Return and volatility spillovers in twelve Eastern European countries, 2006–2015

Dimitrios Angelidis
(corresponding author)
University of West Macedonia
Department of International and European Economic Studies,
Kozani, Greece
E-mail: d.angelidis@hotmail.com

Athanasios Koulakiotis
University of Macedonia
Department of Balkan, Slavic and Oriental Studies,
Thessaloniki, Greece
E-mail: akoulak@uom.edu.gr

This study investigates return and volatility spillovers in the stock markets of 12 Eastern European countries using an augmented univariate AR-EGARCH model. The study introduces two additional explanatory variables: the change in exchange rates of each country's domestic currency to the USD and the return of the S&P 500 index. The previous period's figures were preferred for both parameters. These newly introduced variables are used not only separately, but also in conjunction with and without the liquidity factor. Thus, a ‚bouquet' of eight parallel equations for each sample is formed. According to the empirical results, return and volatility spillovers are confirmed for most cases, regardless of the chosen approach. Furthermore, the expected positive sign for the coefficients regarding the exchange rates and the S&P 500 index is verified most of the time. Moreover, the leverage effect was observed in several cases. In addition, the outcomes illustrate that the trading volume's coefficient mainly carries a positive sign and that this variable accounts for spillover effects in return and volatility. Overall, it can be concluded that the developed univariate AR-EGARCH models successfully capture the effects of volatility transmissions in the examined stock markets.

Keywords:
volatility transmissions,
EGARCH model,
trading volume effect,
exchange rates fluctuations,
S&P 500 index return,
South and Eastern Europe

Introduction

This research attempts to broaden the horizons around the themes of return and volatility spillovers (Sztavrosz 2019, Hung 2020, Kuncoro 2020). This is a topic of continuous and growing scientific research as economic integration at a global level and the advancement of technology has attracted the attention of many scientists in such areas. Scientific interest is reinforced by the potential practical use of the findings by individual and institutional investors. The study contributes to the extant literature by expanding the applied methodology to countries that have not received much attention from scholars yet.

This study aims to examine the return and volatility spillovers for a range of Balkan, Oriental, and Slavic countries. Often, such peripheral countries do not attract the attention of researchers, and their importance is neglected. However, real-life teaches, sometimes in a hard way, that every cycle of the global chain is significant. A typical example is the financial crisis in Greece, which churned violently not only the country or the neighbouring countries, but also had significant consequences in the global economic system, causing nervousness in all four corners of the globe. Through this prism, the empirical results of such a study are of great interest.

Hence, the research question of this study is whether there are spillover effects from one period to the next in a stock exchange and, in parallel, the intensity of transmission effects originating from other markets. The study aspires to cover a decennial period by gathering daily data and processing it according to the preferred methodology. Specifically, the investigation spans the years 2006 to 2015, which includes the great financial crisis and the global economic recession. We chose this period because it was the only one for which we had data. In addition, we formed a sub-period, from 2008 to 2010, to investigate the effects of the financial crisis on our results.

This study focuses on how the spillover effects influence demand and supply of shares. It explores not only the relationships among returns, but also evaluates the volatility spillover phenomenon, which is used as a measurement of the overall risk of financial assets. The volatility spillover effect is quite important, as it is a major factor in spreading the financial risk from one location to another. This effect is mostly visible during periods of intense fluctuations, when the benefits of international portfolio diversification to stockholders are limited, if not reversed. The possible existence of the leverage effect is also explored in the study. According to the results, spillover volatility is asymmetric, which means that „bad news" (price drop) has a bigger impact on volatility than „good news" (rise in price). The findings of this study have both theoretical and practical implications.

Economic spillover effects among countries have increased significantly in recent decades, as the share of world trade in global gross products has risen from an average of 26 percent in the 1960s to 42 percent in the 1990s (Arora–Vamvakidis 2005). It is a common belief that as countries become more integrated, they are increasingly influenced by each other's economic development or recession. Moriyama (2010) estimated the spillover effects of the global crisis on emerging market economies in the Middle East and North African countries, discovering that nearly two-thirds of the increased financial stress in these countries after the Lehman shock was attributable to direct or indirect spillovers of financial stress in advanced economies.

The considerable increased flows of capital among countries and the collapse of restrictions into international commerce, in addition to the development of technology, can be considered as the main factors for the globalisation process among exchange markets. Consequently, understanding the relationships between various financial markets is critical for financial institutions, portfolio managers, and individual investors. Return and volatility spillover impacts are very important for the optimal formation of a rational portfolio based on fundamentals. The decoding, and therefore, the knowledge of transmission mechanisms may provide the prospect to predict the behaviour of a given market by using the necessary information and a suitable methodology, leading to successful trading strategies.

To achieve this and shape a model as reliably as possible, the present study contributes by enriching the analysis of return and volatility spillovers with some additional explanatory variables. As potential extensions of the basic spillover model, this research adds not only the trading volume effect, but furthermore two explanatory variables are tested: i) the exchange rates of each country's domestic currency related to the USD, and ii) the behaviour of S&P 500 index. These variables are used not only independently, but also in combination, both with and without the liquidity factor. To the best of our knowledge, this method is novel because it is the first time that such a combined formula has been formed. It will be interesting to see if these approaches can improve the performance of the basic model in terms of predicting the behaviour of return and volatility spillovers. In domestic markets, a positive relationship between these two variables and conditional variance is expected.

The paper proceeds as follows: the literature review section presents a brief but comprehensive selected literature review of the study's subject, the methodology section explains the preferred methodology, and the data section describes the data. The following section presents the empirical results, while the conclusions section summarises and concludes the paper.

Literature review

This section illustrates some selected studies that refer to spillover effects related to the stock market exchanges of several countries. Western Europe can be considered a very interesting area for studying spillover effects among stock market exchanges due to its economic magnitude. Baele (2005) investigated the extent to which globalisation and regional integration led to an increase in equity market interdependence. The researcher focused on Western Europe, as this region had gone through a unique period of economic, financial, and monetary integration. The results revealed that both the EU and U.S. shock spillover intensity increased substantially over the 1980s and the 1990s, although the rise was more pronounced for EU spillovers. According to the findings, increased trade integration, equity market development, and low inflation contributed to the increase in the EU shock spillover intensity. Finally, there is evidence of contagion from the U.S. market to a number of local European equity markets during periods of high world market volatility.

Regarding Eastern Europe, Egert–Kocenda (2007) analysed the interrelations between three stock markets in Central and Eastern Europe and, in addition, interconnections that may exist between Western European countries (Germany, France, and the United Kingdom) and Central and Eastern European countries' stock markets (Hungary, Czech Republic, Poland). They used five-minute tick intraday price data from mid-2003 to early 2005 for stock indices and found no robust integration relationship for any of the stock index pairs or extended specifications. However, there were signs of short-term spillover effects, both in terms of stock returns and stock price volatility. The results show the presence of bidirectional causality for returns as well as volatility series. In general, spillover effects are stronger from volatility to volatility than contagion effects from the return-to-return series.

Syriopoulos–Roumpis (2009) investigated the presence of time-varying co-movements, volatility implications, and dynamic correlations in major Balkan and mature equity markets to provide quantified responses to international asset allocation decisions. The Balkan stock markets exhibited time-varying correlations as a peer group, although correlations with mature markets remained relatively modest. In conjunction with sensitivity analysis of asymmetric variance, active portfolio diversification to the Balkan equity markets potentially improves investors' risk–return trade-off.

Furthermore, as far as Middle Eastern countries are concerned, Ezzati (2013) studied financial markets' volatility spillover from one market to another, focusing on Iran. Through an analysis of the international transmission of financial volatility movements among six selected countries, the author considered unidirectional effects originating from the U.S., Germany, Japan, Saudi Arabia, and Kuwait to Iran. The analysis was conducted using a two-stage procedure based on the GARCH-M model. The results indicated the existence of significant volatility interdependencies among Iranian financial markets within the Middle East and the rest of the world.

Alikhanov (2013) paid attention to eight Eastern European countries, including Croatia, the Czech Republic, Hungary, Poland, Romania, Russia, Ukraine, and Turkey, with an emphasis on the mean and volatility spillover effects from the US and EU stock markets as well as the oil price market for a weekly period from 2000 to 2012. The results revealed that the stock returns of individual emerging countries were mostly influenced by US volatility spillovers rather than EU or oil markets. In addition, the stock market returns of Hungary, Poland, Russia, and Ukraine responded asymmetrically to shocks in US stock returns. Weak evidence of asymmetric effects was found in the case of Russia, but only with respect to oil market shocks. Moreover, a dummy variable model confirmed the effect of EU enlargement on stock returns only for Romania.

In their study, Moagăr-Poladian et al. (2019) analysed the link between exchange rates and stock markets in four Central and Eastern European countries, namely the Czech Republic, Hungary, Poland, and Romania, from 2003 to 2018. The analysis yielded the following results. First, they found a low degree of convergence between foreign exchange markets, with rising correlations during some crisis episodes. Second, both the 2004 European Union enlargement and the European sovereign debt crisis underpinned stock market co-movements in Central and Eastern European countries. Third, the correlations between the exchange rate returns and stock markets rose mostly during the European sovereign debt crisis and to a lesser extent during the global financial crisis, revealing signs of contagion and lower portfolio diversification opportunities.

More recently, Karkowska–Urjasz (2021) tried to identify the direction and scale of the connectedness of selected post-communist countries from Central and Eastern Europe and major global and European sovereign bond markets, covering the period 2008–2020, including the COVID-19 pandemic. They verified the volatility spillovers in bond markets. Then, the researchers divided the data into four sub-periods and found that the connectedness effects were especially enhanced in the sub-period after the financial crisis of 2007–2008 and later in the sub-period due to COVID-19.

Finally, Hung (2022) examined the evolution of the return and volatility spillover effects between the world stock index and some selected European countries for the years 2010 – 2019. Results indicated that the average return equicorrelation across the countries under consideration and the world stock indices was positive. In addition, the two-way return and volatility between the world stock index's and the selected stock markets' returns, existed in the aftermath of the recent European debt crisis.

Methodology

This section describes the employed methodology based on autoregressive conditional heteroskedasticity (ARCH) processes (Engle 1982). These models are used to characterise time-series data, such as daily returns. It is utilised whenever it is assumed that the variance of the current error terms is a function of the actual sizes of the error terms of the previous period.

The present research prefers a more advanced version of GARCH models, namely the exponential generalised autoregressive conditional heteroskedasticity (EGARCH) model, introduced by Nelson (1991), which permits the estimation of volatility interactions one step ahead. This model is superior to other models, such as QGARCH or GJR-GARCH because while the first model tends to under-predict volatility associated with negative innovations (Engle–NG 1993), the second model does not account for the difference between positive and negative innovations, unlike the EGARCH model. The EGARCH(p,q) model can be written as:

$$\log \sigma_t^2 = \alpha_0 + \sum_{i=1}^{p} \alpha_1 \left(|z_{t-i}| - E|z_{t-i}| \right) + \alpha_2 z_{t-i} + \sum_{j=1}^{q} \alpha_3 \log \sigma_{t-j}^2 \tag{1}$$

where σ_t^2 is the conditional variance; α_0, α_1, α_2, and α_3 are coefficients; and z_t may be a standard normal variable or come from a generalised error distribution.

Return of a given stock index is calculated by the following formula:

$$R_t = \beta_0 + \beta_1 R_{t-1} + \varepsilon_t \tag{2}$$

where R_t is the percentage return at time t for each individual market, and ε_t is the innovation at time t for that market.

To describe the variance, the conditional variance of ε_t is employed. The conditional variance of ε_t is given as:

$$\sigma_t^2 = \exp\{\alpha_0 + \alpha_1[(|z_{t-1}| - E|z_{t-1}|) + \alpha_2 z_{t-1}] + \alpha_3 \ln \sigma_{t-1}^2\} \tag{3}$$

when it is assumed that for a positive α_1, the impact of z_{t-1} on σ_t^2 will be positive if the magnitude of z_{t-1} is greater than its expected value $E|z_{t-1}|$. By contrast, the impact of z_{t-1} on σ_t^2 will be negative if the magnitude of z_{t-1} is smaller than its expected value $E|z_{t-1}|$, supposing again for a positive α_1. Terms ($|z_{t-1}| - E|z_{t-1}|$) measure the magnitude effect, whereas $\alpha_2 z_{t-1}$ measures the sign effect. The sign effect may enhance or offset the magnitude effect. More specifically, when α_2 is negative, a decrease in stock index price ($z_{t-1}<0$) will be followed by higher volatility, while an increase in stock value ($z_{t-1}>0$) will be followed by a more moderate volatility. A negative and statistically significant α_2 value indicates that the leverage effect exists. The leverage effect generally refers to the negative correlation between an asset's returns and volatility.

A statistically significant α_1 with a negative α_2 at the same time means that negative innovations in the stock price index have a higher influence than positive innovations. On the contrary, a positive α_2 means that positive innovations in the stock price index have a higher influence than negative innovations.

The persistence of volatility implied by equation (3) is measured by the parameter α_3. If α_3 is less than one, the conditional variance is finite, whereas if α_3 is statistically equal to one, then the conditional variance follows an integrated process of order 1.

Next, the conditional asymmetric volatility equation (3) is enriched by adding some explanatory exogenous variables, such as trading volume (TV), to discover their ability to explain the transmission mechanism process in each stock market. To achieve this, following Hasan–Francis (1998), the coefficient φ is nested in equation (3) to capture the potential relationship between stock index returns of each market and the impact of (TV). In symbols, it can be represented as:

$$\sigma_t^2 = \exp\{\alpha_0+\alpha_1[(|z_{t-1}| - E|z_{t-1}|)+\alpha_2 z_{t-1}] + \alpha_3 \ln\sigma_{t-1}^2 + \phi TV_t\} \quad (4)$$

Beyond the TV variable, this study seeks to contribute to international literature by introducing additional independent variables, such as the exchange rate fluctuations of each domestic currency against the USD and returns of the US exchange market. The idea for considering these variables arises from the notion that numerous investors in emerging markets may believe that current developments at the world's financial centre act as a signal from lighthouse about their own decisions for local transactions. Moreover, whenever the value of the domestic currency meets a drop (raise), the real price of shares becomes cheaper (more expensive) for international investors and, consequently, some may see it as a bargain (obstacle) to acquire stocks. This theory can also be adjusted for the selling of shares. In any case, past prices are preferred, not only for the percentage change of the exchange rates, but also for the US stock market, as it is considered that some time is needed for information dispersion. Furthermore, these variables are tested with and without the influence of the TV variable.

Based on the above, equation (3) is expanded as follows to include the exchange rate fluctuations (ER) effect as well:

$$\sigma_t^2 = \exp\{\alpha_0+\alpha_1[(|z_{t-1}| - E|z_{t-1}|)+\alpha_2 z_{t-1}] + \alpha_3 \ln\sigma_{t-1}^2 + \chi ER_{t-1}\} \quad (5)$$

where χ is the coefficient of ER variable. In an analogous way, equation (3) leads to equation (4) when the trading volume variable is enclosed, and equation (5) changes as follows:

$$\sigma_t^2 = \exp\{\alpha_0+\alpha_1[(|z_{t-1}| - E|z_{t-1}|)+\alpha_2 z_{t-1}] + \alpha_3 \ln\sigma_{t-1}^2 + \chi ER_{t-1} + \phi TV_t\} \quad (6)$$

because the trading volume in the current period is added. A positive relationship between the (ER) parameters and the conditional variance of domestic markets is expected.

Returning to equation (3), another variable can be used in the model to evaluate the influence of the US stock exchange on each examined European domestic market. For this purpose, the S&P 500 index was selected as a representative of the American stock market. Therefore, an augmented form of equation (3) is shaped as follows:

$$\sigma_t^2 = \exp\{\alpha_0+\alpha_1[(|z_{t-1}| - E|z_{t-1}|)+\alpha_2 z_{t-1}] + \alpha_3 \ln\sigma_{t-1}^2 + \psi SP_{t-1}\} \quad (7)$$

where ψ is the coefficient of the S&P 500 index return (SP) variable. Again, a positive relationship between the (SP) variable and the conditional variance of domestic markets is expected. The trading volume of the current period is added once more to test if it helps to shed extra light on the spillover mechanism process. In symbols:

$$\sigma_t^2 = \exp\{\alpha_0+\alpha_1[(|z_{t-1}| - E|z_{t-1}|)+\alpha_2 z_{t-1}] + \alpha_3 \ln\sigma_{t-1}^2 + \psi SP_{t-1} + \phi TV_t\} \quad (8)$$

A complex model of previous equations is employed by combining the exchange rate (ER) variable and the (SP) variable into a single mathematical sentence with and without the trading volume (TV) level. In particular, equations (5) and (7) are merged into a new single model as follows:

$$\sigma_t^2 = \exp\{\alpha_0+\alpha_1[(|z_{t-1}| - E|z_{t-1}|)+\alpha_2 z_{t-1}] + \alpha_3 \ln\sigma_{t-1}^2 + \chi ER_{t-1} + \psi SP_{t-1}\} \quad (9)$$

To include the liquidity effect as well, equations (6) and (8) are merged into equation (10):

$$\sigma_t^2 = \exp\{\alpha_0 + \alpha_1[(|z_{t-1}| - E|z_{t-1}|) + \alpha_2 z_{t-1}] + \alpha_3 \ln\sigma_{t-1}^2 + \chi ER_{t-1} + \psi SP_{t-1} + \phi TV_t\} \quad (10)$$

The above holistic approaches may contribute to obtaining a more spherical view of the powers that drive conditional variance. To the best of our knowledge, this is the first time that such combined equations are formed, possibly strengthening the ability of the model to predict future volatility.

Finally, we study the impact of the Eurozone crisis on the results. For this purpose, a sub-period was defined in the analysis. This sub-period, 2008–2010, is considered to be the „heart" of the financial crisis.

Data

This study employs data from the stock markets of 12 selected Eastern European countries, namely, Croatia, Cyprus, Czech Republic, Greece, Israel, Poland, Romania, Russia, Serbia, Slovenia, Turkey, and Ukraine. The information consists of the daily return of the major index for every stock exchange over a period of ten years, from 2006 to 2015 (Figure 1). This major index adequately represents each bourse. Table 1 summarizes the information about the indices. In addition, Table 2 reports the diagnostic test statistics.

As shown in Table 1, the stock market of Cyprus suffered the greatest negative mean return, –0.188, among the 12 countries under investigation. Additionally, this was the market with the highest volatility, as the last was measured by standard deviation. The price of the standard deviation of the Cyprus stock exchange was 3.044. These findings cannot be considered as a surprise, given that the domestic financial crisis that prompted the Cypriot economy to sign the Memorandum of Understanding (MoU) occurred during that time period, specifically in 2012. This turn proved to be a fairly good reason for a large number of investors to react nervously, and in some cases, to abandon the Cyprus exchange market. On the antipode, the stock index that achieved the highest mean return was Turkey's BIST 100, with a value of 0.036, followed by Croatia's CROBEX, which had an increase of 0.02. This is despite the great decline in gross domestic product (GDP) in these countries during 2009, which was –4.826% and –7.384%, respectively. In parallel, the most „calm" stock exchange was the Slovenian, as its index SBITOP had the lowest volatility.

Table 1

Indices, 2006–2015

Country	Index	OBS	Mean	Median	SD	Max	Min
						%	
Croatia	CROBEX	2,356	0.02	–0.001	1.286	11.36	–13.73
Cyprus	General Index	1,215a)	–0.188	–0.155	3.044	18.48	–14.37
Czech Republic	PX	2,356	–0.005	0.022	1.559	13.16	–14.94
Greece	General Index	2,345	–0.051	0.02	2.205	14.37	–16.23
Israel	TA 25	1,886	–0.01	–0.058	1.293	7.51	–7.78
Poland	WIG 20	2,356	–0.004	0.03	1.398	8.51	–8.54
Romania	BET 10	2,356	0.012	0.022	1.65	11.14	–12.29
Russia	RTSI	2,353	0.015	0.089	2.356	22.38	–19.1
Serbia	BELEX 15	2,356	–0.014	–0.03	1.393	12.92	–10.29
Slovenia	SBITOP	2,339	–0.011	0.001	1.199	8.71	–8.08
Turkey	BIST 100	2,356	0.036	0.071	1.8	12.89	–13.54
Ukraine	UX	1,89 b)	–0.028	–0.058	2.33	18.2	–12.37

a) From 2010 to 2015.
b) From 2008 to 2015.

Figure 1

Returns of major index by country

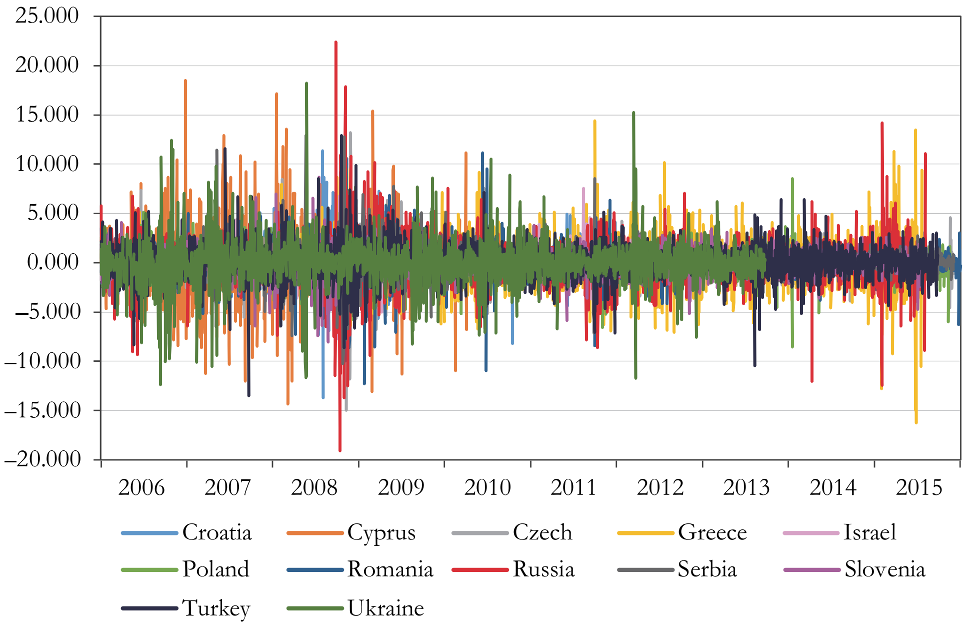


Table 2

Diagnostic tests, 2006–2015

Country	Index	Skewness	Kurtosis	Kolmogorov-Smirnov	LB(20)	LB^2(20)
Croatia	CROBEX	0.365	15.848	–15.857*	153.24*	2804.95*
Cyprus	General Index	0.526	5.649	–7.097*	34.089**	259.846*
Czech Republic	PX	–0.126	13.797	–30.403*	70.161*	3309.797*
Greece	General Index	–0.07	5.646	2.79*	30.552***	627.329*
Israel	TA 25	0.438	3.475	–14.768*	29.105**	1620.076*
Poland	WIG 20	–0.355	4.102	–19.216*	39.323*	1000.864*
Romania	BET 10	–0.344	8.09	–40.018*	67.677*	1787.799*
Russia	RTSI	0.067	10.829	1.068*	67.042*	2217.461*
Serbia	BELEX 15	0.475	14.685	–41.086*	464.002*	909.803*
Slovenia	SBITOP	–0.296	6.588	8.045*	104.29*	1757.869*
Turkey	BIST 100	–0.137	5.478	5.462*	24.139	378.013*
Ukraine	UX	0.186	7.605	–1.142*	89.152*	680.012*

Notes: Asterisks (*) (**) (***) indicate significance at the (1%) (5%) (10%) level, respectively.

Skewness and kurtosis were verified in most cases. Additionally, the null hypotheses about the normality of time series data are rejected according to the Kolmogorov–Smirnov test. These phenomena may originate, at least to a degree, to temporal dependencies in returns. To test whether such dependencies are present, the Ljung-Box (LB) statistic is employed. The Ljung–Box statistics are applied to returns to test for linear dependencies, that is, to test for serial correlation. Furthermore, they are applied to squared returns to test for nonlinear dependencies, that is, to test heteroscedasticity. The findings provide strong evidence that autocorrelation exists and also confirms the existence of heteroscedasticity. A possible explanation for these results could be that common information is impounded into stock prices not only on the disclosure day, but on the following day as well.

The variance specification tests are reported in Table 3. These tests were proposed by Engle–Ng (1993) and were designed to investigate how well the employed models capture volatility dynamics. The Engle–Ng tests are: i) the sign bias test, ii) negative size bias test, iii) positive size bias test, and iv) joint test. The first test examines the asymmetric impact of positive and negative innovations on volatility. The test is based on the t-statistic. The negative size bias test examines how well the model captures the impact of large and small negative innovations. The positive size bias test examines the possible biases associated with large and small positive innovations. Finally, a joint test can be based on the F-statistic of a regression, involving all three explanatory variables.

Table 3

Bias tests, 2006–2015

Country	Sign bias	Negative size bias	Positive size bias	Joint test
Croatia	–4.759*	–3.528*	–7.498*	2.227**
Cyprus	1.377	–1.744***	4.796*	–0.41***
Czech Republic	–1.717***	–1.554	–2.684*	8.827*
Greece	–0.659	0.556	–4.509*	5.7*
Israel	–0.457	0.112	0.876	2.808*
Poland	1.86***	3.033*	0.791**	8.46*
Romania	–0.747	–5.956*	2.048**	2.89*
Russia	–1.008	–5.197*	3.906*	2.301**
Serbia	2.403**	–1.203	7.913*	5.502*
Slovenia	–0.578	–1.785**	0.408	8.402*
Turkey	0.862	–3.128*	1.345	–0.714
Ukraine	2.893*	2.56**	5.345	9.008

Notes: Asterisks (*) (**) (***) indicate significance at the (1%) (5%) (10%) level, respectively.

Empirical results

This section presents the empirical results of the investigation of the return and volatility spillovers. Table A1 in the Appendix shows the findings of the coefficients of mean and conditional variance. The first line for each country refers to the basic model (3), while the line titled „TV" reveals outcomes when the trading volume variable enters into model (4). Therefore, the coefficient φ is added. Below each figure, in parentheses, there are corresponding p-values. Additionally, Table A1 in the Appendix illustrates the maximum log-likelihood estimations for equations (3) and (4). According to Table A1, coefficient β_1 is positive in almost all cases. Thus, a positive first-order autoregressive process exists. As far as the volatility coefficient α_1 and the magnitude effect for variance are concerned, it is positive and statistically significant at the 1% level for every occasion. The leverage effect parameter α_2 was found to be negative and statistically significant for all indices, except for Cyprus and Slovenia. These results indicate that the leverage effect exists in most markets. These findings are in line with previous research which found a leverage effect in the stock returns of various indices (Karpoff 1987). As α_2 is less than zero, a negative shock increases volatility more than a positive shock does. When (TV) parameter is considered, these outcomes seem to be mitigated. The degree of volatility persistence, as measured by coefficient α_3, is close to one for almost all cases. However, the inclusion of (TV) variable in the conditional variance equation caused a decline in the values of the coefficient α_3 for many countries, implying that this variable accounts for some of the volatility persistence in these markets. The penultimate column of Table A1 in the Appendix illustrates the values of the φ coefficient for the (TV) variable. It can be concluded that there is a positive relationship between the volume of (TV) and conditional variance. This can be interpreted as more transactions may lead to greater fluctuations. Subsequently, the addition of (TV) variable influences the log-likelihood values. On nine out of twelve occasions, it is found that the log-likelihood values for equation (4) are higher than those of equation (3). Hence, it can be concluded that, in general, the inclusion of (TV) variable may help to better understand the transmission mechanisms between returns and volatilities in stock exchange markets.

Next, the influence of (ER) variable is added to the model, according to the methodology introduced in this paper. Table A2 in the Appendix illustrates the outcomes for the return spillover coefficients of β_1. These results are quite similar to the corresponding findings for equations in which the (ER) variable is not included. This implies that the use of (ER) variable does not drastically affect the behaviour of the return spillover coefficient. The results for the volatility coefficient α_1 are still the same, regardless of whether the (ER) variable is concerned. Thus, the entry of this variable seems to maintain stable outcomes for the magnitude effect of conditional variance. The figures of coefficient α_2 derived from the equations with the (ER), reveal that the leverage effect is present for the large majority of the examined markets. Specifically, 'bad news' has a greater effect on the conditional variance of the markets than 'good news'. A comparison of these results with those obtained by the basic models, where the (ER) is not included, indicates that the results are, in general, very similar under both methodologies. Furthermore, it is remarkable that for none of the 12 occasions, the value of coefficient α_3 for the model with (ER) is higher than the corresponding value of the model without this parameter. The basic conclusion is that the insertion of the extra variable into the models weakens the shock's persistence in volatility.

The expected positive relationship between the (ER) of the previous period and the conditional variance is confirmed for almost all cases, with the exception of Cyprus. Coefficient χ was found to be significant at 1% level for Croatia, Israel, Romania, Russia, and Serbia, and at 10% level for Poland and Slovenia. Employing the (TV) variable, as well, into the model does not seem to influence the characteristics of the coefficient χ. The results also reveal that when the (ER) are included in the variance equation, the positive relationship between the height of (TV) and the conditional variance seems to be mitigated, as captured by coefficient φ.

Later, research was conducted to determine how the US stock exchange may influence the conditional mean and variance of the examined markets. For this purpose, the S&P 500 (SP) index was employed. It was expected to have a positive relationship between the (SP) index innovations of the previous period and the conditional variance of the domestic markets. According to Table A3 in the Appendix, there is a widely positive first-order autoregressive process, as it is specified by the mean equation, or in other words, the returns of US stock exchange influence domestic European returns in the same direction in the following period for the majority of markets. The coefficient α_1, about the magnitude effect on the conditional (time-varying) variance, is positive and statistically significant at the 1% significance level in every market, with or without the liquidity effect, except for the Czech Republic. These results are by and large the same as those obtained by the basic model with no extra variables (3) and by the equation where the (ER) variable is added (5). Table A3 also reports the results of the parameter measuring asymmetric volatility spillover effects when the (SP) variable is considered. The findings confirm the existence of the leverage effect, at least for most of the markets under examination. The outcomes were identical for every formed equation. The complete agreement about the sign of the coefficient of asymmetric volatility from six differentiated approaches underlines the constant behaviour of that coefficient. In addition, it is remarkable that, for Greece, the value of coefficient α_3 obtained by the model with (SP) variable (7) is higher than the corresponding value of the model without (SP) variable (3). Moreover, the inclusion of (TV) variable in the conditional variance equation leads to a decline in the coefficient's α_3 value, except for Russia. The assumed positive relationship between (SP) variable and conditional variance is confirmed for almost all cases, except for Cyprus and Greece. The inclusion of (TV) in the variance equation does not seem to influence the size of the ψ coefficient in a particular pattern. Moreover, if (SP) variable is included in the variance equation, the influence of (TV) seems to be lessened. Log-likelihood values are greater according to models including the (SP) variable for almost every case. Thus, the use of this particular variable manages to produce superior outcomes for the majority of cases, and it can be considered that its usage contributes to the analysis of conditional variance.

The next phase of the study combines all previous models into a single scheme, with (10) and without (9) the (TV) variable. More precisely, these two blending models, which are based on the previous equations, are shaped by combining the fluctuations of exchange rates as well as the returns of the S&P 500 index into a particular mathematical sentence, to explore how these parameters combinedly influence the conditional variance of the examined markets. According to Table A4 in the Appendix, the spillover coefficient β_1 of the conditional mean is positive for 11 out of the 12 countries. Generally, the inclusion of these two extra variables reduces the volume of the return spillover coefficient. The results for the sign of coefficient β_1 are identical to the findings of the previous equations, that is, the basic model, the model with (ER) and the model with (SP). The outcomes for coefficient α_1 are quite similar throughout the eight equations. Thus, using (ER) and (SP) variables does not seem to radically influence the fundamental characteristics of coefficient α_1, such as its sign. These results can be interpreted as evidence of the conditional variance model's stability. However, it can be said that the inclusion of additional explanatory variables may reduce the size of the coefficient.

In addition, it is remarkable that the signs of coefficient α_2 are precisely the same for each of the eight employed approaches. Consequently, the above findings confirm the reliability of the preferred methodology and the existence of the leverage effect, at least for most markets under examination. This implies that news that runs from the previous period to the next is asymmetric, and in particular that 'bad news' has a bigger impact on volatility than 'good news'. Nevertheless, the inclusion of (TV) variable in the variance equation seems to reduce the levels at which coefficient α_2 is considered statistically different than zero.

This phenomenon could be explained by the traders' lack of trust in long-run stock markets. This type of behaviour may be the source of a lack of confidence in a given market. This lack of confidence, in turn, could originate from a plethora of factors. For example, many of the countries under investigation overthrew their former communist regimes only recently in the late 80s. Thus, some may consider it reasonable that the citizens and local investors to not have developed strong relationships of faith with financial institutions like a stock market exchange, as traders have done in more mature markets. In parallel, the Greece story seems to be quite different. There, the lack of confidence seems to emerge from the financial crisis and the imposition of the Memorandum of Understanding. We consider the negative influence of macroeconomics on listed companies, the limited available incomes of households, which result in individuals' reluctance to make long-term investments, and finally, the capital controls that country had to impose as the main factors that connect the Memorandum of Understanding with this type of traders' pattern.

Additionally, analysis of the degree of volatility persistence, as measured by coefficient α_3, revealed that when the (TV) variable is not used, the coefficient is quite close to one for almost any market. However, when (TV) variable is included in the conditional variance equation, the value of coefficient α_3 is reduced. This is typical for any of the formed models since the inclusion of (TV) seems to move the conditional variance away from an integrated process of order one.

Moreover, Table A4 illustrates the results for additional coefficients, that is, χ for the (ER) variable and ψ for the (SP) variable. The expected positive relationship is confirmed nine times for the first parameter and eleven times for the second. These are statistically important for four and seven cases, respectively. The entry of (TV) variable into the model resulted in the coefficient χ to still be positive for nine occasions and coefficient ψ to be positive for nine markets. Each of these figures is statistically important for the five countries. These mixed findings for the exchange rate factor can be interpreted as follows: as the value of the domestic currency decreases, the purchasing power of foreign capital increases, encouraging the latter to purchase securities. Thus, the observed relationship was justified. In the case of Cyprus, and also in some other countries, the sign is different but not statistically significant. Other domestic factors, such as local macroeconomic performance and distracting investors from the exchange rate effect, prevailed in the market.

When compared to the impact of the additional variables when used separately, incorporating them into a single model concurrently moderates their influence on the conditional variance. This holds true for both approaches, with and without the (TV) variable. When both additional variables are employed, the coefficient φ for (TV) variable is found to be positive and statistically significant most of the time. The results were broadly similar under any methodology. Generally, it can be concluded that (TV) variable can explain some of the conditional variance's behaviour and there is a relatively positive relationship between (TV) and conditional variance.

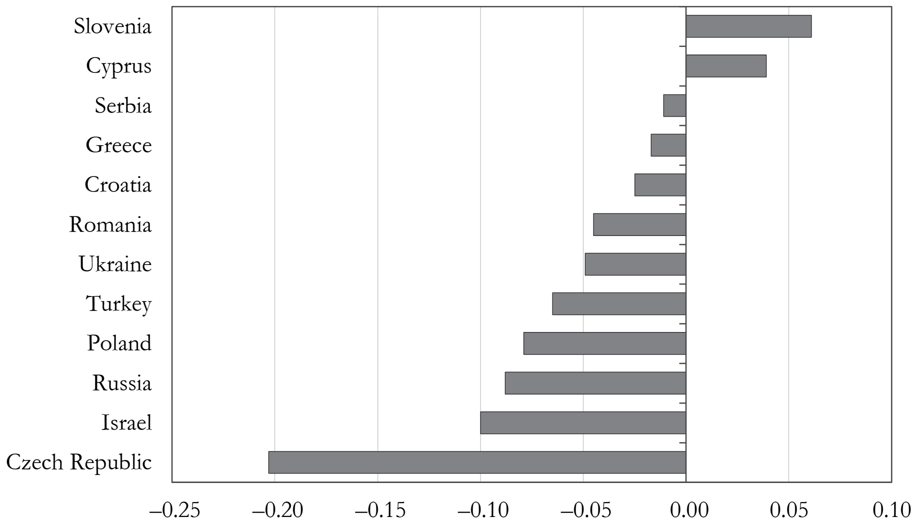
In addition**,** based on the figures in the last column of Table A4 in the Appendix, it can be concluded that the employment of (TV) leads to higher log-likelihood numbers in ten cases. Thus, when (TV) is used in the model, the observed sample is more likely to be a function of the possible parameter values. A comparison of the equations with and without the extra explanatory variables (ER) and (SP) introduced in this paper, reveals that values are greater for the first group in almost every case. Hence, the use of these variables aids in the analysis of the conditional mean and variance. Furthermore, models that use both extra explanatory variables simultaneously often provide higher figures than models that employ them separately. In general, it can be concluded that these extra explanatory variables can better explain the conditional variance.

The intensity of the transmission effects for each case can be proved to be a crucial matter for investors' decisions. More specifically, if a given emerging stock market exchange is only weakly integrated with developed markets, this means that external shocks will have less influence on them. Hence, investors in developed markets can benefit by including emerging market stocks in their portfolios, as this diversification reduces their risk. On the other hand, if the emerging markets are highly or even fully integrated with the developed stock markets, the volatility in the emerging markets will decrease because it will be primarily determined by the developed markets' volatilities, which can be considered more moderate in general. Certainly, in this case, a potential depreciation in equities of developed stock markets will unavoidably negatively influence the developing stock markets.

Lastly, the results for the sub-period of the financial crisis, 2008–2010, reveal that the return spillover coefficients of β_1 are positive for eleven out of twelve countries, with the exception of Greece; thus, there is a positive first-order autoregressive process. These outcomes are consistent across the entire sample period (Table A5 in the Appendix). For Greece, the situation may be different because, as the focal point of the recession, the nervousness of traders may have been at high levels, causing the market to react in its own unique way. As far as the volatility coefficient α_1 is concerned, it is statistically important most of the time, followed by a negative parameter α_2, which verifies the presence of the leverage effect. However, the phenomenon seems to weaken when the results are compared with the total period, indicating that during the crisis, traders may have focused less on the information coming from stock exchanges. This situation is similar in terms of the trading volume parameter. The two additional explanatory variables do not appear to show significant differences in the sub-period.

Figure 2

Prices of parameter α_2 about leverage effect, 2006–2015



Conclusions

This research focuses on the return and volatility spillover phenomenon in 12 equity markets of some selected Eastern European countries. The main purpose of the study is to empirically explore the transmission mechanisms of stock returns and volatilities. Our approach captures both the sign and size of innovations, allowing us to test whether shocks originating from one period can affect the volatility of the next period in an asymmetric way. The asymmetric effect of innovations on volatility refers to a situation in which a negative shock (price drop) increases volatility more than a positive shock (price rise).

In addition to the trading volume (TV) variable, our work introduces two more explanatory variables to the basic model, namely, the exchange rate (ER) changes of the domestic currency to the USD and the return of the US market (SP). Hence, eight equations were created for each country, as extra explanatory variables were employed not only separately, but also in a synthesis of the previous formulas, with and without the TV effect. The mechanism underlying this concept is described analytically in the section that illustrates the employed methodology. The 'fuel' for these models was the information of daily closing prices for the major index of each country's stock exchange. The tests covered a period of over ten years for most countries, from 2006 to 2015.

According to the empirical results, return and volatility spillovers were confirmed for most cases through different approaches. Specifically, the coefficients of return spillovers were positive and statistically significant 64 out of 96 times, while the volatility spillover parameter proved to be positive and statistically significant in almost every case, with the exception of the Czech Republic market. As far as the coefficient that captures the leverage effect is concerned, it was negative and statistically important 68 out of 96 times. Additionally, the volatility persistence measure was found to be statistically equal to one in 27 cases and less than one in 69 cases. In addition, the empirical outcomes of the present study illustrate that (TV) accounts for spillovers as the parameter of this variable was statistically significant on 40 out of 48 occasions. Moreover, the coefficient carried a positive sign 35 times.

Furthermore, the expected positive relationship between the (ER) of each European domestic currency to the USD and the conditional variance was confirmed again on 40 out of 48 occasions. This was statistically significant for 23 of them. In parallel, the coefficient of the other new explanatory variable, (SP), was confirmed to be positive on 39 occasions. This latter parameter was found to be positive and statistically important at the same time 28 times. Finally, for most cases, the log-likelihood figures, an expression of optimal values of estimated coefficients, were proved to be higher for the approach that includes both explanatory variables when compared to the corresponding values of the other models. Therefore, the two additional explanatory variables introduced in the present study can explain the return and volatility spillover phenomena in more detail. In addition, the use of (TV) in models seems to shed further light on the mechanism of return and volatility spillovers, as log-likelihood became superior for a plethora of cases, particularly 41 out of 48 cases. During the sub-period of the financial crisis, volatility spillovers were reduced, while Greece seemed to follow its own path in terms of return spillovers.

To conclude, there is evidence confirming the existence of return and volatility spillovers in the stock markets under examination. Moreover, the results revealed that the (TV) variable was responsible for some of the spillover effects. In addition, asymmetry was found to be substantial for conditional volatility for the majority of cases, largely confirming the leverage effect theory. In addition, the two explanatory variables introduced in this study were proven to be statistically significant on many occasions, suggesting that future scientific investigations into relevant topics could also consider them.

Appendix

Table A1

Univariate AR(1)–EGARCH(1,1) results with or without liquidity effects and spillovers for basic models, 2006–2015

	β_0	β_1	α_0	α_1		α_2		α_3	φ	Log-likelihood
Croatia	0.003	0.033	0.005	0.188		–0.045		0.99	–	–672.913
	–0.81	(0.049)**	(0.055)***	(0.001)*		(0.001)*		(0.001)*	–	
TV	–0.001	0.068↑	–0.426	0.467	↑	–0.066	↑	0.689	0.001	–698.4912
	–0.82	(0.004)*	(0.001)*	(0.001)*		(0.013)**		(0.001)*	(0.001)*	
Cyprus	–0.012	0.059	0.033	0.308		0.042		0.984	–	–965.9422
	–0.72	(0.069)***	(0.001)*	(0.001)*		(0.033)**		(0.001)*	–	
TV	–0.015	0.063 ↑	0.02	0.357	↑	0.041	↓	0.955	0.001	–952.7145
	–0.64	(0.001)*	(0.054)***	(0.001)*		–0.135		0.001)*	(0.001)*	
Czech	–0.077	0.153	0.003	0.026		–0.23		0.962	–	–70.5218
Republic	–0.3	(0.064)***	–0.85	–0.603		(0.001)*		(0.001)*	–	
	–0.063	0.092 ↓	–0.019	–0.129	↑	–0.063	↓	0.991	0.008	–65.9112
TV	(0.001)*	(0.001)*	(0.001)*	(0.001)*		(0.001)*		(0.001)*	(0.001)*	
Greece	0.003	0.084	0.067	0.201		–0.041		0.966	–	–1514.4441
	–0.92	(0.001)*	(0.001)*	(0.001)*		(0.017)**		(0.001)*	–	
TV	–0.004	0.043↓	1.832	0.135	↓	–0.04	↓	–0.368	0.006	–1533.1553
	–0.95	–0.14	(0.001)*	(0.0102)**		–0.276		(0.021)**	(0.001)*	
Israel	0.034	0.025	0.008	0.133		–0.07		0.982	–	–1330.828
	(0.051)***	–0.2	(0.002)*	(0.001)*		(0.001)*		(0.001)*	–	
TV	0.033	0.028↑	0.05	0.142	↑	–0.085	↑	0.973	–0.001	–1325.6284
	(0.08)***	–0.17	(0.004)*	(0.001)*		(0.001)*		(0.001)*	(0.012)**	
Poland	–0.025	0.021	0.007	0.113		–0.074		0.991	–	–1275.02
	–0.31	–0.38	(0.021)**	(0.001)*		(0.001)*		(0.001)*	–	
TV	–0.03	0.019↓	–0.009	0.086	↓	–0.086	↑	0.987	0.001	–1269.6595
	–0.15	–0.22	(0.086)***	(0.001)*		(0.001)*		(0.001)*	(0.002)*	

(The table continued next page.)

(Continued.)

	β_0	β_1	α_0	α_1		α_2		α_3	φ	Log-likelihood
Romania	0.001	0.095	0.006	0.261		–0.079		0.931	–	–745.5649
	–0.95	(0.001)*	–0.16	(0.001)*		(0.001)*		(0.001)*	–	
TV	0.005	0.061 ↓	–0.427	0.447	↑	–0.09	↑	0.51	0.024	–716.2735
	–0.803	(0.035)**	(0.001)*	(0.001)*		(0.009)*		(0.001)*	(0.001)*	
Russia	0.042	0.068	0.046	0.151		–0.079		0.9701	–	–3092.5115
	–0.178	(0.001)*	(0.001)*	(0.001)*		(0.001)*		(0.001)*	–	
TV	0.041	0.066 ↓	0.049	0.142	↓	–0.082	↑	0.9709	–0.001	–3090.9607
	–0.209	(0.001)*	(0.001)*	(0.001)*		(0.001)*		(0.001)*	(0.086)***	
Serbia	0.004	0.192	0.025	0.418		–0.027		0.961	–	–1281.6866
	–0.758	(0.001)*	(0.001)*	(0.001)*		(0.032)**		(0.001)*	–	
TV	0.001	0.194 ↑	0.001	0.419	↑	–0.032	↑	0.954	0.001	–1275.7352
	–0.825	(0.001)*	–0.235	(0.001)*		(0.017)**		(0.001)*	(0.001)*	
Slovenia	0.009	0.155	–0.047	0.324		0.06		0.898	–	–95.9113
	–0.793	(0.002)*	(0.07)***	(0.001)*		–0.146		(0.001)*	–	
TV	0.004	0.166 ↑	–0.105	0.336	↑	0.05	↓	0.876	0.001	–94.54
	–0.883	(0.001)*	(0.028)**	(0.001)*		–0.236		(0.001)*	–0.121	
Turkey	0.059	–0.006	0.059	0.132		–0.083		0.928	–	–1489.2759
	–0.075	–0.798	(0.001)*	(0.001)*		(0.001)*		(0.001)*	–	
TV	0.052	–0.028 ↑	–0.065	0.117	↓	–0.068	↓	–0.445	0.002	–1488.6461
	–0.131	–0.258	–0.59	(0.008)*		(0.033)**		(0.001)*	(0.001)*	
Ukraine	–0.014	0.12	0.09	0.358		–0.045		0.95	–	–1863.8668
	–0.711	(0.001)*	(0.001)*	(0.001)*		(0.009)*		(0.001)*	–	
TV	–0.043	0.145 ↑	0.308	0.63	↑	–0.029	↓	0.73	0.001	–1919.4194
	–0.287	(0.001)*	(0.001)*	(0.001)*		–0.377		(0.001)*	(0.001)*	

Notes: Asterisks (*) (**) (***) indicate significance at the (1%) (5%) (10%) level, respectively.

Table A2

Univariate AR(1)-EGARCH(1,1) results with or without liquidity effects and spillovers for exchange rates models, 2006–2015

	β_0	β_1	α_0	α_1		α_2		α_3	χ	ϕ	Log-likelihood
Croatia	0.001	0.034	–0.01	0.178		–0.042		0.985	0.027	–	–666.3331
	–0.904	(0.021)**	(0.059)***	(0.001)*		(0.001)*		(0.001)*	(0.001)*	–	
TV	0.001	0.056 ↑	–0.068	0.177	↓	–0.036	↓	0.957	0.042	0.001	–644.1103
	–0.698	(0.016)**	(0.001)*	(0.001)*		(0.001)*		(0.001)*	(0.001)*	(0.001)*	
Cyprus	–0.013	0.057	0.041	0.311		0.04		0.982	–0.021	–	–965.6499
	–0.682	(0.078)***	(0.003)*	(0.001)*		(0.062)***		(0.001)*	–0.459	–	
TV	–0.016	0.06 ↑	0.034	0.337	↑	0.044	↑	0.959	–0.048	0.001	–956.2435
	–0.358	(0.001)*	(0.037)**	(0.001)*		(0.091)***		(0.001)*	–0.156	(0.005)*	
Czech	–0.077	0.153	0.003	0.026		–0.23		0.962	0.001	–	–70.5218
Republic	–0.324	(0.041)**	–0.906	–0.642		(0.001)*		(0.001)*	–0.995	–	
	0.023	0.195 ↑	–0.107	–0.138	↑	–0.17	↓	0.29	0.343	–0.02	–67.0585
TV	–0.763	(0.035)**	–0.351	–0.616		–0.208		–0.292	(0.037)**	–0.287	
Greece	0.007	0.085	0.067	0.193		–0.041		0.956	0.043	–	–1513.1782
	–0.912	(0.001)*	(0.001)*	(0.001)*		(0.018)**		(0.001)*	–0.115	–	
TV	–0.003	0.043 ↓	1.821	0.135	↓	–0.04	↓	–0.362	0.005	0.006	–1533.1534
	–0.952	–0.118	(0.001)*	(0.007)*		–0.25		(0.042)**	–0.944	(0.001)*	
Israel	0.037	0.025	0.001	0.141		–0.078		0.972	0.021	–	–1325.5199
	(0.007)*	(0.024)**	–0.61	(0.001)*		(0.001)*		(0.001)*	(0.005)*	–	
TV	0.035	0.027 ↑	0.061	0.144	↑	–0.1	↑	0.957	0.029	–0.001	–1317.483
	(0.047)**	–0.198	(0.002)*	(0.001)*		(0.001)*		(0.001)*	(0.001)*	(0.002)*	
Poland	–0.026	0.021	0.004	0.102		–0.076		0.988	0.004	–	–1273.4118
	–0.329	–0.391	–0.194	(0.001)*		(0.001)*		(0.001)*	(0.08)***	–	
TV	–0.03	0.019 ↓	–0.009	0.084	↓	–0.086	↑	0.986	0.001	0.001	–1269.4473
	–0.261	–0.413	(0.082)***	(0.001)*		(0.001)*		(0.001)*	–0.509	(0.004)*	

(The table continued next page.)

(Continued.)

	β_0	β_1	α_0	α_1		α_2		α_3	χ	ϕ	Log-likelihood
Romania	0.006	0.099	–0.05	0.3		–0.079		0.883	0.116	–	–733.68
	–0.779	(0.001)*	(0.001)*	(0.001)*		(0.001)*		(0.001)*	(0.001)*	–	
TV	0.013	0.063 ↓	–0.593	0.451	↑	–0.081	↑	0.421	0.282	0.025	–685.9563
	–0.513	(0.012)**	(0.001)*	(0.001)*		(0.011)**		(0.001)*	(0.001)*	(0.001)*	
Russia	0.042	0.074	0.057	0.131		–0.086		0.95	0.003	–	–3082.9931
	–0.146	(0.001)*	(0.001)*	(0.001)*		(0.001)*		(0.001)*	(0.001)*	–	
TV	0.04	0.073 ↓	0.06	0.124	↓	–0.088	↑	0.952	0.001	–0.001	–3081.9855
	–0.25	(0.001)*	(0.001)*	(0.001)*		(0.001)*		(0.001)*	(0.001)*	–0.136	
Serbia	0.042	0.073	0.059	0.133		–0.088		0.95	0.003	–	–2987.6127
	–0.188	(0.001)*	(0.001)*	(0.001)*		(0.001)*		(0.001)*	(0.001)*	–	
TV	0.039	0.072 ↓	0.062	0.125	↓	–0.09	↑	0.951	0.001	–0.001	–2986.5136
	–0.247	(0.001)*	(0.001)*	(0.001)*		(0.001)*		(0.001)*	(0.003)*	–0.167	
Slovenia	0.007	0.153	–0.114	0.305		0.059		0.87	0.132	–	–94.2552
	–0.796	(0.001)*	(0.018)**	(0.001)*		–0.102		(0.001)*	(0.07)***	–	
TV	0.001	0.165 ↑	–0.214	0.306	↑	0.043	↓	0.835	0.173	0.002	–92.4953
	–0.98	(0.001)*	(0.003)*	(0.001)*		–0.291		(0.001)*	(0.018)**	(0.063)***	
Turkey	0.06	–0.007	0.061	0.133		–0.083		0.921	0.009	–	–1488.9837
	(0.045)*	–0.765	(0.001)*	(0.001)*		(0.001)*		(0.001)*	–0.421	–	
TV	0.052	–0.031 ↑	–0.09	0.095	↓	–0.065	↓	–0.452	0.063	0.002	–1484.4439
	–0.116	–0.177	–0.435	(0.023)**		(0.018)**		(0.001)*	(0.004)*	(0.001)*	
Ukraine	–0.013	0.12	0.09	0.358		–0.046		0.95	0.001	–	–1864.7347
	–0.71	(0.001)*	(0.001)*	(0.001)*		(0.013)**		(0.001)*	–0.211	–	
TV	–0.019	0.1206 ↑	0.086	0.363	↑	–0.054	↑	0.945	0.001	0.001	–1860.3065
	–0.645	(0.001)*	(0.001)*	(0.001)*		(0.009)*		(0.001)*	–0.162	(0.036)**	

Notes: Asterisks (*) (**) (***) indicate significance at the (1%) (5%) (10%) level, respectively.

Table A3

Univariate AR(1)-EGARCH(1,1) results with or without liquidity effects and spillovers for S&P 500 index models, 2006–2015

	β_0	β_1	α_0	α_1		α_2		α_3	ψ	ϕ	Log-likelihood
Croatia	0.002	0.033	–0.001	0.185		–0.038		0.985	0.002	–	–668.9807
	–0.829	(0.003)*	–0.901	(0.001)*		(0.001)*		(0.001)*	(0.04)**	–	
TV	0.001	0.06 ↑	–0.078	0.209	↑	–0.025	↓	0.94	0.001	0.001	–646.3995
	–0.628	(0.012)**	(0.002)*	(0.001)*		(0.076)***		(0.001)*	(0.012)**	(0.001)*	
Cyprus	–0.011	0.057	0.041	0.301		0.024		0.983	–0.007	–	–956.0171
	–0.722	(0.076)***	(0.001)*	(0.001)*		–0.226		(0.001)*	–0.409	–	
TV	–0.01	0.06 ↑	0.036	0.327	↑	0.027	↑	0.96	–0.019	0.001	–947.6874
	–0.748	(0.081)***	(0.011)**	(0.001)*		–0.234		(0.001)*	(0.097)***	(0.002)*	
Czech	0.024	0.126	–0.179	–0.118		–0.205		–0.122	0.264	–	–72.6681
Republic	–0.763	–0.138	–0.217	–0.524		(0.062)***		–0.624	(0.031)**	–	
	0.032	0.122 ↓	–0.225	–0.133	↑	–0.204	↓	–0.164	0.269	0.011	–72.6229
TV	–0.712	–0.127	–0.268	–0.466		(0.06)***		–0.524	(0.043)**	–0.755	
Greece	–0.002	0.082	0.061	0.194		–0.054		0.976	–0.015	–	–1512.0706
	–0.967	(0.005)*	(0.002)*	(0.001)*		(0.003)*		(0.001)*	(0.036)**	–	
TV	0.005	0.049 ↓	1.518	0.12	↓	–0.019	↓	–0.18	0.05	0.006	–1531.6716
	–0.932	(0.095)***	(0.001)*	(0.03)**		–0.622		–0.334	(0.064)**	(0.001)*	
Israel	0.037	0.025	0.001	0.141		–0.078		0.972	0.021	–	–1325.5199
	(0.007)*	(0.024)**	–0.61	(0.001)*		(0.001)*		(0.001)*	(0.005)*	–	
TV	0.035	0.027 ↑	0.061	0.144	↑	–0.1	↑	0.957	0.029	–0.001	–1317.483
	(0.047)**	–0.198	(0.002)*	(0.001)*		(0.001)*		(0.001)*	(0.001)*	(0.002)*	
Poland	–0.021	0.022	0.003	0.106		–0.068		0.977	0.007	–	–1267.8064
	–0.42	–0.334	–0.384	(0.001)*		(0.001)*		(0.001)*	(0.004)*	–	
TV	–0.027	0.021 ↓	–0.014	0.083	↓	–0.08	↑	0.974	0.006	0.001	–1263.1167
	–0.303	–0.359	(0.037)**	(0.001)*		(0.001)*		(0.001)*	(0.023)**	(0.007)*	

(The table continued next page.)

(Continued.)

	β_0	β_1	α_0	α_1		α_2		α_3	ψ	ϕ	Log-likelihood
Romania	0.024	0.075	–0.154	0.33		–0.048		0.707	0.126	–	–662.4339
	(0.06)***	(0.001)*	(0.001)*	(0.001)*		(0.065)***		(0.001)*	(0.001)*	–	
TV	0.022	0.064 ↓	–0.345	0.398	↑	–0.045	↓	0.62	0.074	0.012	–616.293
	–0.117	(0.001)*	(0.001)*	(0.001)*		–0.139		(0.001)*	(0.001)*	(0.001)*	
Russia	0.043	0.067	0.055	0.153		–0.0874		0.958	0.003	–	–3089.045
	–0.207	(0.001)*	(0.001)*	(0.001)*		(0.001)*		(0.001)*	(0.021)**	–	
TV	0.041	0.066 ↓	0.056	0.146	↓	–0.0878	↑	0.961	–0.001	–0.001	–3087.0134
	(0.047)**	(0.001)*	(0.001)*	(0.001)*		(0.001)*		(0.001)*	(0.056)***	–0.3	
Serbia	0.01	0.198	0.01	0.441		–0.009		0.939	0.008	–	–1273.5997
	–0.472	(0.001)*	–0.184	(0.001)*		–0.503		(0.001)*	(0.001)*	–	
TV	0.001	0.202 ↑	–0.02	0.443	↑	–0.011	↑	0.923	0.011	0.001	–1264.0365
	–0.514	(0.001)*	–0.107	(0.001)*		–0.48		(0.001)*	(0.001)*	(0.001)*	
Slovenia	0.008	0.143	–0.128	0.28		0.075		0.851	0.041	–	–92.6995
	–0.772	(0.003)*	(0.015)**	(0.001)*		(0.084)***		(0.001)*	(0.041)**	–	
TV	0.003	0.155 ↑	–0.214	0.284	↑	0.065	↓	0.821	0.047	0.001	–90.7845
	–0.924	(0.002)*	(0.004)*	(0.001)*		–0.125		(0.001)*	(0.015)**	(0.071)***	
Turkey	0.059	–0.004	0.056	0.126		–0.084		0.927	0.004	–	–1488.7955
	(0.065)***	–0.852	(0.001)*	(0.001)*		(0.001)*		(0.001)*	–0.318	–	
TV	0.051	–0.027 ↑	–0.062	0.12	↓	–0.067	↓	–0.452	–0.004	0.002	–1488.5015
	–0.121	–0.234	–0.588	(0.004)*		(0.018)**		(0.001)*	–0.563	(0.001)*	
Ukraine	–0.013	0.12	0.085	0.348		–0.039		0.946	0.008	–	–1862.5364
	–0.707	(0.001)*	(0.001)*	(0.001)*		(0.03)**		(0.001)*	(0.094)***	–	
TV	–0.02	0.121 ↑	0.084	0.356	↑	–0.047	↑	0.941	0.001	0.001	–1855.8402
	–0.624	(0.001)*	(0.001)*	(0.001)*		(0.033)**		(0.001)*	–0.273	(0.07)***	

Notes: Asterisks (*) (**) (***) indicate significance at the (1%) (5%) (10%) level, respectively.

Table A4

Univariate AR(1)-EGARCH(1,1) results with or without liquidity effects and spillovers for combined models, 2006–2015

	β_0	β_1	α_0	α_1		α_2		α_3	χ	ψ	ϕ	Log-likelihood
Croatia	0.002	0.033	–0.001	0.184		–0.038		0.986	0.004	0.002	–	–670.5858
	–0.827	(0.093)***	–0.952	(0.001)*		(0.001)*		(0.001)*	–0.782	(0.045)**	–	
TV	0.001	0.06 ↑	–0.077	0.207	↑	–0.025	↓	0.941	0.001	0.001	0.001	–646.3727
	–0.574	(0.013)**	(0.005)*	(0.001)*		(0.099)***		(0.001)*	–0.835	(0.033)**	(0.001)*	
Cyprus	–0.016	0.053	0.035	0.319		0.038		0.982	–0.032	0.014	–	–918.6118
	–0.602	–0.1001	(0.012)**	(0.001)*		(0.064)**		(0.001)*	–0.204	(0.044)**	–	
TV	–0.017	0.058 ↑	0.029	0.336	↑	0.039	↑	0.962	–0.058	0.014	0.001	–911.6988
	–0.642	–0.102	(0.083)***	(0.001)*		–0.109		(0.001)*	(0.078)***	–0.129	(0.002)*	
Czech	0.021	0.14	–0.198	–0.127		–0.204		–0.024	0.136	0.218	–	–72.0479
Republic	–0.793	–0.113	–0.17	–0.532		(0.093)***		–0.921	–0.471	–0.143	–	
	0.011	0.143 ↑	–0.178	–0.116	↓	–0.203	↓	–0.006	0.153	0.213	–0.006	–72.3889
TV	–0.89	–0.103	–0.325	–0.576		(0.081)***		–0.98	–0.451	–0.168	(0.834)	
Greece	–0.002	0.084	0.056	0.171		–0.06		0.968	0.066	–0.022	–	–1508.7675
	–0.966	(0.004)*	(0.001)*	(0.001)*		(0.002)*		(0.001)*	(0.014)**	(0.001)*	–	
TV	0.001	0.048 ↓	1.814	0.126	↓	–0.017	↓	–0.401	0.131	0.034	0.006	–1529.634
	–0.978	–0.128	(0.001)*	(0.027)**		–0.629		(0.011)**	(0.022)**	–0.161	(0.001)*	
Israel	0.037	0.025	0.001	0.14		–0.079		0.972	0.021	0.001	–	–1325.4933
	(0.047)**	–0.209	–0.679	(0.001)*		(0.001)*		(0.001)*	(0.005)*	–0.829	–	
TV	0.035	0.027 ↑	0.061	0.144	↑	–0.1	↑	0.957	0.029	–0.001	–0.001	–1317.4812
	(0.066)***	–0.223	(0.001)*	(0.001)*		(0.001)*		(0.001)*	(0.001)*	–0.958	(0.001)*	
Poland	–0.021	0.022	0.003	0.106		–0.068		0.978	0.001	0.007	–	–1267.783
	–0.441	–0.329	–0.392	(0.001)*		(0.001)*		(0.001)*	–0.833	(0.012)**	–	
TV	–0.027	0.021 ↓	–0.016	0.078	↓	–0.079	↑	0.976	–0.005	0.008	0.001	–1261.7623
	–0.304	–0.396	(0.019)**	(0.001)*		(0.001)*		(0.001)*	–0.102	(0.005)*	(0.004)*	

(The table continued next page.)

(Continued.)

	β_0	β_1	α_0	α_1		α_2		α_3	χ	ψ	ϕ	Log-likelihood
Romania	0.02	0.083	–0.065	0.307		–0.046		0.823	–0.03	0.062	–	–636.6018
	–0.169	(0.001)*	(0.007)*	(0.001)*		(0.038)**		(0.001)*	–0.294	(0.001)*	–	
TV	0.021	0.064 ↓	–0.323	0.398	↑	–0.045	↓	0.63	–0.03	0.075	0.012	–615.9548
	–0.289	(0.025)**	(0.001)*	(0.001)*		–0.11		(0.001)*	–0.323	(0.001)*	(0.001)*	
Russia	0.042	0.074	0.058	0.132		–0.087		0.949	0.003	0.001	–	–3082.9731
	–0.158	(0.001)*	(0.001)*	(0.001)*		(0.001)*		(0.001)*	(0.001)*	–0.846	–	
TV	0.04	0.073 ↓	0.06	0.123	↓	–0.088	↑	0.952	0.001	–0.001	–0.001	–3081.9669
	–0.253	(0.001)*	(0.001)*	(0.001)*		(0.001)*		(0.001)*	(0.002)*	–0.866	(0.199)	
Serbia	0.011	0.197	0.012	0.44		–0.009		0.941	–0.001	0.008	–	–1273.4774
	–0.434	(0.001)*	–0.156	(0.001)*		–0.509		(0.001)*	–0.63	(0.001)*	–	
TV	0.001	0.202 ↑	–0.023	0.444	↑	–0.011	↑	0.921	0.001	0.012	0.001	–1263.911
	(0.008)*	(0.001)*	–0.111	(0.001)*		–0.429		(0.001)*	–0.679	(0.001)*	(0.001)*	
Slovenia	(0.008)*	(0.001)*	–0.111	(0.001)*		–0.429		(0.001)*	–0.679	(0.001)*	(0.001)*	
	–0.788	(0.002)*	(0.015)**	(0.001)*		(0.082)***		(0.001)*	–0.281	(0.087)***	–	
TV	0.002	0.162 ↑	–0.287	0.283	↓	0.061	↓	0.79	0.13	0.041	0.002	–90.2443
	–0.935	(0.001)*	(0.005)*	(0.001)*		–0.202		(0.001)*	–0.149	(0.069)***	(0.065)***	
Turkey	0.06	–0.005	0.057	0.127		–0.084		0.921	0.008	0.003	–	–1488.5875
	(0.071)***	–0.822	(0.002)*	(0.001)*		(0.001)*		(0.001)*	(0.008)*	–0.369	–	
TV	0.051	–0.031 ↑	–0.088	0.098	↓	–0.065	↓	–0.457	0.062	–0.003	0.002	–1484.357
	–0.109	–0.194	–0.447	(0.016)**		(0.017)**		(0.001)*	(0.006)*	–0.581	(0.001)*	
Ukraine	–0.012	0.119	0.083	0.345		–0.041		0.945	0.001	0.009	–	–1861.5554
	–0.689	(0.001)*	(0.001)*	(0.001)*		(0.023)**		(0.001)*	–0.194	–0.113	–	
TV	–0.018	0.12 ↑	0.081	0.353	↑	–0.049	↑	0.941	0.001	0.001	0.001	–1859.3628
	–0.636	(0.001)*	(0.001)*	(0.001)*		(0.011)**		(0.001)*	–0.136	–0.171	(0.048)**	

Notes: Asterisks (*) (**) (***) indicate significance at the (1%) (5%) (10%) level, respectively.

Table A5

Univariate AR(1)-EGARCH(1,1) results with liquidity effects and spillovers for combined models during sub-period, 2008–2010

	β_0	β_1	α_0	α_1	α_2	α_3	χ	ψ	φ	Log-likelihood
Croatia	–0.032 (0.051)***	0.132 (0.001)*	–0.062 (0.057)***	0.33 (0.001)*	–0.029 –0.404	0.858 (0.001)*	–0.001 –0.93	0.001 (0.027)**	0.001 (0.002)*	–660.014
Czech Republic	0.057 (0.032)**	0.219 –0.105	–0.025 (0.001)*	–0.355 (0.001)*	–0.133 (0.001)*	0.952 (0.001)*	0.197 (0.055)***	–0.086 –0.212	–0.009 –0.867	–335.4527
Greece	–0.274 (0.059)***	–0.046 –0.448	0.513 –0.119	0.127 –0.399	–0.129 –0.154	–0.269 (0.013)**	0.14 –0.237	–0.036 –0.364	0.052 (0.001)*	–486.763
Israel	0.052 –0.269	0.024 –0.527	0.491 (0.022)**	–0.016 –0.746	–0.208 (0.001)*	0.879 (0.001)*	0.029 (0.012)**	0.001 –0.281	–0.001 (0.017)**	–516.2731
Poland	0.093 (0.001)*	0.015 (0.001)*	–0.041 (0.001)*	–0.061 (0.001)*	–0.115 (0.001)*	0.991 (0.001)*	–0.001 (0.001)*	0.001 (0.001)*	0.001 (0.001)*	–435.8784
Romania	–0.013 –0.81	0.001 –0.997	0.016 –0.703	0.31 (0.001)*	–0.014 –0.797	0.813 (0.001)*	–0.075 –0.203	0.035 (0.094)***	0.002 –0.317	–476.2916
Russia	0.131 (0.055)***	0.085 (0.035)**	0.063 (0.007)*	0.159 (0.001)*	–0.098 (0.001)*	0.159 (0.001)*	0.001 –0.207	–0.001 –0.277	–0.001 (0.022)**	–722.8713
Serbia	–0.042 (0.001)*	0.255 (0.001)*	0.074 (0.042)**	0.622 (0.001)*	–0.022 –0.527	0.853 (0.001)*	0.001 –0.697	0.001 (0.005)*	0.001 (0.005)*	–684.757
Slovenia	–0.024 –0.569	0.265 (0.001)*	–0.276 (0.011)**	0.344 (0.001)*	0.054 –0.394	0.816 (0.001)*	0.191 (0.046)**	0.037 –0.156	0.001 –0.142	–381.8079
Turkey	0.181 (0.004)*	0.042 –0.416	0.203 (0.034)**	0.124 –0.159	–0.223 (0.001)*	0.662 (0.001)*	0.286 (0.022)**	–0.114 (0.011)**	0.001 –0.993	–282.9053
Ukraine	0.215 (0.038)**	0.123 (0.028)**	0.088 (0.045)**	0.287 (0.001)*	–0.028 –0.444	0.915 (0.001)*	–0.013 –0.412	0.028 –0.122	0.001 –0.138	–514.9841

Notes: Asterisks (*) (**) (***) indicate significance at the (1%) (5%) (10%) level, respectively.

REFERENCES

ALIKHANOV, A. (2013): To what extent are stock returns driven by mean and volatility spillover effects? – Evidence from eight European stock markets *Review of Economics Perspectives* 13 (1): 3–29.

ARORA, V.–VAMVAKIDIS, A. (2005): Exploring the impact trading partners have on each other's growth *Finance & Development* 42 (3): 48–50. https://doi.org/10.5089/9781451953985.022

BAELE, L. (2005): Volatility spillover effects in European equity markets *Journal of Financial and Quantitative Analysis* 40 (2): 373–401. https://doi.org/10.1017/S0022109000002350

EGERT, B.–KOCENDA, E. (2007): Interdependence between Eastern and Western European stock markets: Evidence from intraday data *Economic Systems* 31 (2): 184–203. https://doi.org/10.1016/j.ecosys.2006.12.004

ENGLE, R. (1982): Autoregressive conditional heteroskedasticity with estimates of the variance of United Kingdom inflation *Econometrica* 50 (4): 987–1007. https://doi.org/0012-9682(198207)50:4<987:ACHWEO>2.0.CO;2-3

ENGLE, R.–NG, L. (1993): Measuring and testing the impact of news on volatility *Journal of Finance* 48 (5): 1749–1778. https://doi.org/10.1111/j.1540-6261.1993.tb05127.x

EZZATI, P. (2013): *Analysis of volatility spillover effects: two-stage procedure based on a modified GARCH-M* University of Western Australia, Business School, Discussion paper, 13.29 Crawley, Australia.

HASAN, I.–FRANCIS, B. (1998): Macroeconomic factors and the asymmetric predictability of conditional variances *European Financial Management* 4 (2): 207–230. https://doi.org/10.1111/1468-036X.00064

HUNG, N. T. (2020): Volatility spillovers and time-frequency correlations between Chinese and African stock markets *Regional Statistics* 10 (2): 63–82. https://doi.org/10.15196/RS100203

HUNG, N. T. (2022): Return equicorrelation and dynamic spillovers between Central and Eastern European, and World stock markets, 2010-2019 *Regional Statistics* 12 (1): 159–192. https://doi.org/10.15196/RS120108

KARKOWSKA, R.–URJASZ, S. (2021): Connectedness structures of sovereign bond markets in Central and Eastern Europe *International Review of Financial Analysis* 74: 101644. https://doi.org/10.1016/j.irfa.2020.101644

KARPOFF, J. (1987): The relationship between price changes and trading volume: a survey *The Journal of Financial and Quantitative Analysis* 22 (1): 109–126. https://doi.org/10.2307/2330874

KUNCORO, H. (2020): Regional inflation dynamics and its persistence – The case of selected regions in Indonesia *Regional Statistics* 10 (2): 95–116. https://doi.org/10.15196/RS100211

MOAGĂR-POLADIAN, S.–CLICHICI, D.–STANCIU, C. V. (2019): The comovement of exchange rates and stock markets in Central and Eastern Europe *Sustainability* 11 (14): 3985. https://doi.org/10.3390/su11143985

MORIYAMA, K. (2010): *The spillover effects of the global crisis on economic activity in MENA emerging market countries – An analysis using the financial stress index* IMF Working Papers 10/8, IMF, Washington.

NELSON, D. (1991): Conditional heteroskedasticity in asset returns: A new approach *Econometrica* 59 (2): 347–370. https://doi.org/0012-9682(199103)59:2<347:CHIARA>2.0.CO;2-V

SYRIOPOULOS, T.–ROUMPIS, E. (2009): Dynamic correlations and volatility effects in the Balkan equity markets *Journal of International Financial Markets, Institutions and Money* 19 (4): 565–587. http://dx.doi.org/10.1016%2Fj.intfin.2008.08.002

SZTAVROSZ, B. (2019): Analysis of the geographical diversification of financial instruments *Regional Statistics* 9 (1): 13–31. https://doi.org/10.15196/RS090110