.07055	Akaike info criterion	11.51378
Sum squared resid	902729.6	Schwarz criterion	11.55254
Log likelihood	-907.5884	Hannan-Quinn criter.	11.52952
F-statistic	119.9362	Durbin-Watson stat	2.005338
Prob(F-statistic)	0.000000		

Null Hypothesis: D(BEL_20) has a unit root
Exogenous: Constant
Lag Length: 2 (Automatic – based on SIC, maxlag=13)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-9.961328	0.0000
Test critical values:	1% level	-3.472534	
	5% level	-2.879966	
	10% level	-2.576674	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(BEL_20,2)
Method: Least Squares
Sample (adjusted): 5 160
Included observations: 156 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(BEL_20(-1))	-1.262791	0.126769	-9.961328	0.0000
D(BEL_20(-1),2)	0.316203	0.098298	3.216791	0.0016
D(BEL_20(-2),2)	0.237364	0.074153	3.201012	0.0017
C	-0.010897	3.342605	-0.003260	0.9974

R-squared	0.504290	Mean dependent var	0.040257
Adjusted R-squared	0.494506	SD dependent var	58.69119
SE of regression	41.72833	Akaike info criterion	10.32554
Sum squared resid	264670.5	Schwarz criterion	10.40375
Log likelihood	-801.3924	Hannan-Quinn criter.	10.35731
F-statistic	51.54356	Durbin-Watson stat	2.023541
Prob(F-statistic)	0.000000		

Null Hypothesis: D(BET) has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic – based on SIC, maxlag=13)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-12.01429	0.0000
Test critical values:	1% level	-3.471987	
	5% level	-2.879727	
	10% level	-2.576546	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(BET,2)
Method: Least Squares
Sample (adjusted): 3 160
Included observations: 158 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(BET(-1))	-0.961319	0.080015	-12.01429	0.0000
C	28.83499	37.49088	0.769120	0.4430

R-squared	0.480594	Mean dependent var	0.359557
Adjusted R-squared	0.477265	SD dependent var	650.4944
SE of regression	470.3103	Akaike info criterion	15.15724
Sum squared resid	34505925	Schwarz criterion	15.19601
Log likelihood	-1195.422	Hannan-Quinn criter.	15.17298
F-statistic	144.3431	Durbin-Watson stat	2.007692
Prob(F-statistic)	0.000000		

Null Hypothesis: D(CAC_40) has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic – based on SIC, maxlag=13)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-11.12143	0.0000
Test critical values:	1% level	-3.471987	
	5% level	-2.879727	
	10% level	-2.576546	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(CAC_40,2)
Method: Least Squares
Sample (adjusted): 3 160
Included observations: 158 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(CAC_40(-1))	-0.882012	0.079307	-11.12143	0.0000
C	6.716128	15.22438	0.441143	0.6597

R-squared	0.442232	Mean dependent var	-3.818672
Adjusted R-squared	0.438656	SD dependent var	254.9245
SE of regression	190.9968	Akaike info criterion	13.35497
Sum squared resid	5690843.	Schwarz criterion	13.39373
Log likelihood	-1053.042	Hannan-Quinn criter.	13.37071
F-statistic	123.6861	Durbin-Watson stat	1.961586
Prob(F-statistic)	0.000000		

Null Hypothesis: D(DAX) has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic – based on SIC, maxlag=13)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-10.82638	0.0000
Test critical values:	1% level	-3.471987	
	5% level	-2.879727	
	10% level	-2.576546	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(DAX,2)
Method: Least Squares
Sample (adjusted): 3 160
Included observations: 158 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(DAX(-1))	-0.857532	0.079208	-10.82638	0.0000
C	42.67530	28.96581	1.473299	0.1427

R-squared	0.429012	Mean dependent var	1.766521
Adjusted R-squared	0.425351	SD dependent var	476.1962
SE of regression	360.9833	Akaike info criterion	14.62812
Sum squared resid	20328196	Schwarz criterion	14.66688
Log likelihood	-1153.621	Hannan-Quinn criter.	14.64386
F-statistic	117.2105	Durbin-Watson stat	1.934528
Prob(F-statistic)	0.000000		

Null Hypothesis: D(DJIA) has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic – based on SIC, maxlag=13)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-12.02388	0.0000
Test critical values:	1% level	-3.471987	
	5% level	-2.879727	
	10% level	-2.576546	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(DJIA,2)
Method: Least Squares
Sample (adjusted): 3 160
Included observations: 158 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(DJIA(-1))	-0.959248	0.079779	-12.02388	0.0000
C	57.28309	36.34434	1.576122	0.1170

R-squared	0.480992	Mean dependent var	-2.184614
Adjusted R-squared	0.477665	SD dependent var	626.2273
SE of regression	452.5915	Akaike info criterion	15.08043
Sum squared resid	31954894	Schwarz criterion	15.11920
Log likelihood	-1189.354	Hannan-Quinn criter.	15.09618
F-statistic	144.5736	Durbin-Watson stat	1.996124
Prob(F-statistic)	0.000000		

Null Hypothesis: D(FTSE_100) has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic – based on SIC, maxlag=13)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-13.35921	0.0000
Test critical values:	1% level	-3.471987	
	5% level	-2.879727	
	10% level	-2.576546	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(FTSE_100,2)
Method: Least Squares
Sample (adjusted): 3 160
Included observations: 158 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(FTSE_100(-1))	-1.065549	0.079761	-13.35921	0.0000
C	17.40426	16.44214	1.058516	0.2915

R-squared	0.533588	Mean dependent var	-0.248101
Adjusted R-squared	0.530599	SD dependent var	300.6821
SE of regression	206.0060	Akaike info criterion	13.50626
Sum squared resid	6620399.	Schwarz criterion	13.54503
Log likelihood	-1064.995	Hannan-Quinn criter.	13.52201
F-statistic	178.4685	Durbin-Watson stat	2.001054
Prob(F-statistic)	0.000000		

Null Hypothesis: D(IBEX_35) has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic – based on SIC, maxlag=13)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-10.86243	0.0000
Test critical values:	1% level	-3.471987	
	5% level	-2.879727	
	10% level	-2.576546	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(IBEX_35,2)
Method: Least Squares
Sample (adjusted): 3 160
Included observations: 158 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(IBEX_35(-1))	-0.865689	0.079696	-10.86243	0.0000
C	7.904466	43.71733	0.180809	0.8568

R-squared	0.430641	Mean dependent var	-9.428482
Adjusted R-squared	0.426991	SD dependent var	725.4577
SE of regression	549.1521	Akaike info criterion	15.46721
Sum squared resid	47044619	Schwarz criterion	15.50597
Log likelihood	-1219.909	Hannan-Quinn criter.	15.48295
F-statistic	117.9924	Durbin-Watson stat	1.953514
Prob(F-statistic)	0.000000		

Null Hypothesis: D(ISEQ) has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic – based on SIC, maxlag=13)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-9.350333	0.0000
Test critical values:	1% level	-3.471987	
	5% level	-2.879727	
	10% level	-2.576546	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(ISEQ,2)
Method: Least Squares
Sample (adjusted): 3 160
Included observations: 158 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(ISEQ(-1))	-0.746960	0.079886	-9.350333	0.0000
C	4.992841	21.45481	0.232714	0.8163

R-squared	0.359155	Mean dependent var	-7.132215
Adjusted R-squared	0.355047	SD dependent var	335.1928
SE of regression	269.1898	Akaike info criterion	14.04129
Sum squared resid	11304248	Schwarz criterion	14.08005
Log likelihood	-1107.262	Hannan-Quinn criter.	14.05703
F-statistic	87.42872	Durbin-Watson stat	1.999972
Prob(F-statistic)	0.000000		

Null Hypothesis: D(PSI_20) has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic – based on SIC, maxlag=13)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-10.44838	0.0000
Test critical values:	1% level	-3.471987	
	5% level	-2.879727	
	10% level	-2.576546	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(PSI_20,2)
Method: Least Squares
Sample (adjusted): 3 160
Included observations: 158 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(PSI_20(-1))	-0.822894	0.078758	-10.44838	0.0000
C	0.148867	0.623371	0.238810	0.8116

R-squared	0.411695	Mean dependent var	-0.022478
Adjusted R-squared	0.407924	SD dependent var	10.17972
SE of regression	7.832935	Akaike info criterion	6.967129
Sum squared resid	9571.361	Schwarz criterion	7.005896
Log likelihood	-548.4032	Hannan-Quinn criter.	6.982873
F-statistic	109.1686	Durbin-Watson stat	1.988780
Prob(F-statistic)	0.000000		

Null Hypothesis: D(SOFIX) has a unit root
Exogenous: Constant
Lag Length: 1 (Automatic – based on SIC, maxlag=13)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-6.209352	0.0000
Test critical values:	1% level	-3.472259	
	5% level	-2.879846	
	10% level	-2.576610	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(SOFIX,2)
Method: Least Squares
Sample (adjusted): 3 160
Included observations: 158 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(SOFIX(-1))	-0.597122	0.096165	-6.209352	0.0000
D(SOFIX(-1),2)	-0.192382	0.079047	-2.433759	0.0161
C	0.834511	5.089957	0.163952	0.8700

R-squared	0.393029	Mean dependent var	0.143631
Adjusted R-squared	0.385147	SD dependent var	81.31109
SE of regression	63.75812	Akaike info criterion	11.16699
Sum squared resid	626025.2	Schwarz criterion	11.22539
Log likelihood	-873.6090	Hannan-Quinn criter.	11.19071
F-statistic	49.85953	Durbin-Watson stat	2.056702
Prob(F-statistic)	0.000000		

Null Hypothesis: D(GEPU) has a unit root
Exogenous: Constant
Lag Length: 2 (Automatic – based on SIC, maxlag=15)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-13.71260	0.0000
Test critical values:	1% level	-3.455990	
	5% level	-2.872720	
	10% level	-2.572802	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(GEPU_CURRENT,2)
Method: Least Squares
Included observations: 158 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(GEPU_CURRENT(-1))	-1.636623	0.119352	-13.71260	0.0000
D(GEPU_CURRENT(-1),2)	0.467962	0.091507	5.113953	0.0000
D(GEPU_CURRENT(-2),2)	0.270403	0.061102	4.425472	0.0000
C	0.634926	1.482016	0.428420	0.6687

R-squared	0.596807	Mean dependent r	0.015918
Adjusted R-squared	0.591969	SD dependent var	36.96355
SE of regression	23.61132	Akaike info criterion	9.176953
Sum squared resid	139373.7	Schwarz criterion	9.232659
Log likelihood	-1161.473	Hannan-Quinn criter.	9.199363
F-statistic	123.3502	Durbin-Watson stat	2.018057
Prob(F-statistic)	0.000000		

Null Hypothesis: D(VIX) has a unit root
Exogenous: Constant
Lag Length: 10 (Automatic – based on SIC, maxlag=31)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-30.39226	0.0000
Test critical values:	1% level	-3.431564	
	5% level	-2.861961	
	10% level	-2.567037	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(VIX,2)
Method: Least Squares
Included observations: 158 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(VIX(-1))	-4.106350	0.135112	-30.39226	0.0000
C	-0.002948	0.068796	-0.042848	0.9658

R-squared	0.771664	Mean dependent var	-0.000346
Adjusted R-squared	0.771126	SD dependent var	9.840622
SE of regression	4.707831	Akaike info criterion	5.938891
Sum squared resid	103526.5	Schwarz criterion	5.955423
Log likelihood	-13893.91	Hannan-Quinn criter.	5.944705
F-statistic	1435.060	Durbin-Watson stat	2.001629
Prob(F-statistic)	0.000000		

Null Hypothesis: D(WIG) has a unit root
Exogenous: Constant
Lag Length: 6 (Automatic – based on SIC, maxlag=22)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-13.82150	0.0000
Test critical values:	1% level	-3.435356	
	5% level	-2.863638	
	10% level	-2.567937	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(WIG,2)
Method: Least Squares
Included observations: 158 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(WIG(-1))	-0.750501	0.054300	-13.82150	0.0000
C	-0.000881	0.002703	-0.325891	0.7446

R-squared	0.388168	Mean dependent var	-2.55E-05
Adjusted R-squared	0.384728	S.D. dependent var	0.121964
SE of regression	0.095668	Akaike info criterion	-1.849506

Sum squared resid	11.39464	Schwarz criterion	-1.816732
Log likelihood	1166.716	Hannan-Quinn criter.	-1.837187
F-statistic	112.8387	Durbin-Watson stat	1.987898
Prob(F-statistic)	0.000000		

Null Hypothesis: D(BUX) has a unit root

Exogenous: Constant

Lag Length: 0 (Automatic – based on SIC, maxlag=24)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-44.18478	0.0001
Test critical values:	1% level	-3.433781	
	5% level	-2.862942	
	10% level	-2.567563	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation

Dependent Variable: D(BUX,2)

Method: Least Squares

Included observations: 158 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(BUX(-1))	-1.044094	0.023630	-44.18478	0.0000
C	0.002487	0.001173	2.120753	0.0341

R-squared	0.520571	Mean dependent var	0.000125
Adjusted R-squared	0.520304	S.D. dependent var	0.071762
SE of regression	0.049703	Akaike info criterion	-3.164409
Sum squared resid	4.441686	Schwarz criterion	-3.158303
Log likelihood	2849.968	Hannan-Quinn criter.	-3.162155
F-statistic	1952.294	Durbin-Watson stat	1.980210
Prob(F-statistic)	0.000000		

Null Hypothesis: D(PX) has a unit root

Exogenous: Constant

Lag Length: 0 (Automatic – based on SIC, maxlag=24)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-40.18088	0.0000
Test critical values:	1% level	-3.433667	
	5% level	-2.862891	
	10% level	-2.567536	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation

Dependent Variable: D(PX,2)

Method: Least Squares

Included observations: 158 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(PX(-1))	-0.929718	0.023138	-40.18088	0.0000
C	6.50E-05	7.02E-05	0.925853	0.3546

R-squared	0.465073	Mean dependent var	-2.13E-06
Adjusted R-squared	0.464785	S.D. dependent var	0.004135
SE of regression	0.003025	Akaike info criterion	-8.762471
Sum squared resid	0.016997	Schwarz criterion	-8.756524
Log likelihood	8146.717	Hannan-Quinn criter.	-8.760279
F-statistic	1614.503	Durbin-Watson stat	2.004954
Prob(F-statistic)	0.000000		