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MODELLING VOLATILITY SPILLOVERS, CROSS-MARKET CORRELATION AND CO-MOVEMENTS BETWEEN STOCK MARKETS IN EUROPEAN UNION: AN EMPIRICAL CASE STUDY

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Abstract. *Purpose* – This article examines volatility spillovers, cross-market correlation, and co-movements between selected developed and former communist emerging stock markets in the European Union. Modelling the behavioural dynamics of European stock markets represents a vital topic in a fascinating context, but also a current challenge of great interest.

Research Methodology – We propose to estimate and model volatility using GARCH family models for selected European markets. We aim to explore volatility movement, presence of leverage effect/asymmetry in selected financial markets.

Findings – The econometric approach includes GARCH (1, 1) models for the sample period from 1, January 2000 to 12, July 2018. The empirical results revealed that exists a significant presence of volatility clustering in all selected financial markets except Poland and Croatia. The empirical analysis also indicates that both recent and past news generate a considerable impact on present volatility.

Research limitations – Our empirical study has certain limitations regarding the relatively small number of only eight stock markets.

Practical implications – It can provide a useful perspective for researchers, academics, investors, investment managers, decision-makers, and scientists.

Originality/Value – The empirical analysis is focused on 8 European stock markets, which are classified as developed (Spain, UK, Germany, and France) and emerging (Poland, Hungary, Croatia, and Romania).

Keywords: volatility spillover, GARCH family models, stock market dynamics, investor behaviour, diversification, news.

JEL Classification: C58, G15, D53.

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Introduction

The global financial crisis of 2007–2008, which, according to many experts, one of the biggest crises in the world since the crisis of the 1930s affected not only the American economy but also the economies of many countries. Hence, it has been likened to a huge tsunami that started in the United States and gradually spread to European countries and then to other parts of the world, and in the meantime, even affected the economies of small countries (Park & Mercado, 2014). Following this economic crisis, various financial institutions were declared bankrupt and bought by the government or rival companies. The price index in the world's major and small stock exchanges fell sharply. Lending and liquidity to financial institutions declined sharply. Also, with the spread of the crisis to the real sector of the economy, economic growth decreased, and the unemployment rate in the world increased.

The global financial crises of 2007–2009 revealed that increasing stress in financial markets is of great importance for analyzing and forecasting economic activity and can experience severe adverse effects on the real activity of the economy in terms of production, employment, and welfare. Many researchers have examined the methods and extent to which financial stress is associated with most cases before economic contractions. Following this crisis, the economy witnessed the bankruptcy of various financial institutions and their purchase by the government or rival companies. The price index in large and small stock exchanges of the world decreased significantly. Lending and liquidity to financial institutions declined sharply. Also, with the spread of the crisis to the real sector of the economy, economic growth decreased and the unemployment rate in the world increased. Mehdiabadi et al. (2020) suggested that global economy is constantly changing, so innovation and technological development represent essential pillars in terms of sustainability.

Financial markets are hardly represented in macroeconomic models. The history of financial markets shows that financial crises are often followed by a widespread and continuous decline in real economic activity. Memon et al. (2019) argued that uncertainty and crises which spread among the stock markets highlight a minor or major impact on economies. Modelling the behaviour of European stock markets represents a current challenge of great interest. A quantitative approach focused on modelling stock volatility, and asset returns lead to the identification of investment opportunities based on the international diversification of the portfolio. Spulbar et al. (2020) argued that portfolio diversification is a significant investment strategy used in order to manage stock market risks.

In literature, various empirical comparative studies on "co-movements" have been represented in various ways by scholars and academics. In this research paper, co-movements reflect the comparative survey of randomly selected European markets. It focuses on volatility movement pattern (in a comparative manner) within stock chosen markets. None of the selected European stock markets attempted to correlate with other stock markets not covered in this study. Instead, this paper explores changes in different level of volatility within the same time-period and captures the risk parameter of selected markets. Our contribution to the related existing literature also includes new empirical evidence based on a cluster of 8 European stock markets, which are classified as developed (Spain, UK, Germany, and France) and emerging (Poland, Hungary, Croatia, and Romania). There is no similar evidence based on previous contributions. Most empirical studies that analyze the behaviour of European stock markets also include an essential stock market such as US or China.

Lane (2007) analyzed the connection between the former communist states and the European Union and suggested that the collapse of the former communist regimes, and the subsequent transformation of their political, economic and social systems, determined a significant change in their international linkages. Moreover, Paczoski et al. (2019) examined the issues of general government debt (GGD), government deficit (GD), and economic growth rate in the case of Post-Communist European Union Member States, and concluded that the Baltic countries have the most favourable position, while all other countries were generally stable, except Hungary, Croatia, and Slovenia.

Hanousek and Kočenda (2011) investigated the existence of spillovers in a cluster of emerging EU stock markets, i.e. the Czech Republic, Hungary, and Poland, and concluded that these rather new EU stock markets are strongly determined by mature stock markets as well as the macroeconomic news originating thereby for the sample period 2004–2007. Hassan et al. (2006) examined correlations among several emerging markets in Europe, and the empirical results denote the existence of autocorrelation while sample European emerging markets overall are unpredictable. Tilfani et al. (2019) investigated the issue of integration in Central and Eastern European stock markets and concluded that stock markets in Czech Republic, Hungary, Croatia, Poland, and Romania are the most integrated, while the stock markets in Bosnia, Montenegro, Serbia, and Slovakia are less integrated. Rim and Setaputra (2018) investigated the co-movements between stock markets in Asia, Europe, and North America and the empirical results revealed that selected stock markets in these regions had not been fully integrated, and they still exist potential diversification benefits to be exploited by investors.

We have employed several GARCH family models to investigate the behaviour of selected stock markets and their long-run volatility dynamics. However, not all of these models could be applied to selected datasets. Certain models are not suitable for simultaneous modelling of the selected daily financial dataset, which includes the sample period from 1, January 2000 to 12, July 2018. The Asymmetric Power ARCH model is also known as APARCH encloses both TGARCH and GJR models. The Threshold GARCH also is known as the TGARCH model was developed by Zakoian (1994) and Glosten et al. (1993) and it is equivalent to the GJR GARCH model (El Jebari & Hakmaoui, 2018).

1. Literature review

The literature on GARCH family models and their empirical implications are very broad and diversified. Becker et al. (2018) consider that multivariate volatility modelling literature continues to be an active field of research. Whitelaw (1994) conducted an empirical study and concluded that there is an asymmetric relation between conditional mean and volatility. Also, Silvennoinen and Teräsvirta (2009) stated that understanding the co-movements of financial returns has a significant practical relevance considering multivariate GARCH (MGARCH) models. Marquering and de Goeij (2002) suggested that conditional volatility and the existence of (co)variances between asset returns play an important role in the allocation process and risk management in the case of financial systems. Duffee (2005) argued that when stock market wealth reaches a high level relative to consumption, it turns out that both the conditional covariance and correlation are high. King et al. (1994) pointed out that "observable economic variables" determine only an insignificant part of the time-variation in covariances between stock markets, the main effect being generated by "unobservable economic variables". Uğurlu (2014) applied GARCH, EGARCH, TARCH and PARCH models to forecast the volatility of the emerging stock market in Romania (BET index) and argued that the EGARCH model is the most suitable model for modelling the behaviour of sample stock returns considering that has also identified the presence of leverage effect. Pagan and Schwert (1990) conducted a comparative research study using the GARCH, EGARCH, Markov Regime Switching model, and certain nonparametric models to forecast the monthly volatility of the US stock-market returns. The empirical findings revealed that the GARCH model followed in second place by the EGARCH model were the most suitable models, while the other applied models provided low accuracy results.

Czapkiewicz and Wójtowicz (2017) suggested that international portfolio diversification and global investors have an essential contribution to the process of interconnection and generating short and long-term linkages between different stock markets from all around the world. Živkov et al. (2018) investigated the inter-linkages between the developed stock market in Germany and several Eastern European emerging stock markets, such as Czech Republic, Poland, Hungary, and Romania, and revealed the existence of a high level of integration between selected stock markets. Harrison and Moore (2009) examined co-movements between emerging stock markets in Central and Eastern Europe and developed stock markets in Western Europe using time-varying realized correlation ratios, cointegration statistics, and Multivariate Generalized Autoregressive Conditional Heteroscedasticity (MGARCH) models. Alberg et al. (2008) suggested that conditional changing variance models such as GARCH family models exhibit a forecasting performance accuracy rather similar to younger asymmetric GJR and APARCH models. Moreover, Horvath and Petrovski (2013) investigated international stock market co-movements between Central Western Europe (Czech Republic, Hungary, and Poland) and South-Eastern Europe (Croatia, Macedonia, and Serbia) by applying multivariate GARCH models in the sample period 2006–2011 and concluded that the global financial crisis had not affected the degree of stock market integration between these clusters of countries.

Egert and Kocenda (2007) analyzed high-frequency co-movements between selected European Union stock markets, i.e. Czech Republic, Hungary, Poland, Germany, France, and the UK from mid-2003 to early 2005 and detected the presence of bidirectional causality for stock returns and volatility series, but also higher correlations in the case of daily data than in the case of high-frequency data. Dedi, Yavas, and McMillan (2016) analyzed the interconnections between stock returns and volatility spillovers in the case of Germany, United Kingdom, China, Russia, and Turkey using MARMA, GARCH, GARCH-in-mean, and exponential GARCH (EGARCH) models, and revealed the existence of volatility spillovers from other stock markets for Germany, China, Russia, except for UK and Turkey.

Drachal (2017) used GARCH family models, including GARCH-M and asymmetric T-GARCH, E-GARCH, GJR-GARCH, and APARCH models with generalized error distribution for modelling volatility clustering and leverage effects on emerging stock markets in Central and Eastern Europe, and concluded that GARCH-M, TGARCH, and E-GARCH models are the most suitable. Savva and Aslanidis (2010) examined stock market integration between selected EU member states in Eastern Europe and the Euro-zone and suggested that a high level of correlation is not the effect of global financial integration, but the result of EU-related developments.

Ben Slimane et al. (2013) argued that interrelationship between stocks markets in Europe registered an increasing trend during the global financial crisis, including by severe accentuation of volatility spillovers. Tripathi (2012) investigated co-movement among sample stock markets from Asia, Europe, and the USA based on the correlation technique and observed an intensification of interdependence between a significant number of developed and emerging stock markets primarily in the context of extreme financial events. Syriopoulos (2007) investigated interconnections between emerging European Union stock markets (Poland, Czech Republic, Hungary, Slovakia) and developed stock markets (Germany, USA) and empirical results indicated stronger linkages with Germany rather than with the USA despite its global influence. Forbes and Rigobon (2002) investigated co-movements and contagion across the stock market, and they proposed a new research direction by analyzing, in particular, the causes that generate a high integration between the stock markets both during the periods of relative stability and financial crisis or extreme turmoils. However, the authors suggested that cross-market linkages include the following categories, i.e., correlation of asset returns, cross-market correlation coefficients, and transmission of shocks or volatility, but if such stock linkages are permanently maintained at high levels both before and after a shock, there is no financial contagion, just interdependence. Goetzmann et al. (2005) argued that the structure of global correlations is significantly reshaped over time because investment opportunities based on the international portfolio diversification are influenced by the constantly growing share of stock markets all over the globe and reduced average correlation between available stock markets. Pinto et al. (2020) suggested that stocks with low historical volatility exhibit superior risk-adjusted returns and higher absolute returns over high volatility stocks.

Engle (2002) examined the predictive accuracy of the new dynamic conditional correlation (DCC) family models and concluded that they have the adaptability of univariate GARCH models coupled with parsimonious parametric models for the correlations, but the results are more robust and accurate, whether the criterion is mean absolute error, diagnostic tests, or tests based on the value at risk calculations. Spulbar et al. (2020) examined abnormal volatility transmission patterns between selected emerging and developed stock markets based on 12 major stock indices such as IBEX 35 index (Spain), DJIA index (USA), FTSE 100 (UK), TSX Composite index (Canada), Nikkei 225 (Japan), DAX Index (Germany), CAC 40 (France) and five selected emerging stock market indices, i.e. BET index (Romania), WIG 20 index (Poland), BSE index (India), SSE Composite index (China) and BUX index (Hungary) from January 2000 to June 2018. The empirical results revealed that US stock index exhibits the highest transmitting pattern in volatility, while most emerging stock markets follow the movement pattern of essential developed stock markets, such as the US market (Dow Jones or S&P 100 stock indices are significant in this regard). Moreover, Spulbar and Birau (2019) implied that volatility does not diverge to infinity, while it seems to react rather different for high positive or high negative stock returns.

2. Research methodology

This paper aims to estimate volatility spillovers in selected European developed and emerging financial markets. The data divided into two parts, i.e. the cluster of developed stock markets and former communists emerging stock markets by using 4630 daily observations. The cluster formed by FTSE 100 index, IBEX35 index, CAC40 index, and DAX index represents the selected developed stock market indices of the UK, Spain, France, and Germany. The other cluster represents European emerging markets based on the daily closing price of the WIG20 index (Poland), BUX index (Hungary), CROBEX index (Croatia), and BET index (Romania). Moreover, Poland, Hungary, Croatia, and Romania are former communists European emerging countries. Moreover, emerging economies are characterized by certain stylized facts such as pro-cyclical policies, a high rate of economic growth or vulnerability to foreign currency volatility movements (Shakila et al., 2020). We propose to employ symmetric and asymmetric GARCH models, i.e. GARCH (1, 1) by Bollerslev and Exponential GARCH by Engle (2002) to model symmetric and asymmetric volatility of selected European stock markets.

For comparative volatility estimation, we employ Bollerslev (1986) GARCH (1, 1) to series returns. The data is converted into log-returns and first log difference considered using the following formula:

$$r_t = \ln\left(\frac{p_t}{p_{t-1}}\right) = \ln\left(p_t\right) - \ln\left(p_{t-1}\right).$$

Further to test the normality, Augmented Dickey-Fuller test is used.

$$\left(1-L\right)y_t = \beta_0 + \left(\alpha-1\right)y_t - 1 + \varepsilon_i.$$

In the process of the first equation, *rt* represents logarithmic daily return in selected European indices for time *t*, where *Pt* represents the closing price at time *t* and *Pt*-1 represents the corresponding price in a period of time *t*-1. Second equation (ADF Test) used to justify normality in series returns. To examine the nature of volatility and relationship between volatility and return among developed and emerging markets, GARCH (1, 1) model is used. The model introduced by Bollerslev in 1986 that contains conditional variance represented as a linear function of lags. ARCH coefficient (*a*1) suggests that there is a significant impact of previous period volatility shocks on the current period. Where the other coefficient GARCH (β_i) measures the impact of previous period variance on present volatility and also indicates the presence of volatility clustering in series returns. GARCH (1, 1) by Bollerslev (1986) represented by following:

$$h_t = \omega + \alpha_1 u_{t-1}^2 + \beta_1 h_{t-1}.$$

Formula process contains mean equation and variance equation represented as the following:

Mean equation is the following: $r_t = \mu + \varepsilon_t$.

Variance equation is the following: $\sigma_t^2 = \omega + \alpha\varepsilon_{1t-t}^2 + \beta\sigma_{1t-1}^2$.

GARCH (1, 1) model examines the dynamics of volatility and suggests that if the sum of coefficient (ARCH and GARCH) terms equals to 1 in that case any shock (Negative or

Positive) can lead to creating perpetual change in all future values. In another case, a shock to conditional variance identified as persistent in nature. European actual series returns and volatility shocks and comparative asset returns are presented in graphs and details explained. This study examines detail empirical analysis of the movement of volatility pattern of selected European markets where each markets being addressed provided impact of volatility for the same time-duration stretching the risk and return factor. The correlation matrix is being applied to selected samples attempting to demonstrate co-movements within selected European financial markets. Hence, the co-movements is being demonstrated to focus on capturing relativity of market movement pattern within European stock markets.

Standard GARCH (1, 1) model designed by Bollerslev (1986) suggests that shock in ε_{t-1} has the same effect regardless of whether $\varepsilon_{t-1} > 0$ or $\varepsilon_{t-1} < 0$. However, a typical feature of financial data is that negative shocks generate more volatility compared to positive shocks. In order to capture asymmetry in return, an extension of GARCH required that need not to depend on non-negative restrictions. Aiming to incorporate this asymmetrical effect in financial data, Nelson (1991) proposed exponential generalized autoregressive conditional heteroscedasticity (EGARCH) model or Exponential GARCH. In the EGARCH specification, γ is the asymmetry parameter measuring leverage effect, where, α is the size parameter measuring the magnitude of shocks, and persistency is captured through β. An important feature of the EGARCH specification is that conditional variance is an exponential function that allows rejection for non-negative restrictions which were restricted by in earlier GARCH specifications.

The EGARCH model, which was developed by Nelson (1991) captures asymmetric responses of time-vary variances to volatility shocks and also ensures that variance is always positive.

$$\log\left(\sigma_t^2\right) = \omega + \sum_{j-i}^{p} \beta i \log\left(\sigma_{t-i}^2\right) + \sum_{j-1}^{q} \alpha i \frac{\varepsilon i - t}{\sigma}_{i-t} \left| \frac{-\sqrt{2}}{n} \right| - yi \frac{\varepsilon i - t}{\sigma i - t}.$$

3. Empirical results

We process analysis of descriptive statistics first to understand the value of investor's return in selected developed and emerging stock markets for the sample period from 1, Jan 2000 to 12, July 2018. Detail study of Figure 1 suggests a marginal change in asset price of European developed financial markets considering the UK, Spain, France and Germany. However, asset returns of Spain and France trading even lower index level than on January 2000. FTSE 100 index represents to the UK financial market generated marginal returns for investors as asset price trading 15% higher from the beginning of data. Germany, one of best return provider amongst developed European market group, provided almost double asset price within over 18 years.

Poland, Hungary, Croatia and Romania were selected as former communists European emerging stock markets where returns seem highly escalated within selected time range except Poland where asset return is less than 10% in the selected period. At the same time, Croatia index price is marginally more than double from its starting point 888.50 to 1744.40.

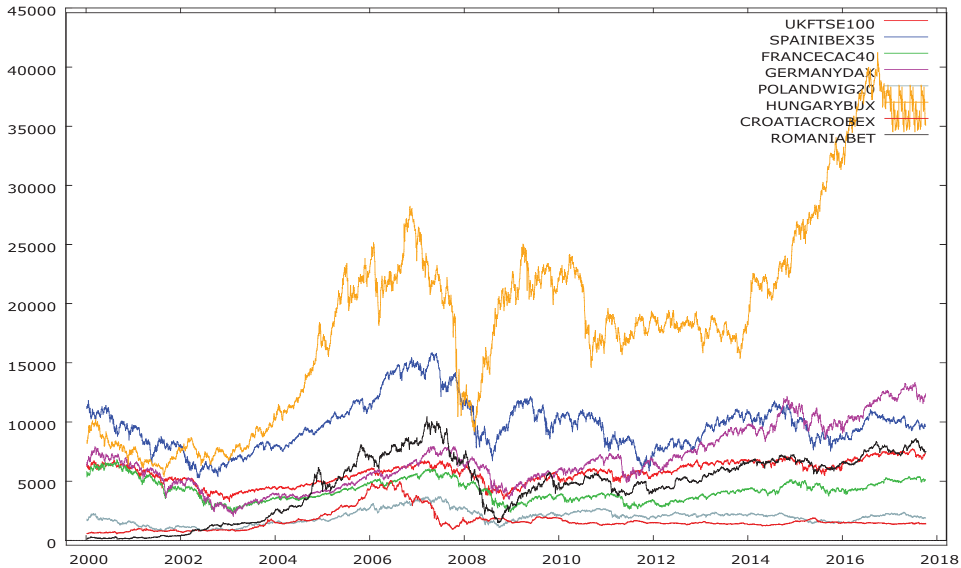

Figure 1. Comparative graph between European developed and former communists emerging market series returns (source: author's computation)

Romania financial market represented by BET provided highest asset price returns exceeding 17 times or 1700 percentage, which found the highest return among emerging as well as developed financial markets from selected samples. Followed by Hungary where asset price returns exceed 4 times or 400 percent return makes index move from 8715.49 to 35373,59. Observation of Figure 1 suggests that Poland and France are stock markets reacted least compared to other selected observations during the global financial crisis. Financial market movement of BUX, i.e. Hungary, provides sharp growth during the selected time period. The exponential growth of Hungary appears significant and much different while compared with the rest of the selected specimen markets. The following Figure 2 presents the trend of selected stock market indices.

Movement change in volatility transmitting pattern for developed European market represents different pattern compared to emerging European markets for the selected period. FTSE 100, a European developed market specimen index for the UK financial market indicates down trading trend approaching 3500 as low level twice from about 6500 whereas IBEX35 marked level of 6000 from almost 12000. Financial market specimen of France CAC40 created low traded level at the same time almost 2.5 times of 25 percent almost double fall compared to the FTSE 100 index and IBEX35 index. DAX index, a German specimen index, falls historically lower amongst developed financial markets, which is almost 2000 from 8000, which is four times slip and lost 400 percent of market capitalization.

The index movement pattern for emerging European markets (EEM) represents much higher volatility during ups and downs. For instance, WIG20 index (Poland) first fall 1.5 times of 150 percent as a negative trend and jumped to a new level of 3500 from 1000 making 3.5 times positive movement. Followed by a higher rate as observed in BUX series returns of

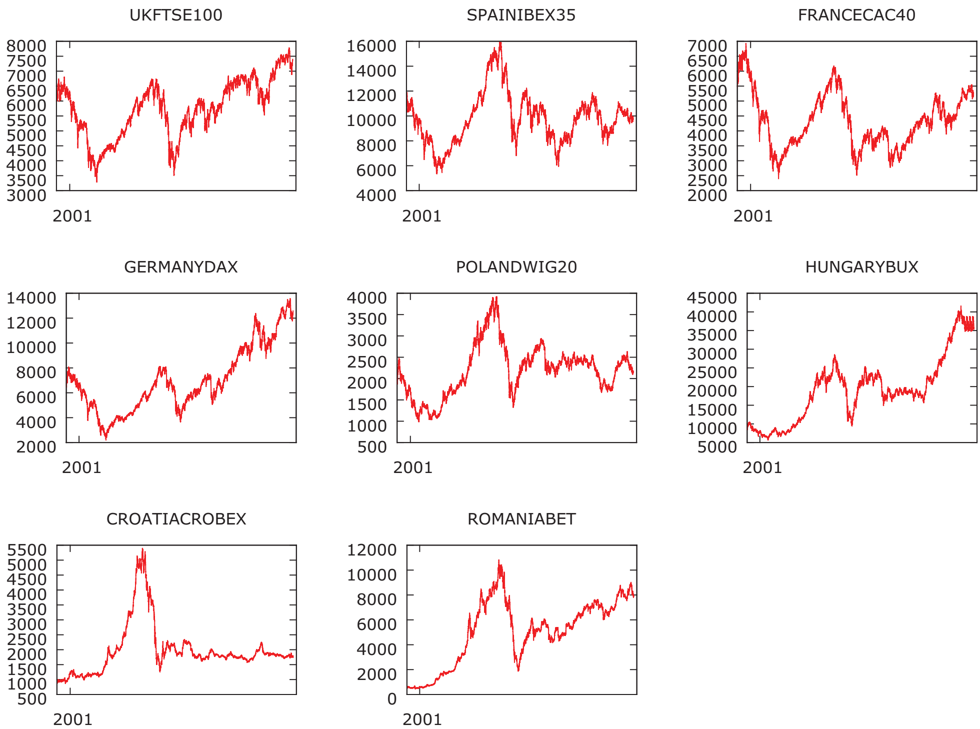

Figure 2. The trend of selected stock market indices (source: author's computation)

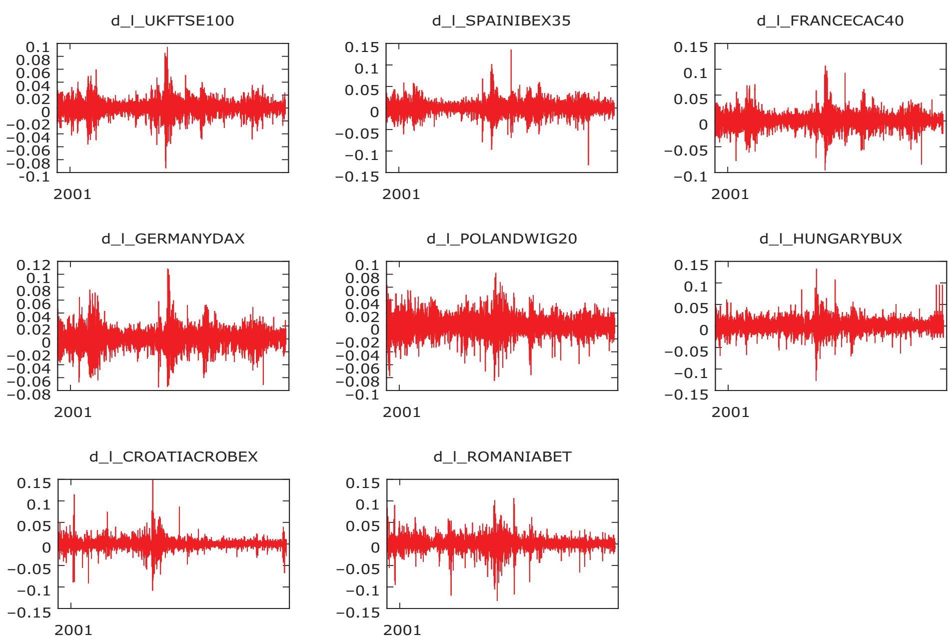

Figure 3. Volatility scale for developed and former communists emerging European stock markets (source: author's computation)

Hungary making capitalization loss 50%, i.e. 10000 to 5000 and approached to new high level of 30000 making six times or 600 percent positive movement. Financial index of Croatia, i.e. CROBEX and Romania BET shows different movement at the same time where other stocks are falling; both indexes remained constant. Both of these indexes moved positively were other European markets falling. CROBEX, a specimen index for Croatia moved five times or 500 percent return where specimen index for Romania BET treaded index level of almost 1000 making 17 times growth for the same period. Volatility sketches appear in Figure 3 indicates positive and negative shocks for all developed and emerging European markets from January 2000 to 12, July 2018. Hungary BUX shows major positive jumps that escalated trading index level to a new high, which too with significantly positive shocks, noticed at least 2.6 times higher than the movement of negative market patterns.

Emerging markets, particularly CROBEX index (Croatia) and BET index (Romania) respectively created a maximum number of positive shocks at high to very high magnitude level (see Figure 4). Further, the property of summary of statistics also suggests the movement of each index along with the risk involved in asset movement. Figure 5 is based on the property of minimum and maximum index level from the summary of statistics. It indicates histograms for negative and positive market movement. It is seen that all financial markets have doubled the asset investment overtime period from low trading level to high trading level. BUX, an emerging economy, Hungary breached highest index trading level 41000 compared to the rest of European markets. However, BET, a Romanian financial market has grown 17 times from its lower trading level to high trading level.

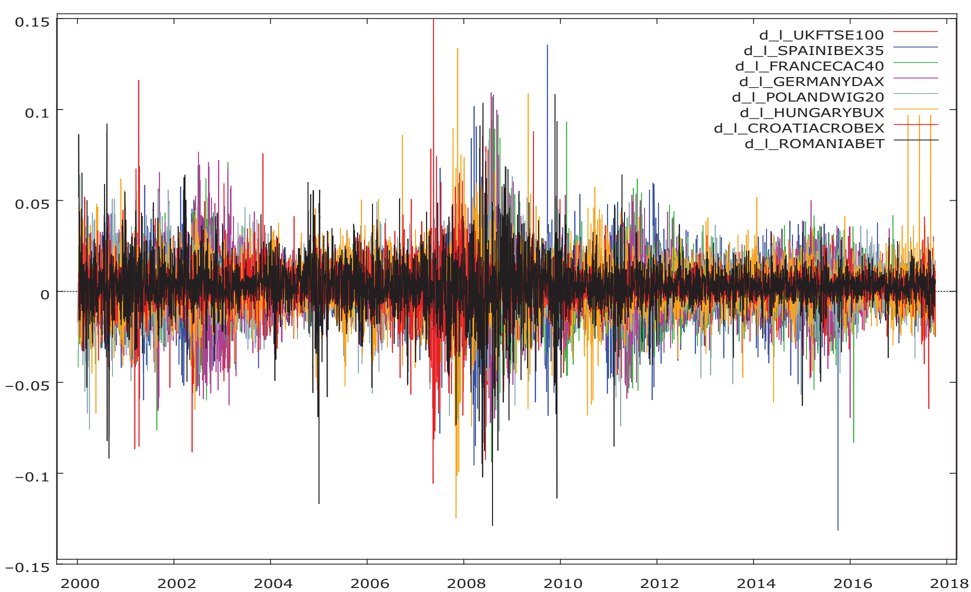

Figure 4. Comparative volatility sketches for selected developed and former communists emerging European markets (source: author's computation)

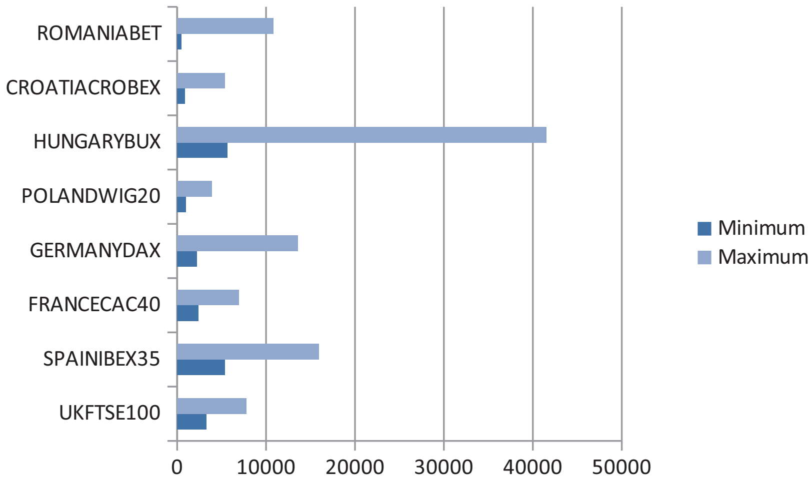

Figure 5. Minimum and Maximum index level analysis (source: author's computation)

Table 1 presents the summary of statistics using observations for the sample period, as follows:

Table 1. Summary of statistics using observations for the sample period (source: author's computation)

Variable	Mean	Median	Minimum	Maximum
UK_FTSE100	2.99511e-005	0.000292808	−0.0926557	0.0938434
SPAIN_IBEX35	−3.27050e-005	0.000663476	−0.131852	0.134836
FRANCE_CAC40	−2.61478e-005	0.000272142	−0.0947154	0.105946
GERMANY_DAX	0.000134564	0.000746166	−0.0743346	0.107975
POLAND_WIG20	1.36839e-005	0.000141028	−0.0844276	0.0815484
HUNGARY_BUX	0.000302628	0.000335632	−0.126489	0.131777
CROATIA_CROBEX	0.000145740	0.000204938	−0.107636	0.147790
ROMANIA_BET	0.000614499	0.000543984	−0.131168	0.105645
Variable	Std. Dev.	C.V.	Skewness	Ex. kurtosis
UK_FTSE100	0.0117927	393.731	−0.139631	6.38786
SPAIN_IBEX35	0.0147716	451.662	−0.0830107	6.01698
FRANCE_CAC40	0.0145275	555.590	−0.0359500	5.00974
GERMANY_DAX	0.0149532	111.123	−0.0205531	4.30730
POLAND_WIG20	0.0149155	1090.00	−0.162087	2.63795
HUNGARY_BUX	0.0153084	50.5848	0.0939871	6.69502
CROATIA_CROBEX	0.0116245	79.7617	−0.0834989	18.6688
ROMANIA_BET	0.0152629	24.8380	−0.508121	9.18279

Property of summary of statistics indicates that Mean return is positive, suggesting that asset price is increased over the period except for Spain and France. The property also shows that returns are negatively skewed except BUX – Hungary index. Degree of excess Kurtosis is exceeding normality level of 3 except the case of Poland financial market. CROBEX, Croatia financial market represents the highest degree of Kurtosis, creating a leptokurtic impact on series return, making the fat tail.

Selected European developed and emerging markets confirmed volatility clustering and scattered return over the period. Further investment gained returned over the period except for Spain and France financial market. Volatility clustering is confirmed with return series and stationarity using Augmented Dickey-Fuller test. The study objected to best fit of GARCH (1, 1) to selected developed and emerging European financial markets. Result of GARCH (1, 1) model property following VCV robust method shown in Table 2.

The result of GARCH (1,1) property indicates that coefficient $\alpha_1$and β_1 are statistically significant except the case of WIG20 and CROBEX, emerging financial markets of Poland and Croatia. The further result also within a parametric restriction and suggesting a greater impact of shocks on volatility. ARCH coefficient (α_1) found 0.108, 0.100, 0.095, 0.089, 0.071 and 0.194 representing details of UK, Spain, France, Germany, Hungary and Romania respectively indicates that derived position of (α_1) indicates the significant impact of previous period shocks on present period volatility. Result statistics property shows a maximum of 19.44% impact in the financial market of Romania, followed by 10.8% UK. It means that given value indicates the impact of yesterday volatility on today. Another GARCH coefficient (β_1) processes the impact of yesterday's variance on today's volatility. It also indicates the presence of volatility clustering and suggests that negative asset price changes impose further negative shocks on asset returns and vice versa. The higher degree of (β_1) indicates a larger memory of shock. The sum of ARCH (α_1) and GARCH (β_1) provides a degree of the extent at which volatility shock is persistent over time for selected European developed and emerging markets. The GARCH (1, 1) model property also indicates the sum of ARCH and GARCH terms (see Table 2) showing significantly the highest degree of volatility persistent

Table 2. The empirical results for GARCH (1, 1) model (source: author's computation)

Variable	Constant	omega	alpha	beta	alpha+beta
UK_FTSE100	0.00035	1.65E-06	0.108437	0.879646	0.988083
SPAIN_IBEX35	0.00053	2.46E-06	0.100655	0.891055	0.99171
FRANCE_CAC40	0.000496075	2.02E-06	0.095298	0.896818	0.992116
GERMANY_DAX	0.000712442	2.21E-06	0.089057	0.900906	0.989963
POLAND_WIG20*	0.00025441	1.72E-06	0.0553	0.93695	0.99225
HUNGARY_BUX	0.00070009	3.63E-06	0.071882	0.913364	0.985246
CROATIA_CROBEX*	0.000121315*	7.29E-07	0.085462	0.915459	1.000921
ROMANIA_BET	0.000746296	4.03E-06	0.194475	0.80575	0.9994

Note: *Provided statistical property is significant at 1% to selected European financial markets except financial market of Poland (WIG20) and Croatia (CROBEX) where GARCH (1, 1) not fitted.

for the emerging European market of Romania (BET index) approaching 0.999 followed by France (CAC40 index) and Spain (BEX35 index). The property of the table provides detail statistical information about significance or fitness of values to GARCH class models.

In the following Table 3 we have included the empirical results of EGARCH model:

Table 3. The empirical results for EGARCH (1,1) model

lOG_UKFTSE100, (T = 4630), VCV method: Robust Conditional mean equation				
	coefficient	std. error	z	p-value
const	8.72867	0.0167890	519.9	0.0000 ***
omega	−1.31418	0.0961173	−13.67	1.48e-042 ***
alpha	1.08839	0.0699990	15.55	1.63e-054 ***
gamma	−0.0259631	0.0155655	−1.668	0.0953 *
beta	0.945124	0.00956002	98.86	0.0000 ***
Llik: 4200.35701 AIC: -8390.71401				
BIC: −8358.51245 HQC: −8379.38382				
lOG_SPAIN_IBEX35, (T = 4630), VCV method: Robust				
Conditional mean equation				
	coefficient	std. error	z	p-value
const	9.23318	0.00339488	2720	0.0000 ***
omega	−1.30044	0.0855659	−15.20	3.64e-052 ***
alpha	1.09662	0.0668458	16.41	1.75e-060 ***
gamma	−0.0183073	0.00701352	−2.610	0.0090 ***
beta	0.944597	0.00759750	124.3	0.0000 ***
Llik: 3537.10383 AIC: −7064.20765				
BIC: −7032.00609 HQC: −7052.87746				
lOG_FRANCECAC40, (T = 4630), VCV method: Robust				
Conditional mean equation				
coefficient	std. error	z	p-value	
const	8.39337	0.0456270	184.0	0.0000 ***
omega	−1.15027	0.298184	−3.858	0.0001 ***
alpha	0.970756	0.236454	4.105	4.03e-05 ***
gamma	−0.00675849	0.0162363	−0.4163	0.6772
beta	0.948662	0.0163740	57.94	0.0000 ***
Llik: 3015.03172 AIC: −6020.06343				
BIC: −5987.86187 HQC: −6008.73324				
D1_lOG_POLAND_WIG20, (T = 4629), VCV method: Robust				
Conditional mean equation				
	coefficient	std. error	z	p-value
const	0.000126534 0.000163322	0.7747	0.4385	

End of Table 3

omega	−0.186319	0.0284426	−6.551	5.73e-011 ***
alpha	0.117934	0.0125637	9.387	6.18e-021 ***
gamma	−0.0334085	0.00779986	−4.283	1.84e-05 ***
beta	0.988922	0.00273595	361.5	0.0000 ***
Llik: 13379.06454 AIC: −26748.12909				
BIC: −26715.92861 HQC: −26736.79915				
lOG_HUNGARY_BUX, (T = 4630), VCV method: Robust				
Conditional mean equation				
coefficient	std. error	z	p-value	
const	9.99769	0.428367	23.34	1.78e-120 ***
omega	−0.977351	2.31181	−0.4228	0.6725
alpha	0.905494	1.53280	0.5907	0.5547
gamma	−0.00906108 0.255536	−0.03546	0.9717	
beta	0.965984	0.314666	3.070	0.0021 ***
Llik: 254.94282 AIC: −499.88565				
BIC: −467.68408 HQC: −488.55545				
lOG_CROATIA_CROBEX, (T = 4630), VCV method: Robust				
Conditional mean equation				
	coefficient	std. error	z	p-value
const	7.50055	0.00398506	1882	0.0000 ***
omega	−1.32413	0.0748643	−17.69	5.27e-070 ***
alpha	1.21357	0.0661205	18.35	3.07e-075 ***
gamma	−0.00107110	0.00632996	−0.1692	0.8656
beta	0.965382	0.00458996	210.3	0.0000 ***
Llik: 3873.13284 AIC: −7736.26568				
BIC: −7704.06412 HQC: −7724.93549				
lOG_ROMANIA_BET, (T = 4630), VCV method: Robust				
Conditional mean equation				
coefficient	std. error	z	p-value	
const	8.84818	0.00325332	2720	0.0000 ***
omega	−1.26235	0.119710	−10.55	5.35e-026 ***
alpha	1.20328	0.111373	10.80	3.29e-027 ***
gamma	−0.0249973	0.00937252	−2.667	0.0077 ***
beta	0.972410	0.00686335	141.7	0.0000 ***
Llik: −566.83713 AIC: 1143.67426				
BIC: 1175.87582 HQC: 1155.00445				

The property of Table 3 indicates the fitness of asymmetry model, i.e. EGARCH (1, 1) indicating the presence of leverage effect. FTSE100, IBEX35 and BET of the UK, Spain and Romania fitted well. Results indicate that those fitted markets react significantly for negative shocks than positive. The financial series of selected European developed and emerging stock market have been processed for ADF Test and stationary test. We have also applied Exponential GARCH (EGARCH) designed by Nelson (1991) to selected emerging and developed European markets. FTSE100 index (UK) consisting of 4630 daily observations fitted using log-returns. The empirical findings indicate the **significance level** of 1% except for asymmetry, which is also significant at 10%. The negative sign of gamma indicates the presence of leverage effect in sample financial series returns. In the case of Spain, the model fitted perfectly for a **significance level** of 1%. P-Value indicates the **significance level** at 0.009 for (y), which indicates the presence of leverage effect in financial series return. In the case of the UK and Spain, the stock markets react more on negative shocks and less on positive shocks. EGARCH model outcome for selected financial series returns of France and Poland indicates **significance level** for asymmetry in the case of France and insignificant constant value for Poland based on daily stock returns of selected stock market indices. Selected groups of European markets clearly define volatility transmitting as well as movement pattern of shocks at the same period of time. Volatility pattern found relatively more effective in case of financial markets of the UK and Spain when considered for negative movements (without any impact of news), where other markets observed comparative least negative or positive movements.

Correlation matrix indicates the movement pattern of selected European markets for the same time. It suggests inter-relationship and similarity of movements for the selected time period. Above statistical property indicates that stock markets of Germany (DAX index) and Croatia (Crobex index) exhibit contrast co-movements for the same time period. Insignificant empirical results have been identified in the case of stock market returns of the BUX index (Hungary) and CROBEX index (Croatia). It is well established after considering test up to AR-1, AR-2, AR-3, AR-4 and AR-5 in case of financial stock market returns of France, Poland, Hungary and Croatia. It is evident that autoregressive coefficients of the lagged dependent variable represented insignificant value in case of WIG20 index (Poland) financial series returns. Nevertheless, the coefficient of GARCH model components provided statistically insignificant value for the CAC40 index (France), BUX index (Hungary) and CROBEX index (Croatia). On the other hand, the BET index (Romania) fitted well and achieved

Table 4. Correlation Matrix for selected EFM

FTSE	IBEX	CAC	DAX	WIG	BUX	CROBEX	BET	Correlation
1.00	0.44	0.62	0.89	0.53	0.62	0.10	0.63	UK
	1.00	0.55	0.26	0.81	0.38	0.61	0.63	SPAIN
		1.00	0.48	0.36	0.17	0.15	0.23	FRANCE
			1.00	0.33	0.73	–0.06	0.61	GERMANY
				1.00	0.45	0.61	0.79	POLAND
					1.00	0.35	0.79	HUNGARY
						1.00	0.57	CROATIA
							1.00	ROMANIA

statistical significance at the level of 1%. The EGARCH model property results derived using log series and considering all sample European stock markets based on Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC). Moreover, BET index (Romania) represents the perfect fit for asymmetric EGARCH model. In other cases, the coefficient of lagged squared residual is negative and statistically insignificant, which indicates that positive shocks do not affect conditional volatility.

Property of Table 4 indicates a correlation of selected markets with each other, in particular considering FTSE100 of the UK as a base financial market. It is observed that only German financial market follows movement pattern of FTSE100 almost a degree of 90%, and the other strong correlation of market movement identified between Spain and Poland which contributes merely 50% as an average together during the following pattern of the UK. We found a negative correlation between market movement pattern of Croatia and Germany, where Croatia contributed or follows only 10% similar movement to FTSE, contrasting movement of Germany that follows over 89% to the movement of FTSE. This simplifies that financial market of Croatia is no longer adopting changes to relative changes or least contribute to volatility transmitting pattern. It suggests possibility observing financial market of Croatia tends to be positive despite negative movements in FTSE and vice-versa. Such statistical property also invites arguments considering contrasting changes in the index level of FTSE and BET over the period of study. BET is no longer trading even anywhere near to the trading level that noticed at the start of the study period, where FTSE does. It gives the idea that either BET followed only positive changes of FTSE and that too with high magnitude of impact, or least followed negative changes, probably with least magnitude of negative impact. BET is significantly correlated to FTSE at least not lower than 63% correlation.

The study on selected developed, and emerging financial markets of Europe reveals that the volatility is significantly high and persistent. In a particular financial market of Poland identified highly volatile amongst other specimen financial markets. In addition to positive movements, BUX, the financial market of Hungary, escalates trading level with three major positive shocks at different levels. The movement of changes in asset prices with changes in index level provides different impacts over the same period of time. For instance, financial markets of WIG20, and CROBEX indicates changes and impact on asset prices at highest magnitudes at changes in indices over 93 and 91 percentages respectively. Further, it appears on BUX and DAX at the level of 91 and 90 percentages. Many researchers do not accept changes or impact of alpha – considering any relative arguments for having a positive effect. We proposed assumptions based on considering the presence of alpha – directing signifies the possibility of positive news. In the same arguments, the financial market of BET of Romania found with the highest level of alpha, approaches to over 19 percentages having over 80 percent of impact changes in asset prices with the movement of the index. Only FTSE100 and IBEX35 of Spain found with the level of alpha over 10% and with asset price movement with indices percentile to 89 & 87 respectively. In case such effect of alpha provides the probability of positive movements, the financial market which identified as highest effective in terms of capturing transmitting pattern of volatility across the selected European market, WIG20 of Poland identified with least presence of alpha that is less than 6 percentage, amongst the lowest.

Otherwise, considering probability to test whether the value of alpha really even exists or works, we provide the outcome of statistical property that incidentally indicates that "higher the value of alpha, higher the trading point of index". To add supportive arguments, we consider the level of base index points of all selected European financial markets at the start of the study period. FTSE index (UK) is being traded almost above 6000 and gained about 15% in over 18 years in case only changes considered from first and last trading levels. During the same period of time, Spain, France and Poland did not generate any positive returns from a period of over 18 years. Instead, IBEX35 specimen of Spain is being traded even at lower trading level, i.e. below 10000 that it was actually in the year 2000. CAC40 or France and WIG20 of Poland shares same trading terminology, being traded to a lower point than it was achieved eighteen years ago. Almost above 100% index trading point gain is delivered by DAX of Germany and CROBEX of Croatia during the same period. Further, over five hundred percent growth noticed in BUX of Hungary, where the trading level of index escalated to fivefold during the period of eighteen years. At the same time,the highest gain across all selected market is being noticed only in the financial market of Romania, BET. The index movement escalated to over 9000 trading points from below 500 of trading levels during the same period. BET financial index is also amongst the one that is having a positive alpha sign to merely 20 percentages, which is found highest from the alpha level of the rest of selected European stock markets.

Conclusions

GARCH (1, 1) model revealed that stock of WIG20, specimen index of Poland reacts upmost, followed by CROBEX specimen of Croatia and BUX of Hungary. On the other side, stock prices of BET, a specimen of Romania financial market found to at least 13% less effective compared to the movement of index and impact on stock prices. That indicates that along with the movement of the index, listed stocks also moving aggressively in case of WIG20, CROBEX and BUX. Exponential GARCH (EGARCH) reveals the presence of leverage effects in selected European stock markets, indicating a significant signal that negative shocks dominate markets. Our empirical study on selected developed, and emerging financial markets of Europe reveals that the volatility is significantly high and persistent. Series returns exhibit characteristics like volatility clustering, series movement pattern and persistent of volatility in their daily return considering from January 2000 to July 2018. The study finds that there exists a significant presence of volatility clustering in all selected financial markets except Poland and Croatia (where the model did not fit series returns). Further, it indicates that both recent and past news create an impact on present volatility. The study further examines that there is an insignificant relationship between volatility, volatility pattern and asset return over a period of time.

The movement of asset price indicates that an emerging market of Europe (BET index) specimen of Romania having a significantly high degree of volatility in persistent and delivered over 17 times asset returns. None alike, asset return from one of developed European financial market, i.e. France (CAC40 index) found the second highest volatility is persistent, delivered negative returns. It is clear that Hungary, (BUX) consist of more substantial exponential impact for positive and negative movements. While contrasting with BUX, the

DAX of Germany indicates much stable and more robust positioning to perceive and react over the news. The study also found that higher positioning of the value of alpha impacts on the trading pattern of indices over a period of time. For instance, BET, the financial market of Romania found being shifting their trading point from below 500 (the base point at the start of the study period) to over 9000 at the end of the study. Such escalation of the trading level is not observed with the rest of the selected financial markets. Further, the study clearly provides understanding about the existence of volatility, cluster impact, the persistence of yesterday's volatility, and the reaction of the market in a negative trend. Out of the study, financial markets of Romania and Hungary have provided best returns to investors over a period of time. At the same time, well developed financial markets such as financial markets of the UK and France provided stability of investment over a period of time. However, any dividend over investment either for a short or long tenure, is highly solicited by any category of investors, and probably will be a primary element for investors across the world.

The main limitations of our research study is due to the relatively small number of only 8 selected European countries (4 developed and 4 emerging) for the sample period from 1, January 2000 to 12, July 2018. A future extension of this research study will include a much larger number of countries, not just members of the European Union. Another objective will focus on extending the analysis period, so as to also include significant events such as Brexit or the Covid-19 pandemic. Unlike the current research study which for daily data were collected from the official websites of individual stock markets of each sample countries, for the future research study we will obtain daily data for selected countries from DataStream database. Modern portfolio theory assigns tremendous importance to portfolio diversification strategies in order to minimize risk. However, in globalized stock markets, co-movements and correlations represent a challenge of great interest for international investors and financial decision-makers. Stock market dynamics depends on the time domain and frequency domain. A future direction of this research study will focus on investigating co-movements and correlation between selected stock markets based on wavelet analysis. As an effective alternative to GARCH approach, we will analyze the new time-series information based on a different methodology and will examine the following aspects: Individual power spectrum, wavelet coherence and cross wavelet transforms.

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Conflicts of interest

The authors declare no conflict of interest.

Author contributions

All authors contributed equally to this research work. All authors discussed the results and contributed to the final manuscript. All authors read and approved the final manuscript.

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