

Asymmetric Return and Volatility Transmission in Euro Zone and Baltic Countries Stock Markets

Viorica Chirilă
Ciprian Chirilă

“Alexandru Ioan Cuza” University of Iași,
Faculty of Economics and Business Administration, Romania

vchirila@uaic.ro

hcip@uaic.ro

Abstract

This paper analyzes the transmission of return and volatility from different stock markets. The stock markets that are analysed in the paper are from Lithuania, Estonia, Latvia and Euro zone. The indices that quantify the evolution of this stock markets are EURO STOXX 50, OMX Tallinn, OMX Vilnius and OMX Riga. These indices are used for determinations of return and risk in the case of this stock's markets. Multivariate asymmetric heteroscedastic BEKK model was applied for estimate the transmission of return and volatility between the markets. The results of the empirical study confirm the existence of spillovers phenomenon: first, the spillover return from the Euro Zone stock market to the Baltic stock markets, second, the spillover volatility from the Euro Zone to Estonia and Lithuania stock market and third, the asymmetry of volatility transmission only between markets from Lithuania and Estonia.

Key words: BEKK model, Baltic stock markets, asymmetric spillovers

J.E.L. classification: G11, G15, C51

1. Introduction

In the las years, the national financial markets, have become more correlated and interconnected. The adherence of Central and East European countries to the European Union facilitated the phenomenon of integration of financial markets. Thus, researchers focused on the transmission of volatility and return between capital markets in all periods of economic cycles, not only in times of economic crisis, as it was the case before. Harris and Pisedtasalasai (2006) mention a disadvantage of the existence of the transmission phenomenon of return: stock markets are inefficient. Existence of return spillovers may offer the possibility to forecast future returns. Knowing return spillover is also useful for portfolio management.

The results obtained when studying volatility spillover are useful to the financial institutions, the policy makers, international investors in order to make decisions for the diversification of their portfolios while estimating the conditional volatility is necessary in the option pricing, value at risk and hedging.

The current paper analyzes the spillovers phenomenon between the Baltic stock markets and the Euro zone stock market. The study of the stock markets of the Baltic countries is attractive for several reasons. The first reason is determined by the fact that the creation of a portfolio using the stocks sold on the three markets in Tallin, Vilnius and Riga are relatively easy due to the common institutional setup. Another reason was pointed out by Brännäs and Soutanaeva (2011) and reveals the fact that the stock markets in the Baltic countries are analysed less. Therefore, it is important for an investor who wants to diversify a portfolio to know whether the capital markets in Tallin, Vilnius and Riga react in the same manner and with the same intensity in transmitting volatility and return. The reduction of the risk for a portfolio which includes Baltic markets stocks would be rather difficult since these markets have evolution in terms of return and volatility. Also the periodic evaluation of

characteristics of spillovers is important for attaining and preserving international financial markets stability.

The studies on the stock markets from Estonia, Latvia and Lithuania are important for potential investors if this offer opportunities of international diversification. If between stock markets it does not exist the phenomenon of spillovers, or this phenomenon is not intense, than the stock markets are not integrated, so then the investors can diversify their portfolio with the assets from this markets.

Maneschiöld, in a study published in 2006, approaches the integration of Baltic stock markets in United States, Japan, Germany, the United Kingdom, and France. The analyzed period is from June 3, 1996, to September 16, 2005. The results obtained confirm the integration on long term of the Latvia market on the German market. This result confirms the possibility for international investors to diversify their portfolios through the investments performed in the Baltic countries.

Aktan, et al. 2010 publish a study of stock markets from Estonia, Latvia and Lithuania during 01.02.2002–03.01.2009. Empirical study highlighted that conditional volatility has asymmetry and that volatility can be modelled with asymmetric heteroscedastic models.

First objective of this paper is to evaluate if exist returns transmission between stock markets from Baltic countries and Euro zone. The second objective of this paper is to evaluate if exist volatility transmission between stock markets from Baltic countries and Euro zone and the third objective of this paper is to evaluate in spillovers volatility presents the characteristics of asymmetry.

The results obtained confirm the existence of the unidirectional transmission phenomenon of return, unidirectional volatility transmission and the bidirectional asymmetric transmission of volatility between two stock markets from the Baltic countries in Estonia and Lithuania.

The paper is structured as follows: section 2 presents the literature review with studies regarding the return and volatility spillover phenomenon; section 3 presents the entire empirical statistical analysis, section 4 describes the models used, the multivariate heteroscedastic models; section 5 presents the empirical results. The paper ends with conclusions.

2. Literature review

Alotaibi and Mishra (2015) study the spillovers effects from Saudi Arabia and US markets to the Bahrain, Oman, Kuwait, Qatar and United Arab Emirates stock markets (named GCC). The study is performed during the period June 2005 – May 2013. The results obtained confirm: a) spillover effects are statistically significant for all GCC stock markets; b) spillover effects from US market to all GCC stock markets and c) spillover effects from Saudi Arabia to GCC stock markets with the exception of Bahrain stock market.

The volatility transmission is also studied between the developed countries (Europe, US and Japan) and twenty Asian and MENA emerging markets (Balli, et al. 2015) during 2000-2003 and the results obtained show that volatility transmission is performed from the developed countries towards the emerging countries. The study demonstrates that volatility spillovers present different intensities for the countries within the sample.

The analysis of spillover effects of return and volatility conducted by (Chiang et al., 2013) from US stock market to Brasilia, Russia, India, China and Vietnam (BRICV) during the period which starts when each markets begins to function until 31st of December 2009 with the aim to determine the sub-prime mortgage crises effect on the markets behaviour. The results obtained confirm the existence of certain significant spillover from US to BRICV countries. Remarkable spillover effects from US to BRICV countries are those towards Russia and Vietnam.

Nishimura, Tsutsui and Hirayama (2015) analyze the spillover volatility phenomenon in stocks markets from the China to the Japan during the period November 2003 – November 2011 taking into consideration data registered during the trading days and values of the indices registered every five minutes. They estimate the volatility transmission from the China especially towards the stocks of the companies from Japan which run their activity in China but also towards the Tokyo market. Moreover, the volatility spillover phenomenon is stronger in the last years considered in the analysis when China's economy became more important at global level.

The empirical results obtained by Chirilă et al. (2015) demonstrate the transmission of volatility of the European stock market towards markets in Central and East Europe for the period comprised between 2005 and 2015. Volatility transmission in the Eastern Europe countries has also been

analysed by Popa et al. (2015). Studies on volatility spillover are also performed for other asset markets: bonds (Christiansen, 2005; Skintzi and Refenes, 2006; Claeys, and Vasicek, 2012), currency markets (Bubak et al., 2011; Antonakakis, 2012).

We also encounter more recent preoccupations regarding volatility transmission between different asset categories (Liou, 2015) money, currency, stock, bond, and public real estate within the G7 member states. The results obtained for these five asset categories for the period January 1997 – December 2013 indicate low cross-asset volatility spillover in this country group. The general stock portfolio represents the main contributor to the total volatility transmission.

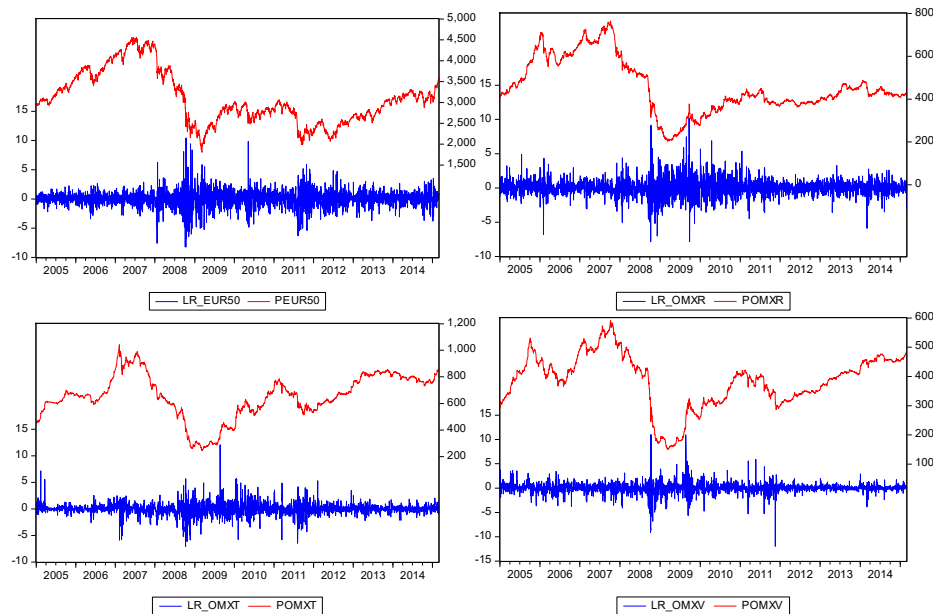
Grobys (2015) analyzes volatility transmission between foreign exchange rate markets and the US stock market. The results published confirm the existence of volatility spillover phenomenon especially during high-peak volatility periods. When studying volatility transmission one can remark the asymmetry phenomenon. The study of Koutmos and Booth (1995) for stock markets volatility transmission between New York, Tokyo and London, present the result for volatility transmission that is stronger when new negative shocks occur in comparison with the new positive shocks.

Haris and Pisedtasalai (2006) study spillover effects between the larger stock portfolios and small stock portfolios through the FTSE 100, FTSE 250 and FTSE Small Cap equity indices. Asymmetry is the characteristic of return and volatility transmission that they find. Return and volatility spillovers is recorded mainly from larger stock portfolios to small stock portfolios. Conclusions of this study are in compliance with the previously ones obtained by Reyes (2001) for the stock market in Tokyo.

3. Data and preliminary empirical analysis

The study is conducted for the stock markets in the Baltic countries: Estonia, Latvia, and Lithuania. To determine the overall evolution of these capital markets we took into consideration the following stock indices: OMX Riga (Latvia), OMX Tallinn (Estonia) and OMX Vilnius (Lithuania); at the same time in order to quantify the capital market from the Euro zone we considered the EURO STOXX 50 stock index.

Figure no. 1. The evolution of indices and returns of stock markets in the Euro zone, Riga, Tallinn and Vilnius



Source: author’s realization

The daily closing values of the stock indices are taken from the Datastream database for the interval of 31 December 2004 – 21 April 2015 and comprise 2,650 records for each index. The values of indices are expressed in the current local currency as they are also used in the empirical analysis conducted by Syriopoulos (2004), Yang, Hsiao, and Wang (2006), Diebold and Yilmaz (2009). Stock indices are, in the paper with the name PEURO50, POMXR, POMT and POMXV. LR_EUR50, LR_OMXR, LROMXT and LR_OMXV represent the returns of stock markets under analysis.

Several empirical features of financial returns are identified in the graphical representations, Figure 1. All the returns have a stationary mean and volatility varies within an interval without tending to infinity. The returns present big volatility during the general downturn periods and much small volatility. during the general growth periods of the market suggesting the existence of the volatility asymmetry phenomenon.

The highest volatility both of the Euro zone market and the Baltic countries stock markets is noticed throughout the years 2008 and 2009, year when the latest economic and financial crisis took place. In Riga, this high volatility maintained for a longer period of time in comparison with the other stock markets under consideration.

Table no. 1 Unit root tests on daily returns for the Euro zone, Riga, Tallinn and Vilnius

Variable	t statistics for ADF test		t statistics for PP test	
	Without trend	With trend	Without trend	With trend
LR_EUR50	-53.90139***	-53.89493***	-54.26778***	-54.26300***
LR_OMXR	-54.19067***	-54.18146***	-54.41077***	-54.40229***
LR_OMXT	-44.75268***	-44.74435***	-47.52223***	-47.51558***
LR_OMXV	-45.19842***	-45.19011***	-49.52781***	-49.52092***

Note: LR_EUR50, LR_OMXR, LR_OMXT, LR_OMXV – return of the Euro zone, Riga, Tallin and Vilnius stock markets

***, **, * represents significance levels for 0,01, 0,05, 0,10.

Source: author's calculation

The market volatilities are presented by clusters: high volatilities maintain long time and also the small volatilities maintain for a long period of time. This characteristic suggests that returns can be modelled by means of the heteroscedastic models and that at the same time, volatility persists in time.

Figure 1 also shows that the lowest volatility is met on the Vilnius and Tallinn markets, feature that is confirmed by the standard deviation in table 2 and that measures the total risk of the market in the period considered.

The testing of return stationarity with ADF test (Dickey, and Fuller, 1981) and the PP test (Phillips, and Perron, 1988) show the stationarity of returns. Therefore, the average return determined for returns may be considered return expected by the investors. The highest daily expected return is in Tallinn which has a value of 0.02438% while the lowest expected return is for the Riga stock market.

Table no. 2 Indicators of descriptive statistics estimated for the returns of Euro zone, Riga, Tallinn and Vilnius stock markets

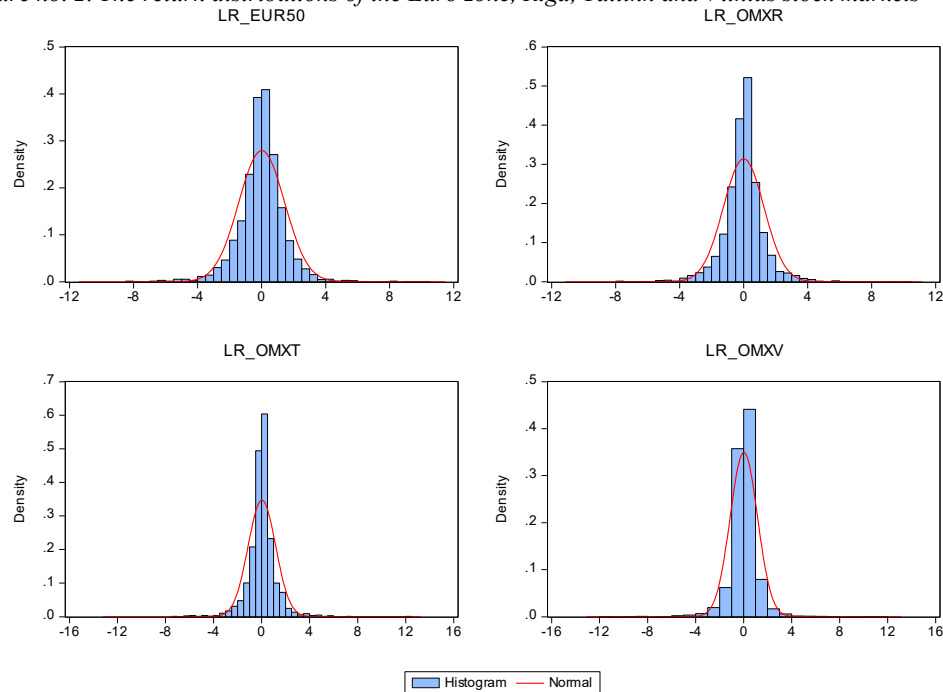
Indicators	LR_EUR50	LR_OMXR	LR_OMXT	LR_OMXV
Mean	0.007491	0.000615	0.024387	0.018690
Median	0.001402	0.000000	0.000000	0.000000
Maximum	10.43765	10.17979	12.09448	11.00145
Minimum	-8.207879	-7.858646	-7.045882	-11.93777
Std. Dev.	1.428516	1.269800	1.149502	1.140863
Skewness	0.010094	0.154902	0.230401	-0.352370
Kurtosis	9.411021	10.18043	13.50908	22.21700
Jarque-Bera	4538.301	5703.522	12217.94	40830.95
Probability	0.000000	0.000000	0.000000	0.000000
Observations	2650	2650	2650	2650

Note: LR_EUR50, LR_OMXR, LR_OMXT, LR_OMXV – return of the Euro zone, Riga, Tallin and Vilnius stock markets

***, **, * represents significance levels for 0,01, 0.05, 0.10.

Source: author’s calculation

Figure no. 2. The return distributions of the Euro zone, Riga, Tallinn and Vilnius stock markets



Source: author’s realization

The distribution of returns presents kurtosis excess. This feature is highlighted also by figure 2. Since the return distributions are leptokurtic, feature also known as fat tails, the extreme returns are more likely to occur.

To identify which model is more appropriate for modelling the returns we will analyze the total autocorrelation function, the partial autocorrelation function and the Ljung-Box test.

The results of Ljung-Box test present the fact that the daily returns of the stock markets are autocorrelated and can be modelled with ARMA models.

The Ljung-Box test but applied to the return squares confirm the cluster presentation of the return volatility that can be modelled by means of the heteroscedastic models.

The most appropriate models are the heteroscedastic ones and for estimate the interdependences among markets as regards return and risk, the heteroscedastic multivariate models will be considered.

4. The study methodology

Since the determination of interdependences among the four stock markets, Estonia, Latvia, Lithuania and the European Union is desired, a multivariate GARCH model, the BEKK model, is used, developed by Engle and Kroner (1995).

The mean equation of the model is:

$$Y_t = \alpha + \Gamma Y_{t-1} + \varepsilon_t \quad \varepsilon_t | I_{t-1} \sim N(0, H_t) , \quad (1)$$

Since there are four stock markets:

Y_t is a 4×1 vector of return

α is a vector 4×1 of the constants of the model,

Γ is a matrix 4×4 of the parameters associated to the lagged returns

The matrix Γ has on the diagonal parameters that show the impact of returns of stock markets on own past returns and the elements outside the diagonal highlight the relationships between the returns across markets.

ε_t is a vector 4×1 of residuals and has 4×4 conditional variance-covariance matrix which is noted with H_t .

Bollerslev Engle and Wooldrige (1988) propose H_t as follows:

$$vech(H_t) = vech(C) + \sum_{i=1}^q A_i vech(\varepsilon_{t-1} \varepsilon'_{t-1}) + \sum_{i=1}^p G_i vech(H_{t-i}) \quad (2)$$

where $vech$ is the operator transforming a k dimensional symmetric matrix into an $k(k+1)/2 \times 1$ array containing the elements on and below the main diagonal.

Bollerslev Engle and Wooldrige (1988), present two inconveniences: first, the number of parameters is very high and second, the matrix H_t to be positively defined, restrictions on parameters are needed. In order to solve the two problems Engle and Kroner (1995) create the BEKK model of the following form:

$$H_t = C' C + A' \varepsilon_{t-1} \varepsilon'_{t-1} A + G' H_{t-1} G \quad (3)$$

The model which will be used in this paper is proposed by Kroner and Ng (1998) and introduces in the previously presented model the empirical characteristic of volatility asymmetry. The volatility asymmetry resides in the different reaction of return to shocks: when negative shocks (bad information) occur, the determined volatility is higher than when positive shocks (positive information) of the same intensity appear. This model also allows to capture the asymmetric response of volatility in variances and covariances. It is of the form:

$$H_t = C' C + A' \varepsilon_{t-1} \varepsilon'_{t-1} A + G' H_{t-1} G + D' \xi_{t-1} \xi'_{t-1} D \quad (4)$$

where:

ξ_t takes the value ε_t if $\varepsilon_t < 0$ and 0 for the rest.

C is a 4×4 lower triangular matrix of constants;

A, G, D are 4×4 matrices.

The last term of the right-side model highlights the asymmetric characteristic of the time-varying variance-covariance. The parameters on the diagonal G matrix measure the effects of the own previous volatilities on its conditional variance while the parameters outside the diagonal g_{ij} measure the cross-market effects of volatility known as volatility spillover. In the D matrix, parameters which are on the diagonal, measure the effects of a market i to its previously negative shocks and the parameters outside the diagonal d_{ij} measure the response to a market i to the negative information of other markets named cross-market asymmetric responses.

The previously presented system is estimated using the full information maximum likelihood method. The conditional log-likelihood of residual vector of the observation t , (n being the number of stock exchange) is:

$$L = \sum_{t=1}^T L_t, \quad L_t = \frac{n}{2} \ln(2\pi) - \frac{1}{2} \ln |H_t| - \frac{1}{2} \varepsilon_t' H_t^{-1} \varepsilon_t \quad (5)$$

For the estimation, the algorithm BHHH is used since it maximizes the log-likelihood function.

5. Empirical results

The asymmetric multivariate model GARCH-BEKK(1,1) is estimated. The results are in table 3. The stock market in the Euro zone is noted with 1, the stock market (Latvia) is noted with 2, the stock market in Tallinn (Estonia) is noted with 3 and the stock market in Vilnius (Lithuania) is noted with 4. The results obtained from the estimation of this multivariate model offer information about the return and volatility spillovers between markets and eventually the asymmetric characteristic of this transmission.

The mean equation presents the transmission between returns. The parameters γ situated on the diagonal ($\gamma_{11}, \gamma_{22}, \gamma_{33}, \gamma_{44}$) show whether the returns of the Tallinn Vilnius Euro zone and Riga, depend on their first lag. The estimations of the parameters γ on the matrix diagonal are all statistically significant; therefore, the returns of these stock markets depend on their own returns from the previous day.

As regards the coefficients outside the diagonal, we notice the estimated significant parameters $\gamma_{14}, \gamma_{13}, \gamma_{12}$ while their counterparts, $\gamma_{41}, \gamma_{31}, \gamma_{21}$, are not statistically significant. Therefore, there is a unidirectional transmission of return from the Euro zone towards the Baltic countries markets. The return is not spillover from the Baltic countries to Euro zone. “Global centre” hypothesis implies that a stock market may play a major role in the transmission of new information which appears in the macroeconomic environment.

The spillovers of return are only in the direction from Euro zone to Baltic countries (unidirectional transmission). This result tells us that macroeconomic shocks from European level are transmitted towards the Riga, Tallinn and Vilnius.

Table no. 3 The estimation of the GARCH asymmetric multivariate model

	EUR (i=1)	OMXR(i=2)	OMXT(i=3)	OMXV(i=4)
γ_{i1}	-0.069 ***	-0.005	0.004	-0.036
γ_{i2}	0.060 ***	-0.118 ***	0.082 ***	0.083 ***
γ_{i3}	0.076 ***	0.024	0.103 ***	0.015
γ_{i4}	0.061 ***	0.022	0.042 **	0.062 ***
a_{i1}	0.011	0.021	-0.105 ***	-0.014
a_{i2}	0.015	0.166 ***	-0.006	0.108 ***
a_{i3}	0.047 **	0.027 **	0.224 ***	0.029
a_{i4}	0.054 ***	0.024	0.008	0.293 ***
g_{i1}	0.815 ***	-0.026	0.512 ***	-0.113 ***
g_{i2}	-0.049 ***	0.973 ***	0.053 ***	-0.047 ***
g_{i3}	-0.262 ***	-0.008	0.986 ***	-0.016
g_{i4}	-0.054 ***	-0.018 ***	0.064 ***	0.911 ***
d_{i1}	-0.261 ***	-0.007	-0.095	0.004
d_{i2}	-0.048 ***	-0.87 **	0.029	-0.048 *
d_{i3}	-0.184 ***	0.024	0.046	-0.066 **
d_{i4}	-0.042 ***	-0.011	0.230***	-0.229 ***

Note: ***, **, * represents significance levels for 0,01, 0,05, 0,10.

Source: author’s calculation

Unidirectional return transmission exist from the Tallinn to the Riga and Vilnius and from the Vilnius the Riga. Thus, the return of the Riga is influenced by the Euro zone and by Tallinn and Vilnius and the return of Vilnius is determined within the emerging markets only by Tallinn. The results are the same with the results obtained by Li and Majeroska (2008) who for the period January 1998 – December 2005 they find unidirectional transmission of return from markets in the developed countries Germany and United States of America towards the emerging countries Poland and Hungary as well as an influence between the neighboring emerging stock markets Poland and Hungary.

The A and G matrices presented in table 3 transmit information on the volatility spillovers between markets. The elements of the A matrix, on the diagonal, show the own ARCH effects. The elements on the G matrix on the diagonal measure the own GARCH effects. The parameters estimated on the A matrix, a_{22}, a_{33}, a_{44} and on the G matrix, $g_{11}, g_{22}, g_{33}, g_{44}$ are statistically

significant. So the conditional variance of the return for the markets follows a GARCH (1,1) process. The conditional variances of the Riga, Tallinn and Vilnius stock markets are determined by their own shocks and previous volatilities while the Euro zone stock market is determined by its own previous volatility and not by previous shocks (a_{11} is not statistically significant).

The elements outside the diagonal of the A matrix captures the cross-market effects. Since a_{13} and a_{31} are statistically significant, there is a bidirectional transmission of shocks (new pieces of information) between the Euro zone market and the Tallinn market. Between the Euro zone and the Vilnius market there is a unidirectional transmission of shocks (a_{14} is statistically significant while a_{41} is not). There is also a unidirectional transmission of shocks from Riga towards Tallinn. The shocks are not transmitted between the Euro zone stock market and the Riga market. Still, the Riga stock market shocks are indirectly influenced by the shocks of the Euro zone because the of Vilnius market which transmits in a unidirectional way the shocks towards the Riga market (a_{42} is statistically significant while a_{24} is not). One can also witness a unidirectional transmission of shocks from Riga to Tallinn (a_{23} is statistically significant while a_{32} is not).

The elements outside the G diagonal capture the cross-market effects concerning the volatility transmission. The pairs of the parameters estimated, g_{12} and g_{21} , g_{13} and g_{31} and respectively g_{14} and g_{41} are statistically significant and show that there is a bilateral transmission of volatility between the Euro zone markets and the Baltic markets: Riga, Tallinn, Vilnius. There is also a bilateral transmission of volatility between Riga and Vilnius (g_{24} and g_{42} are statistically significant). There is volatility spillovers from the Tallinn market towards the Riga market (g_{32} is statistically significant while g_{23} is not) as well as from Tallinn towards Vilnius (g_{34} is statistically significant while g_{43} is not). The results confirmed by the parameters estimations suggest that these emerging markets are connected with the Euro zone market in the case of volatility. The Baltic countries are integrated in the Euro zone market in the case of volatility.

The asymmetry of markets volatility implies that the occurrence of a new negative event (shock) determines a higher volatility than the appearance of a new positive event. The elements of the D matrix highlight both the potential asymmetric responses of the stock markets determined by their own previous shocks and the asymmetric responses determined by the other stock markets included in the analysis.

The estimators of the parameters d_{11} , d_{22} , d_{44} are statistically significant so that the Euro zone, Riga, Vilnius markets have asymmetric responses to their own shocks while d_{33} is not statistically significant implying that the Tallinn stock market does not have an asymmetric response of volatility determined by its own shocks. Therefore, the sign of the own previous shocks influences the conditional variance of two of the three stock markets in the Baltic countries.

Few of the parameters estimated outside the diagonal of the D matrix are statistically significant. As regards the asymmetric transmission of volatility between the Baltic countries one may say that it is bidirectional for Vilnius, Tallinn markets on one side (d_{43} and d_{34} are statistically significant) and it is unidirectional from Vilnius towards Riga.

6. Conclusions

The interconnection of the stock markets resulted as a consequence of their globalization implies taking into consideration in the portfolio management the spillover volatility and return phenomenon. The paper we conducted focused on the study of the spillovers of return and also of volatility between the Baltic and Euro Zone stock market. Riga, Vilnius, Tallinn, Euro Zone has stationary returns, autocorrelated and dependent. The volatility of the stock markets returns is presented by clusters and it is also characterised by asymmetry because it has big values in the periods of downturn of the

market and low values during in the period growth of the market. The features of return and risk of these stock markets imply the use the heteroscedastic models. To obtain information about the transmission of return and volatility between stock markets the GARCH-BEKK multivariate model was used.

As regards the return we can ascertain that all stock markets have returns which depend on their own returns from the previous day. The Baltic stock markets also have returns that are dependent on the returns in the Euro Zone, fact which confirms the “global centre” hypothesis. The transmission of return from the Euro Zone towards markets from the Baltic countries is unidirectional. The return of the Riga market is also influenced by the return of the Tallinn and Vilnius markets and the return of the Vilnius market is influenced by the return of the Tallinn market. Thus, we can say that the emerging markets are also influenced by neighbouring emerging markets.

As concerns the volatility of a stock market, it can be influenced both by shocks (ARCH effects) and by previous volatilities (GARCH effects). The conditional variance from the Euro Zone is determined by its own previous volatility while the Baltic stock markets are determined both by their own shocks and by their own previous volatilities.

The study shows that there is a unidirectional transmission of shocks between the Euro Zone market and the Vilnius stock market as well as unidirectional transmission of shock from Riga to Tallinn. The shocks are not transmitted between the Euro Zone stock market and the Riga stock market. There is also a unidirectional transmission of shocks from Riga to Tallinn.

The bilateral transmission of volatility is between markets from the Euro Zone and markets from the Baltic countries. There is bilateral transmission of volatility among the Baltic countries (Riga and Vilnius) and unilateral volatility transmission from the Tallinn market towards the Riga one and from Tallinn to Vilnius. The results prove that these emerging markets relate to the Euro Zone market from the point of view of volatility. Thus the Baltic countries are integrated in the European Union as far as volatility is concerned.

Asymmetric responses of volatility to own shocks are identified on all markets except for the Tallinn market. The asymmetric transmission of volatility is bidirectional between Vilnius and Tallinn and unidirectional between Vilnius and Riga. Is not asymmetric the transmission of volatility from the Euro Zone to the Baltic countries.

7. Acknowledgment

This project is funded by the Ministry of Research and Innovation within Program 1 – Development of the national RD system, Subprogram 1.2 – Institutional Performance – RDI excellence funding projects, Contract no. 34PFE/19.10.2018.

8. References

- Aktan, B., Korsakienė R., Smaliukiene R. 2010. Time-varying volatility modelling of Baltic stock markets. *Journal of Business Economics and Management*. 11(3), 511-532.
- Alotaibi, A. R., Mishra A. V. 2015. Global and regional volatility spillovers to GCC stock markets. *Economic Modelling*, 45, 38–49.
- Antonakakis, N. 2012. Exchange return co-movements and volatility spillovers before and after the introduction of Euro. *Journal of International Financial Markets, Institutions and Money*, 22(5), 1091–1109.
- Balli, F., Hajhoj, H. R., Basher, S. A., Ghassan, H. B. 2015. An analysis of returns and volatility spillovers and their determinants in emerging Asian and Middle Eastern countries. *International Review of Economics & Finance*, 39(C), 311-325.
- Brännäs, K., Sultanaeva A. 2011. Influence of news from Moscow and New York on returns and risks of Baltic States’ stock markets. *Baltic Journal of Economics*, 11 (1), 109-124.
- Bubak, V., Kocenda, E., Zikes, F. (2011). Volatility transmission in emerging European foreign exchange markets. *Journal of Banking & Finance*, 35, 2829–2841.
- Bollerslev, T., Engle, R. F., Wooldridge, J. M. (1988). A capital asset pricing model with time-varying covariances, *The Journal of political Economy*, 96(1), 116-131.
- Chiang S.-M., Chen H.-F., Lin C.-T. (2013). The spillover effects of the sub-prime mortgage crisis and optimum asset allocation in the BRICS stock markets. *Global Finance Journal*, 24, 30–43.

- Chirila V., Turturean C.-I., & Chirila C. 2015. Volatility spillovers between Eastern European and Euro Zone stock markets. *Transformations in Business & Economics*, 14 (2A), 464-477.
- Christiansen, C., 2007. Volatility-spillover effects in European bond markets. *European Financial Management*, 13, 923–948.
- Claeys, P., Vasicek, B. (2012). Measuring sovereign bond spillover in Europe and the impact of rating news. *Working paper 09, Mimeo, Czech National Bank*.
- Dickey, D. A., Fuller, W.A. (1981). Likelihood ratio statistics for autoregressive time series with a unit root. *Econometrica*, 49(4), 1057-1072.
- Diebold F., Yilmaz K. 2009. Measuring financial asset return and volatility spillovers, with application to global equity markets. *The Economic Journal*, 119(534), 158–171.
- Engle, R., Kroner, K. 1995. Multivariate simultaneous generalised ARCH. *Econometric Theory* 11(1), 122–150.
- Grobys K. 2015. Are volatility spillovers between currency and equity market driven by economic states? Evidence from the US economy. *Economics Letters*, 127, 72–75.
- Harris, R. D. F., Pisedtasalasai, A. 2006. Return and Volatility Spillovers between Large and Small Stocks in the UK. *Journal of Business Finance & Accounting*, 33(9-10), 1556–1571.
- Koutmos, G., Booth, G. G. 1995. Asymmetric volatility transmission in international stock markets. *Journal of International Money and Finance*, 14 (6), 747–762.
- Kroner, K. F., Ng, V. K., 1998, Modeling Asymmetric Movements of Asset Prices. *Review of Financial Studies*, 11, 844–871.
- Li, H., Majerowska, E. 2008. Testing stock market linkages for Poland and Hungary: A multivariate GARCH approach. *Research in International Business and Finance*, 22 (3), 247-266.
- Liou K. H. 2015. Volatility spillover dynamics and relationship across G7 financial markets. *North American Journal of Economics and Finance*, 33, 328-365.
- Maneschiöld, P. O. 2006. Integration between the Baltic and International Stock Markets. *Emerging Markets Finance and Trade*, 42, 25–45
- Nikkinen J., Piljak V., Äijö J. 2012. Baltic stock markets and the financial crisis of 2008-2009. *Research in International Business and Finance*, 26, 398-409.
- Nishimura, Y., Tsutsui Y., Hirayama K. (2015). Intraday return and volatility spillover mechanism from Chinese to Japanese stock market. *Journal of the Japanese and International Economies*, 35 (C), 23-42.
- Phillips, P., Perron, P. 1988. Testing for a unit root in time series regression. *Biometrika*, 75 (2), 335-346.
- Popa, I., Tudor, C., Paraschiv, D. 2015. Shocks spillover within emerging eastern European equity markets. *Economic Computation and Economic Cybernetics Studies and Research*, 1, 41-58.
- Reyes G. M. 2001. Asymmetric volatility spillover in the Tokyo stock exchange. *Journal of Economics and Finance*, 25(2), 206-213.
- Skintzi, V.-D., Refenes, A.-N. 2006. Volatility spillovers and dynamic correlation in European bond markets. *Journal of International Financial Markets, Institutions and Money*, 16, 23–40.
- Syriopoulos, T. 2004. International portfolio diversification to Central European stock markets. *Applied Financial Economics*, 14 (17), 1253-1268.
- Yanan, L. Giles D. E. 2015. Modelling Volatility Spillover Effects between Developed Stock Markets and Asian Emerging Stock Markets. *International Journal of Finance & Economics*, 20 (2), 155–177.
- Yang, J., Hsiao, C., Li, Q., Wang, Z. 2006. The emerging market crisis and stock market linkages: further evidence. *Journal of Applied Econometrics*, 21 (6), 727-744.