Effects of US Monetary Policy on Eastern European Financial Markets

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Abstract

The announcement made by the Fed Chairman, Ben Bernanke, on May 22, 2013 regarding the reduction of the quantitative easing programme that took by storm the financial markets determined the significant volatility increase of the US markets and it was not limited to it. The financial markets in the emerging countries that benefited from an increase in their financial flows during the quantitative easing programme were the most affected by this announcement through the volatility increase, depreciation of exchange rate and massive capital outflows. The current paper tackles volatility and volatility transmission from the US market determined by the change of monetary policy to the Eastern European markets. To study the volatility of each stock and bond market of the countries in Eastern Europe, we used univariate heteroscedastic models while for the analysis of volatility transmission from the US market to the Eastern European markets we used the multivariate heteroscedastic models. The results obtained confirm the volatility transmission both on the stock markets, with the exception of Latvia and Lithuania, and on the bond markets in Eastern Europe.

Keywords: stock market, bond markets, return spillover, volatility spillover, multivariate heteroscedastic model

Introduction

After the latest economic and financial crisis from 2008-2009, USA has adopted a relaxed monetary policy known as quantitative easing (QE). The programme has aimed to reach performance on the financial markets. This programme has translated into the monthly purchase of long-term financial assets with a total worth of 85 billion in 2013. The effects of this policy are embodied in the growth of the monetary basis, the decrease in the deflation pressure (occurred due to the crisis), very low interest rates, the flattening of the return curve. All these have determined the improvement of the economic activity in the USA. Yet, the low returns have caused great capital inflows in emerging countries whose attractive feature is the higher return obtained with a higher risk (Aizenman *et al*., 2014). Even if the emerging countries were characterised during the QE by current account deficit,

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slow economic growth, high inflation, budget deficit and important public debt relative to GDP, they received significant short-term international financial flows.

On the 22nd of May 2013, the Chairman of the Federal Reserve (Fed), Ben Bernanke, makes an unexpected declaration in the Congress regarding the tapering of the quantitative easing programme. At that moment, the conclusion that the economy had become strong enough in order not to need stimulation anymore had been reached. The tapering talk surprised both the USA and the emerging markets. This unforeseen information determined an increase in the volatility of the markets and significant changes of the emerging markets. The anticipation of the interest rate growth in the USA determines massive capital outflows from the emerging markets (Cevik *et al.*, 2016).

Gosh and Saggar (2017) study the transmission of volatility determined by Bernanke's announcement regarding QE tapering towards the financial markets of the following emerging countries: Brazil, Russia, China, India, South Africa, Indonesia, Malaysia and Thailand. The results obtained confirm the significant transmission of volatility from the USA to the emerging countries studied.

Volatility transmission, in a globalised world, plays an important role in the diversification of financial asset portfolios. This is the reason why before the previously mentioned study, the volatility transmission among the capital markets drew the attention of many researchers and investors. The literature contains studies conducted regarding volatility transmission among the capital markets, between developed and emerging capital markets, among different capital markets of the same country, among the capital markets of countries which have common economic, financial and even monetary features.

Volatility transmission among developed capital markets appears in the studies conducted by Tanizaki and Hamori (2009), In (2007), Diebold and Yilmaz (2012), Baele (2005). The study of volatility transmission among the stock markets in Japan, UK and USA made by Tanizaki and Hamori (2009) highlights that there is bidirectional transmission between the stock markets in Japan and the USA, respectively between UK and the USA during April 2, 1984 - February 2, 2007. In (2007) approaches the swap markets from the same countries and identifies a significant bidirectional volatility transmission between Japan and UK during January 8, l996 - June 29, 2001.

Diebold and Yilmaz (2012) study volatility transmission among the stock market, bond market, stock exchange market and goods markets in the USA during January 1999 – January 2010. The results obtained confirm a limited transmission of volatility until the global financial crisis in 2007 even if the markets are characterised by important volatility and at the same time a volatility transmission that intensifies during the crisis. The stock market has the most significant volatility transmission towards other markets.

Volatility transmission among the EU countries and especially West European countries represented Baele (2005)'s research topic. Volatility transmission was studied in those countries that went through a growth of economic, financial and monetary integration. The results obtained confirm the increase in volatility transmission along with the integration growth, both from the US markets to the European markets and the shocks of the European Union towards the individual markets of the composing countries. This study also confirms the lack of a constant volatility transmission, result also confirmed by the study belonging to Diebold and Yilmaz (2012), which mentions the explosive nature of volatility transmission.

Chirilă, Turturean and Chirilă (2015) study the volatility transmission between the stock markets from Eastern European countries: Romania, Hungary, Czech Republic, Bulgaria and Poland and the Euro Zone stock market. The results obtained for the period December 31, 2014 – April 21, 2015 confirm that volatility transmission from the Euro zone to the Eastern European markets is unidirectional and is performed to a little extent, while the volatility transmission between the Eastern European countries is bidirectional and more significant.

Diebold and Yilmaz (2009) identify the crises that could generate volatility transmission and they group them in major events and additional important events. The results obtained confirm the volatility transmission determined both by major events and by additional events. Among the major economic events they include: the currency exchange crisis from Eastern Asia in 1997, the crisis in Russia during June-August 1998, the change of capital flows on the emerging markets from May-June 2006 and the turmoil caused by the real estate loan market started in 2007. Among the additional events they count: the Brazil crisis in 1999, the terrorist attack in 2001 and the dollar crisis in 2005.

The studies of volatility transmission was especially performed during the economic and financial crises. After the announcement made by Ben Bernanke regarding the QE tapering, Gosh and Saggar (2017) underline the need to study the volatility transmission determined by the change of policies and problems of advanced economies towards the economies of emerging markets.

The aim of the current study is to contribute to the existing literature on the analysis of volatility transmission from the US market to the Easter European countries, volatility determined on the US markets by the changes in the monetary policy. Since the US decision affected especially the emerging countries, the current paper aims to determine to which extent the volatility caused in the USA by the unexpected notice of QE tapering affected the Eastern European capital markets and if this volatility was transmitted both on the stock and bond markets. Therefore, this study will answer the following questions: Has the volatility of US markets transmitted to the stock and bond markets in the Eastern European countries? Are the shocks or the new information that occur on the US market transmitted to the stock and bond markets in the Eastern European countries? Is the return of the US markets transmitted to the stock and bond markets in the Eastern European countries?

To answer these questions, we used univariate heteroscedastic models and namely, the GARCH(1,1) model in order to estimate the conditional volatility of stock and bond markets. We also used multivariate heteroscedastic models in order to estimate the transmission from the US market to the Eastern European markets both of shocks and volatility. The estimated models offered information also on the reactions of the markets to their own shocks and volatility.

The results obtained highlight cross-mean spillovers effects on the stock markets from Hungary, Bulgaria and Poland and volatility spillovers from the US market to the Eastern European stock markets with the exception of Latvia and Lithuania. The volatility of the US market is also transmitted to the bond market in Eastern Europe.

1. Literature review

The studies related to the change of monetary policy in the USA focused on: the impact determined by Fed tapering announcements on the economies of emerging markets by means of the macroeconomic indicators (Mishra *et al.*, 2014) the in-depth study of one of the most affected emerging country, India, by Basu, Eichengreen and Gupta (2014), the study of volatility transmission from the US markets to Brazil, India, China, South Africa, Indonesia, Thailand, Malaysia (emerging countries) performed by Gosh and Saggar (2017).

Mishra, Moriyama, N'Diaye and Nguyen (2014) study the reaction of the 21 emerging markets. The results obtained by the researchers demonstrate that the market reaction is different and is influenced by several factors such as: the economic and financial structure, the value of basic macroeconomic indicators, the type of the macroprudential policy and the economic ties with China. The countries that were characterised by strong macroeconomic indicators, financial depth and more restrictive macroprudential policies had markets less affected by Fed tapering. The countries that had commercial trading with China were also less affected by the change of the US monetary policy.

A detailed analysis of the impact the change of the US monetary policy had on India is conducted by Basu, Eichengreen and Gupta (2014). India was the most affected emerging country. The national currency reduced by 18% and the currency exchange reserves, the bond and stock prices greatly increased. The existence of a difficult economic situation three years before the USA event which translated into the decrease of macroeconomic indicators, the previous occurrence of important flows of foreign capital, great gold imports, the current account deficit, over-assessed currency exchange are among the causes identified by Basu, Eichengreen and Gupta (2014).

Aizenman, Binici and Hutchinson (2014) determine the impact of the tapering announcement made by Fed Chairman Bernanke on the financial markets in the emerging countries. The results obtained confirm differentiated effects on the emerging markets. Aizenman, Binici and Hutchinson (2014) group the emerging countries in two categories: a group of countries with “robust” fundamentals characterised by low external debits, current account excess and great international reserves and another group with “fragile” fundamentals. The countries in the first group have more developed financial markets and are more affected by tapering than the countries with “fragile” fundamentals. We would like to mention in the second group the following countries in the Eastern Europe: Romania, Poland, Lithuania, Latvia, and Czech Republic while Hungary and Bulgaria are part of the group with “robust” fundamentals.

2. Methodology

For the estimation of stock and bond market volatility, we used the autoregressive conditional models. The univariate GARCH models were developed after the first papers published by Engle (1982) and Bollerslev (1986). Being adapted to the statistical characteristics specific to financial time series, the use of autoregressive heteroscedastic models within the univariate frame, can provide information only about an individual capital market. The heteroscedastic models within the multivariate frame (MGARCH) Bollerslev, Engle and Nelson (1994) appeared very quickly and can be used to complete an overall perspective of the common evolution of capital markets. These models allow the modelling of volatility transmission among markets providing information both for volatilities and for co-volatilities in the markets analysed.

To estimate the volatility of stock and bond markets we used the GARCH(1,1) model which is the most adequate for volatility modelling according to the works of Bollerslev *et al.* (1994), Charles and Darné (2006), Nikkinena *et al.* (2008) and Ramlall (2010). The GARCH model allows the modelling of volatility variation in time, of the leptokurtic characteristic of financial variables and the cluster presentation of volatility. A heteroscedastic process is represented by two equations, the mean equation and the conditional variance equation.

The Augmented Dickey-Fuller and Philips Perron tests were used to test the stationarity of the variables. Since these tests show that the variables, the variation of the stock price and interest rate for governmental bonds, are stationary, we can estimate heteroscedastic models where the mean equation should be represented by ARMA(p,q).

The Generalized ARCH (GARCH) model is sufficient to capture the volatility clustering (Brooks, 2014)

The equation of the mean of univariate model GARCH(1,1) has the general ARMA(p,q) form:

$$r_t = \alpha_0 + \alpha_1 r_{t-1} + ... + \alpha_p r_{t-p} + \varepsilon_t + \beta_1 \varepsilon_{t-1} + ... + \beta_q \varepsilon_{t-q}, \qquad \varepsilon_t = \sigma_t z_t \tag{1}$$

The equation of the conditional variance specific to the GARCH(1,1) model has the form:

$$\sigma_t^2 = \delta_0 + \delta_1 \varepsilon_{t-1}^2 + \phi_1 \sigma_{t-1}^2 \tag{2}$$

where: r_t - log returns of a stock market between the moment t-1 and t; ε_t - residual variable; σ_t^2, σ_{t-1}^2 - conditional variance at moment t, respectively t-1; z_t - identically distributed standardized residuals.

In order for the variance σ_t^2 to be positive the parameters of the equation of conditional variance $\delta_0, \delta_1, \phi_1$ are non-negative and meet the condition $\delta_1 + \phi_1 < 1$. A lot of financial series have $\delta_1 + \phi_1$ close to 1, which means that they have persistence in volatility.

To determine the spillovers volatility from the US stock market to the Central and Eastern European capital markets we used the heteroscedastic autoregressive multivariate models. If the autoregressive univariate models allow the consideration of volatility clustering characteristic on an individual market of a country or for a financial asset, autoregressive multivariate models allow modelling the volatility transmission between markets or financial assets. We can thus analyse co-volatilities on at least Eastern two markets.

The VECH multivariate heteroscedastic model was proposed by Bollerlev *et al*. (1988). It is one of the most frequently used models because, unlike others, has a reduced number of parameters. The admissibility and stationarity conditions are also simple (Scherrer and Ribarits, 2007)

The equation of the mean within the VECH model is specified as follows:

$$R_{it} = \mu_i + u_{it}, \quad (i = 1,2) \text{ and } u_t / I_{t-1} \sim N(0, H_t) \tag{3}$$

where: u_{it} - is the conditional residual term; H_t - the conditional variance at time t.

The VECH model according to Engle and Wooldridge (1988)'s proposal can be presented as follows:

$$VECH(H_t) = C + A \times VECH(\Xi_t \Xi_{t-1}^{'}) + B \times VECH(H_{t-1}) \tag{4}$$

where: H_t - a N×N conditional variance-covariance matrix; Ξ_t - a N×1 disturbance vector; I_{t-1} - the information at the moment t-1; C – dimensional vector with n(n+1)/2 parameters; A, B square matrices with n(n+1)/2 parameters;

For N=2 Brooks (2014) defines the elements of the VECH model as follows:

$$H_t = \begin{bmatrix} h_{11t} & h_{12t} \\ h_{21t} & h_{22t} \end{bmatrix}, \; \Xi_t = \begin{bmatrix} u_{1t} \\ u_{2t} \end{bmatrix}, \; C = \begin{bmatrix} c_{11} \\ c_{21} \\ c_{31} \end{bmatrix}$$

$$A = \begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix}, \qquad B = \begin{bmatrix} b_{11} & b_{12} & b_{13} \\ b_{21} & b_{22} & b_{23} \\ b_{31} & b_{32} & b_{33} \end{bmatrix}$$

The $VECH\left(H_t\right)$ operator implies taking into account the 'upper triangular' part of the matrix and stacks each element into a vector with a column. In the case of N=2 $VECH\left(H_t\right)$ becomes:

$$VECH\left(H_t\right) = \begin{bmatrix} h_{11t} \\ h_{22t} \\ h_{12t} \end{bmatrix}$$

where h_{iit} represents the conditional variances at the moment t of two returns of the markets, h_{ijt} when $i \neq j$ represents the conditional co-variances between the stock markets.

If we have the returns of two capital markets by means of the VECH model 21 parameters can be estimated. In order to reduce the number of parameters, Bollerslev, Engle and Wooldridge (1988) assume A and B to be diagonal. The model, known as diagonal VECH, (DVECH), is:

$$h_{ij,t} = c_{ij} + f_{ij} u_{i,t-1} u_{j,t-1} + g_{ij} h_{ij,t-1} \text{ for } j,i = 1,2 \tag{5}$$

The equations of the diagonal model are:

$$\begin{aligned} h_{11,t} &= c_{11} + f_{11} u_{1,t-1}^2 + g_{11} h_{11,t-1} \\ h_{12,t} &= c_{12} + f_{12} u_{1,t-1} u_{2,t-1} + g_{12} h_{12,t-1} \\ h_{22,t} &= c_{22} + f_{22} u_{2,t-1}^2 + g_{22} h_{22,t-1} \end{aligned} \tag{6}$$

The parameters of the GARCH multivariate models, under the assumption of conditional normality can be estimated by maximising the log-likelihood function:

$$\ell\left(\theta\right) = -\frac{TN}{2} \log 2\pi - \frac{1}{2} \sum_{t=1}^{T} \left(\log \left| H_t \right| + \Xi_t^{'} H_t^{-1} \Xi_t \right) \tag{7}$$

where: θ are all the parameters to be estimated, N the number of the return series of the markets and T the number of observations.

To obtain optimal values of the parameters we use the BHHH algorithm (Berndt *et al.* 1974).

The shocks determined by the own volatility of a market are measured by means of the elements on the diagonal of the A matrix which are marked with a_{11} and a_{22}. The parameters which are not on the diagonal, a_{ij}, for which $i \neq j$, indicate cross-volatility shocks. The elements on the diagonal of the B matrix, b_{11} and b_{22} show own-volatility spillovers or, in other words, show the previous volatility transmission on the current volatilities of a market. The elements that are not on the diagonal of the B matrix, b_{ij}, where $i \neq j$ highlight cross-volatility spillovers and signify the volatility transmission between the capital markets.

3. Empirical Study

The markets considered in this study are from the following emerging countries in the Central and Eastern Europe: Bulgaria, Czech Republic, Hungary, Latvia, Lithuania, Poland, Romania and Slovakia, while the period under consideration is January 1, 2012 – July 31, 2014.

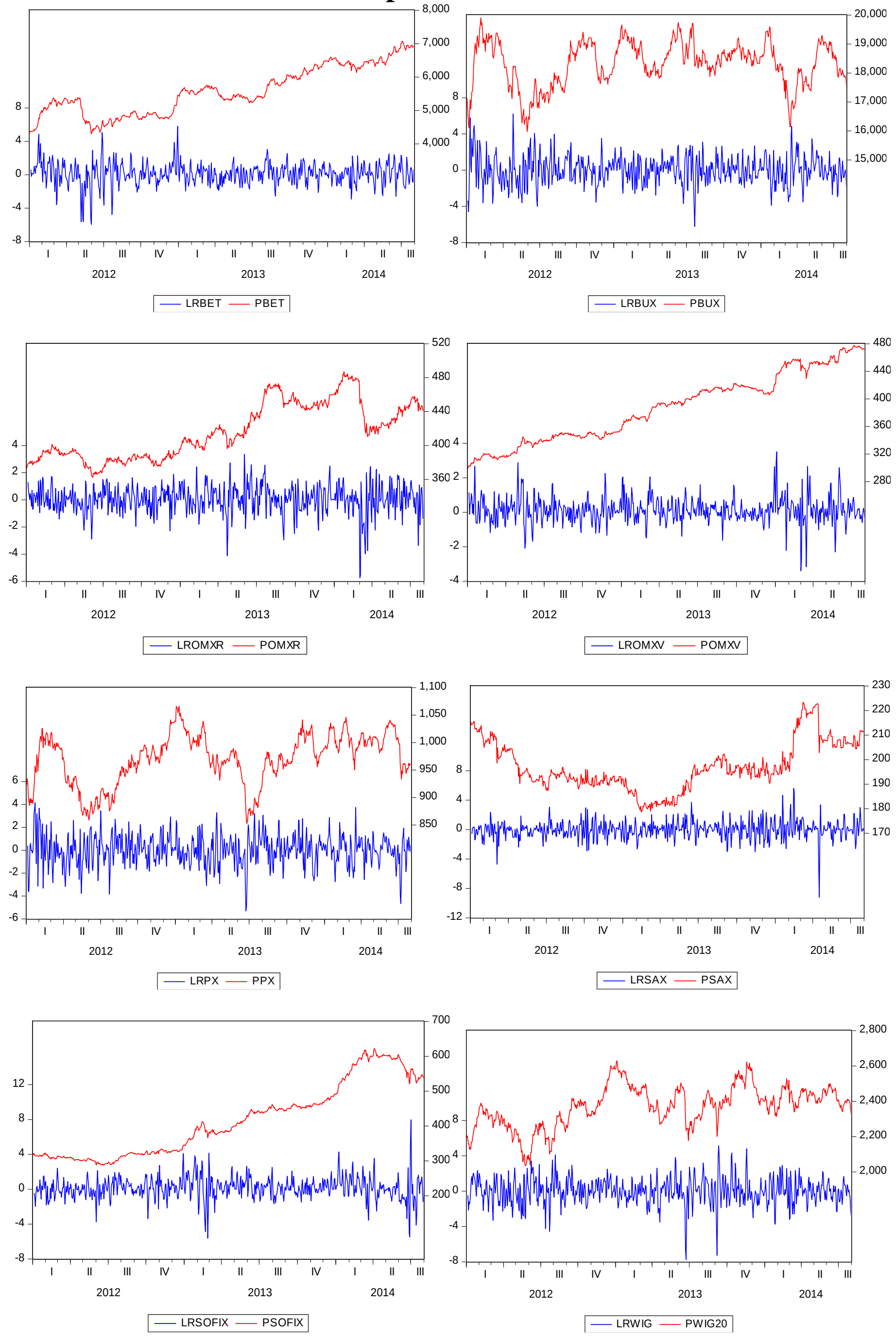
The variables needed for the empirical study of this paper are registered on a daily basis and are represented by: the values of the blue-chip indices of the stock exchanges in the countries analysed and the interest rate for the treasury certificates issued on a 10-year period. The blue-chip indices of these countries are SOFIX, PX, BUX, OMXR, OMXV, WIG 20, BET and respectively SAX. In order to test the volatility transmission during taper talk, we took into consideration the index S&P 100 for the US.

The daily relative variation of the markets under consideration was computed according to the formula corresponding to log-returns as follows:

$$r_t = \left(ln\left(P_t\right) - ln\left(P_{t-1}\right)\right) \cdot 100 \tag{7}$$

where: P_t, P_{t-1} represents the value of the index at the moment t, respectively t-1.

Figure 1. The evolution of indices value and the returns of capital markets in the Eastern European countries



Note: a) PBET; PBUX; POMXR; POMXV; PPX; PSAX; PSOFIX; PWIG20 represent the values of the indices of the stock markets in Romania, Hungary, Lithuania, Latvia, Czech Republic, Slovakia, Bulgaria and Poland; b) LRBET; LRBUX; LROMXR; LROMXV; LRPX; LRSAX; LRSOFIX; LRWIG20 represent the returns of the stock markets in Romania, Hungary, Lithuania, Latvia, Czech Republic, Slovakia, Bulgaria and respectively Poland.

The graphical representation of the evolution of stock markets in Eastern Europe as well as of their returns is presented in Figure 1. It shows that returns and volatilities of the Eastern European markets have characteristics specific to the financial time series. Volatilities are presented by clusters which shows that a new information determines volatility which persists in time. We also notice the increase in volatility during the downturn periods of the markets and reduction of volatility during the growth periods of the markets. The figure also suggests that the average returns of the markets are stationary. The fact that market volatilities are within certain limits and do not increase infinitely makes us ascertain that volatilities are stationary.

The daily returns of the stock markets considered and the statistical descriptive indicators are presented in table 1.

Table 1. The statistical descriptive indicators for the returns of the stock markets in Central and Eastern Europe during 1.01.2012 – 7/31/2014

	LRBET	LRBUX	LROMXR	LROMXV	LRPX	LRSAX	LRSOFIX	LRWIG
Mean	0.06917	0.00327	0.02480	0.06763	0.00521	-0.00293	0.07697	0.00834
Median	0.04523	0.00000	0.00000	0.01228	0.00000	0.00000	0.02136	0.00544
Maximum	3.41265	4.13239	3.29332	2.91027	3.35807	5.44731	5.63831	3.47861
Minimum	-4.2966	-3.8813	-5.8804	-3.8437	-3.9636	-5.0260	-4.7371	-5.2428
Std. Dev.	0.86182	**1.08418**	0.80584	0.51932	0.94262	0.95916	0.87992	1.04310
Skewness	-0.5300	0.1353	-0.6805	-0.1547	-0.1906	0.0028	-0.0833	-0.3886
Kurtosis	6.89217	4.11359	8.16262	10.4438	4.08577	8.538438	8.53699	5.49006
Jarque-Bera	456.321	36.827	799.329	1556.49	37.1362	860.159	860.490	190.815
Probability	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Observations	673	673	673	673	673	673	673	673

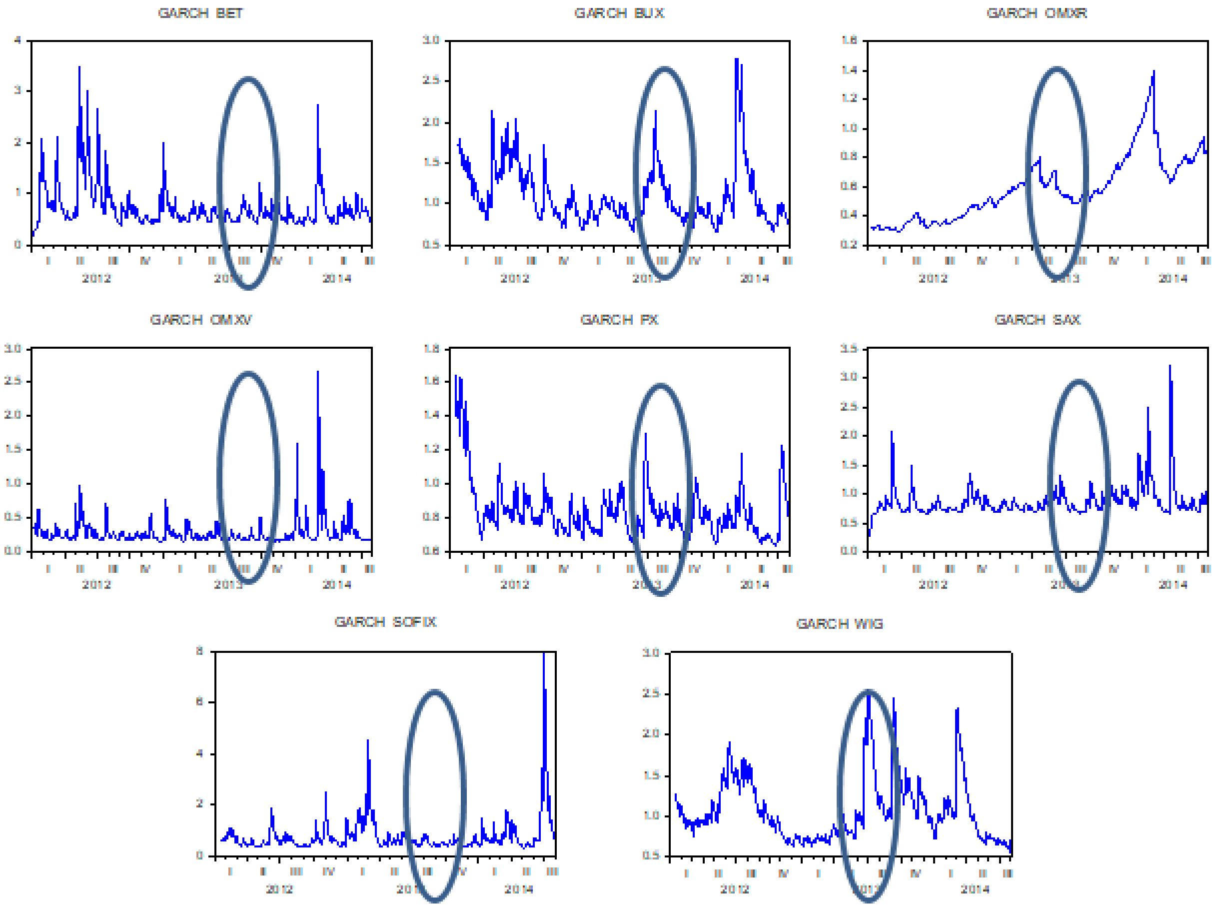
Source: data processed by means of the Eviews
Note: LRBET; LRBUX; LROMXR; LROMXV; LRPX; LRSAX; LRSOFIX; LRWIG20 represent the returns of the stock markets in Romania, Hungary, Lithuania, Latvia, Czech Republic, Slovakia, Bulgaria and respectively Poland

The returns of the capital markets are stationary. The results of the stationarity tests are presented in Appendix. The statistical descriptive indices presented in Table 1 show that investors should expect to get profit on these stock markets with the exception of the Slovak stock market which has a negative average return.

The highest average return belongs to the BET index computed for the Romania's stock market which does not have the highest total risk. The highest risk can be found on the stock market in Hungary where the BUX index is computed. The distributions of all returns are characterised by fat tails, because the values of all kurtosis indices are much higher than 3 and it is obvious that due to this feature it does not follow normal distributions laws as the Jarque-Bera test also indicates.

To estimate the volatility of the stock markets from the countries analysed as well as of the bond markets we used heteroscedastic models and namely the GARCH(1,1) model. The estimation of this model for the returns of the stock markets allows us to estimate the conditional volatility of the markets studied. The conditional volatilities obtained are graphically represented for both the stock markets and the bond markets in Figure 2 and respectively Figure 3.

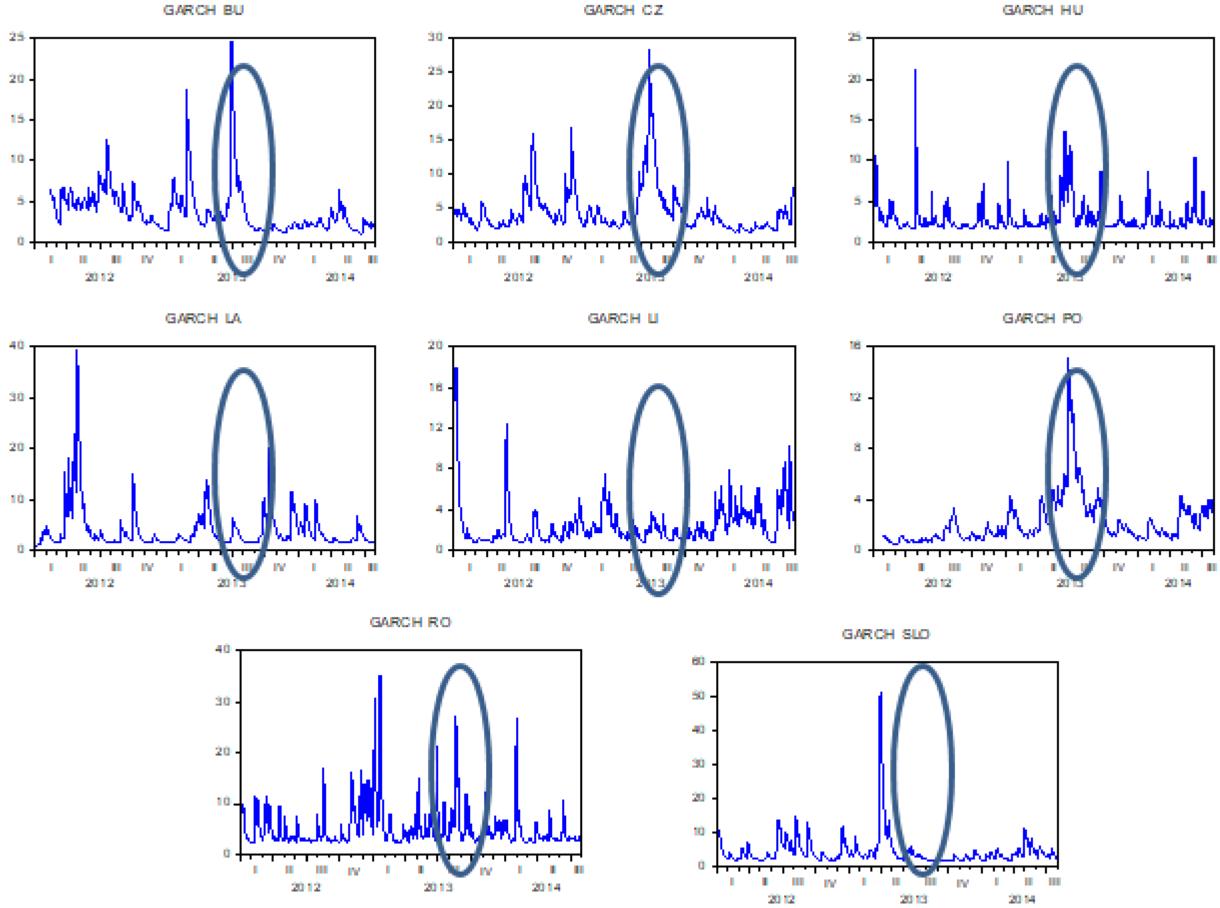
Figure 2. Volatility of stock markets



Note: GARCH_BET, GARCH_BUX, GARCH_OMXR, GARCH_OMXV, GARCH_PX, GARCH_SAX, GARCH_SOFIX, GARCH_WIG represent the volatility of the stock markets estimated through the GARCH(1,1) model from Romania, Hungary, Latvia, Lithuania, Czech Republic, Slovakia, Bulgaria, Poland

The stock markets in Romania, Hungary, Czech Republic, Slovakia and Poland show a significant volatility at the beginning of 2012 which decreases towards the end of the year. After May 22, 2013, the moment when the Chairman of Federal Reserve (Fed), Ben Bernanke, made the announcement, the Eastern European countries have volatility increases but only the stock markets in Hungary, Czech Republic and Poland have the same intensity as that from the start of 2012. Moreover, these stock markets are the most developed in the region which could confirm results previously found according to which more developed emerging capital markets had been more affected by tapering talk. The stock market in Latvia is the only one whose volatility decreases after the announcement about the change of monetary policy in the US but its volatility will increase again by the end of 2013.

Figure 3. Volatility of bond markets in the Eastern European countries



Note: GARCH_BU, GARCH_CZ, GARCH_HU, GARCH_LA, GARCH_LI, GARCH_PO, GARCH_RO, GARCH_SLO represent the volatility of bond markets estimated through the GARCH(1,1) model in Bulgaria, Czech Republic, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia

The bonds in the Czech Republic, Hungary, Latvia, Lithuania, and Poland register higher volatility towards the end of 2012, situation also met on the stock markets. After the announcement regarding the change of monetary policy in the US, the bond volatility on all markets registered major growth with just one exception: Lithuania.

For the volatility transmission from the US stock market to the stock and bond markets in the Eastern European countries we estimated multivariate GARCH models where a variable is represented by the return of the US stock market and another variable is represented by the return of a stock market in Eastern Europe. The parameters estimated for the MGARCH model alongside the probabilities associated to the significance tests are presented in Table 2. Since the activity of the markets is influenced by time differences we took into consideration a 1-day lag.

In Table 2 the M(1,1) parameters present own-mean spillovers on the US stock market and respectively M(2,2) on each of the Eastern European markets. All the parameters estimated M(1,1) and M(2,2) are statistically significant therefore they can confirm the transmission of own return both on the US stock market and on the Eastern European markets. The M(1,2) parameters highlight the volatility transmission from the US stock market to the Eastern Europe markets. We may find the confirmation for positive cross-mean spillovers effects from the US to the markets in Hungary, Bulgaria and Poland. The biggest and most significant cross-mean spillovers impact belongs to Poland (0.09). Most of the Eastern European countries are not affected by a return transmission from the US to these ones during the period under study, therefore previous shocks of the returns of US stock market did not affect greatly the Eastern European stock markets.

Table 2. Volatility spillovers from US to the stock markets in Eastern Europe

	BET	Prob.	BUX	Prob.	OMR	Prob.	OMV	Prob.	PX	Prob.	SAX	Prob.	SOFIX	Prob.	WIG	Prob.
C(1)	0.06	0.00	0.07	0.00	0.07	0.00	0.07	0.00	0.06	0.00	0.07	0.00	0.07	0.02	0.07	0.00
C(2)	0.04	0.15	0.01	0.64	-0.02	0.27	0.04	0.02	0.008	0.80	-0.004	0.89	0.09	0.03	0.02	0.45
M(1,1)	0.08	0.00	0.07	0.00	0.09	0.00	0.09	0.00	0.11	0.00	0.09	0.00	0.09	0.00	0.10	0.00
M(1,2)	-0.0003	0.51	0.004	0.04	0.01	0.31	0.01	0.83	0.02	0.38	-0.0009	0.76	0.05	0.06	0.09	0.01
M(2,2)	0.08	0.00	0.04	0.02	0.006	0.00	0.05	0.00	0.01	0.00	0.13	0.00	0.05	0.00	0.15	0.00
A1(1,1)	0.12	0.00	0.11	0.00	0.13	0.00	0.14	0.00	0.12	0.00	0.13	0.00	0.13	0.00	0.10	0.00
A1(1,2)	-0.02	0.00	**0.001**	**0.92**	0.04	0.17	**0.009**	**0.80**	**0.01**	0.45	**0.01**	**0.56**	**0.09**	**0.05**	**0.08**	**0.00**
A1(2,2)	0.13	0.00	0.05	0.00	0.02	0.00	0.13	0.00	0.03	0.00	0.07	0.00	0.14	0.00	0.08	0.00
B1(1,1)	0.70	0.00	0.74	0.00	0.69	0.00	0.67	0.00	0.65	0.00	0.69	0.00	0.67	0.00	0.70	0.00
B1(1,2)	0.91	0.00	**0.93**	**0.00**	0.35	0.38	**0.79**	**0.41**	**0.86**	0.00	**0.93**	**0.00**	**-0.58**	**0.00**	**0.58**	**0.00**
B1(2,2)	0.75	0.00	0.89	0.00	0.92	0.00	0.67	0.00	0.91	0.00	0.78	0.00	0.78	0.00	0.77	0.00

Note: a) i=1 for the US market, i=2 for the Eastern European markets; b) BET, BUX, OMR, OMV, PX, SAX, SOFIX, WIG represent the returns of the stock markets in Romania, Hungary, Lithuania, Latvia, Czech Republic, Slovakia, Bulgaria and respectively Poland

Source: data processed by means of the Eviews

The presence of the ARCH effects is highlighted by the estimated parameters a(1,1) and a(2,2). The significant estimations a(1,1) show that the shocks that occur on the US market will have the biggest impact on its future volatility. The estimations a(2,2) show the significant presence of own-volatility shock for all the 8 markets from Eastern Europe. Thus, the presence of the ARCH effects shows that they are more influenced by own shocks, among which the market in Bulgaria holds the first place (a(2,2)=0,14). The results obtained are in accordance with the results obtained by Chirilă *et al.* (2015). The new information that appears on the US stock market affects the volatility of the Romanian stock market to a lesser extent than its own shocks, Poland to an equal extent to its own shocks and Bulgaria to a greater extent than its own shocks.

The persistence of stock market volatility is highlighted by the estimations b(1,1) and b(2,2). All the stock markets are characterised by persistent volatilities, therefore volatility maintains in time, the market volatility is influenced by its previous values and that is why it is presented by clusters. The markets from Latvia (b22=0.92) and Czech Republic (b(2,2)=0.91) are characterised by the highest persistence of volatility while at the opposite spectrum is Lithuania. The existence of volatility spillovers from the US market to the Eastern Europe markets is highlighted by the b12 coefficients. These are statistically significant therefore the volatility from the US stock market is transmitted to almost all Eastern European countries. The only exceptions are the stock markets from Latvia and Lithuania.

Table 3. Volatility spillovers from US to the bond markets in Eastern Europe

	Bul	Prob.	RCeh	Prob.	Hun	Prob.	Lat	Prob.	Lith	Prob.	Pol	Pro.	Rom	Pro.	Slov	Pro.
C(1)	0.07	0.00	0.08	0.00	0.08	0.00	0.08	0.00	0.07	0.00	0.08	0.00	0.07	0.00	0.08	0.00
C(2)	-0.03	0.58	-0.18	0.00	-0.15	0.01	-0.15	0.00	-0.15	0.00	-0.11	0.01	-0.02	0.68	-0.17	0.01
M(1,1)	0.06	0.00	0.06	0.00	0.07	0.00	0.06	0.00	0.06	0.00	0.06	0.00	0.06	0.01	0.06	0.00
M(1,2)	-0.001	0.63	0.003	0.15	-0.008	0.26	-0.005	0.78	-0.0003	0.90	-1E-05	0.98	-0.006	0.17	-0.005	0.24
M(2,2)	0.12	0.00	0.18	0.00	0.65	0.00	0.22	0.00	0.15	0.00	0.02	0.02	0.79	0.00	0.32	0.00
A1(1,1)	0.13	0.00	0.11	0.00	0.10	0.00	0.11	0.00	0.11	0.00	0.11	0.00	0.094	0.00	0.10	0.00
A1(1,2)	**0.008**	**0.51**	**0.001**	**0.81**	**0.01**	**0.26**	**0.04**	**0.45**	**-0.03**	**0.19**	**0.01**	**0.17**	**-0.02**	**0.12**	**0.01**	**0.22**
A1(2,2)	0.08	0.00	0.09	0.00	0.17	0.00	0.11	0.00	0.16	0.00	0.09	0.00	0.23	0.00	0.13	0.00
B1(1,1)	0.74	0.00	0.76	0.00	0.76	0.00	0.76	0.00	0.76	0.00	0.76	0.00	0.79	0.00	0.77	0.00
B1(1,2)	**0.95**	**0.00**	**0.97**	**0.00**	**0.94**	**0.00**	**0.77**	**0.08**	**0.92**	**0.00**	**0.98**	**0.00**	**0.95**	**0.00**	**0.95**	**0.00**
B1(2,2)	0.88	0.00	0.86	0.00	0.61	0.00	0.84	0.00	0.77	0.00	0.89	0.00	0.63	0.00	0.79	0.00

Note: a) i=1 for the US market, i=2 for the Eastern European markets; b) Bul, RCeh, Hun, Lat, Lith, Pol, Rom, Slov represent the returns of the bond markets in Bulgaria, Czech Republic, Hungary, Latvia, Lithuania, Poland Romania and respectively Slovakia.
Source: data processed by means of the Eviews

The same MGARCH models are estimated to determine volatility spillovers to the bond markets in the Eastern European countries.

The results obtained and presented in table 3 prove that the US bond market presents own-mean spillovers because the M(1,1) coefficients are significant. The bond markets from the Eastern European countries are also characterised by own-mean spillovers, Romania and Hungary having the highest coefficients M(2,2)=0.79 and M(2,2)=0.65, are mostly affected while the bond market from Poland has the smallest coefficient of only 0.02. The bond markets in Eastern Europe, without any exception, are not characterised by cross-mean spillovers; moreover the US market does not transmit return to the bond markets from Eastern Europe.

All the bond markets considered are characterised by the presence of ARCH effects, thus, the shocks or the new information occurring on the markets have impact on their future volatility. The bond market in Romania is the most influenced by its own shocks having the highest significant coefficient of 0.23 while Czech Republic and Poland have the smallest coefficients of 0.09. The shocks from the US market are not transmitted to the Eastern European markets.

The volatility of bond markets in Eastern Europe is persistent, the highest B(2,2) coefficient belonging to Poland (0.89), followed closely by Bulgaria (0,88) while the smallest coefficient belongs to Hungary (0.61). The results presented in table 3 show that there is volatility transmission from the US market to the bond markets in the Eastern European countries analysed without any exception. The highest volatility spillover is felt by Poland (0.89) and Bulgaria (0.88) while Hungary is affected the least and has the smallest coefficient (0.61).

Conclusions

The announcement in the USA about the reduction of quantitative easing programme determined a growth of capital market volatility. The emerging countries were significantly affected by the change of the monetary policy in the USA: the capital markets registered high volatilities, they were faced with great capital outflows, the exchanges rates depreciated etc. Within this framework, we aimed to study volatility and volatility transmission from the USA to the Eastern European emerging countries. The study of volatility transmission caused by the changes of policies and advanced economies in the Eastern European countries has never been conducted before.

To determine the conditional volatility of stock and bond markets we used univariate heteroscedastic models and to test whether there is volatility transmission from the USA to the financial markets of the Eastern European countries we used multivariate heteroscedastic models.

Previous studies prove that emerging countries with more developed financial markets were the most affected. The results obtained from the study of the risk of Eastern European stock markets confirm this hypothesis because the highest volatilities, in comparison with the previous periods, are exposed by Hungary, Czech Republic and Poland. On the bond markets in Eastern Europe countries one can notice a volatility increase excepting Lithuania.

The multivariate heteroscedastic models estimated allow us to answer the research questions proposed. There are cross-mean spillovers effects from SUA only to the stock markets from Hungary, Bulgaria and Poland. The shocks that appear on the US stock market affect the stock markets from Romania, Poland and Bulgaria but they are more strongly influenced by their own shocks. The volatility of the US stock market is also transmitted to almost all Eastern European markets, excepting of Latvia and Lithuania.

As for the bond markets in Eastern Europe the situation is somehow different. The change in the US monetary policy does not determine a transmission of the return from the USA stock market to the Eastern European bond market. At the same time, volatility of the USA stock markets caused by the change of the QE programme is transmitted to all the bond markets from the Eastern European countries.

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Appendix A - Testing the stationarity of the variables

Table A1. Testing the stationarity of the returns for bond markets

	ADF test		PP test	
Returns	Model with intercept	Model without intercept	Model with intercept	Model without intercept
Bulgaria	-18.91291*	-18.86862*	-35.79221*	-35.68904*
Czech Republic	-31.19583*	-31.06842*	-30.79608*	-30.61845*
Hungary	-24.50149*	-24.42297*	-24.45738*	-24.41079*
Latvia	-34.03583*	-33.84042*	-35.21161*	-34.56713*
Lithuania	-25.15310*	-24.66321*	-41.58223*	-39.78899*
Poland	-25.07568*	-25.01773*	-25.04750*	-24.98986*
Romania	-20.39185*	-20.29514*	-40.75950*	-40.34397*
Slovakia	-13.34346*	-13.26763*	-28.41861*	-28.34783*

Source: data processed by means of the Eviews
Note: ADF test. PP test represents Augmented Dickey-Fuller and Philips Perron tests

Table A2. Testing the stationarity of the returns for stock markets

	ADF test		PP test	
Returns	Model with intercept	Model without intercept	Model with intercept t	Model without intercept
LRBET	-22.13823*	-22.03719*	-22.13698*	-22.07179*
LRBUX	-24.70332*	-24.72135*	-24.67618*	-24.69488*
LROMR	-31.15478*	-31.14484*	-30.75179*	-30.73198*
LROMV	-26.25803*	-25.85701*	-26.27325*	-25.86685*
LRPX	-25.70631*	-25.72523*	-25.70692*	-25.72578*
LRSAX	-22.80876*	-22.82558*	-34.95395*	-34.98285*
LRSOFIX	-25.33399*	-25.15499*	-25.32839*	-25.16061*
LRSP	-26.65052*	-26.47364*	-27.05804*	-26.60013*
LRWIG20	-25.32135*	-25.33898*	-25.31398*	-25.33203*

Source: data processed by means of the Eviews
Notes: a) LRBET, LRBUX, LROMXR, LROMXV, LRPX, LRSAX, LRSOFIX, LRSP, LRWIG20 represent the returns of the stock markets in Romania, Hungary, Lithuania, Latvia, Czech Republic, Slovakia, Bulgaria, United States and respectively Poland
b) ADF test. PP test represents Augmented Dickey-Fuller and Philips Perron tests