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ANALYZING VOLATILITY TRANSMISSIONS BETWEEN STOCK MARKETS OF TURKEY, ROMANIA, POLAND, HUNGARY AND UKRAINE USING M-GARCH MODEL

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Gürkan BOZMA
Res.Assist., Iğdır University
Faculty of Economics and Administrative Sciences
Department of Economics
gurkan.bozma@igdir.edu.tr

Selim BAŞAR
Prof.Dr., Atatürk University
Faculty of Economics and Administrative Sciences
Department of Economics
selim@atauni.edu.tr

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Abstract: Due to technological advances, stocks and commodity markets have become single market. There is a high degree of volatility among the stock markets especially opening in the same period. In this study, the volatility between Turkey, Romania, Poland, Hungary and Ukrainian stock market is examined by using the VAR (1) M-GARCH model. Before applying the VAR (1)-M-GARCH model, it is tried to determine by using the Johansen Cointegration method based on the maximum likelihood method whether there is a long-run relationship between stock exchanges. A long-run relationship is determined among the stock market according to the Johansen Cointegration test. The volatility of stock exchange volatility is examined by VAR (1) -M-GARCH-BEKK model. As a result of the findings, the conditional variance of the Turkey (BIST-100) is affected by its own short-run shocks and long-run volatility as well as the short-run shocks and the long-run volatility that have occurred in the Poland and Hungary stock markets. In addition, the conditional variance of the Turkey (BIST-100) is affected by the long-run volatility of the Romanian stock market.

Keywords: *Stock Market, Volatility Transmission, Romania, Poland, Turkey, Hungary, Ukraine, VAR-GARCH Model, BEKK.*

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TÜRKİYE, ROMANYA, POLONYA, MACARİSTAN VE UKRAYNA BORSALARI ARASINDAKİ OYNAKLIK GEÇİŞKENLİĞİNİN M-GARCH MODELİ İLE ANALİZİ

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Gürkan BOZMA
Arş. Gör., Iğdır Üniversitesi
İktisadi İdari Bilimler Fakültesi
İktisat Bölümü
gurkan.bozma@igdir.edu.tr

Selim BAŞAR
Prof.Dr., Atatürk Üniversitesi
İktisadi İdari Bilimler Fakültesi
İktisat Bölümü
selim@atauni.edu.tr

Bu çalışma Romanya'nın Iasi eyaletinde gerçekleştirilen 4. Perspectives in Humanities and Social Sciences: Hinting At Interdisciplinarity kongresinde bildirim olarak sunulmuştur.

Öz: Teknolojik gelişmeler, hisse senetleri ve emtia piyasaları tek pazar haline gelmiştir. Özellikle aynı zaman diliminde açılan borsalar arasında yüksek derecede oynaklık olduğu literatürde sıklıkla incelenmiştir. Bu çalışmada, Türkiye, Romanya, Polonya, Macaristan ve Ukrayna borsaları arasındaki oynaklık VAR (1) M-GARCH modeli kullanılarak incelenmiştir. VAR (1) -M-GARCH modelini uygulamadan önce, hisse senedi borsaları arasında uzun dönemli bir ilişki olup olmadığı, maksimum olabilirlik yöntemi dayalı Johansen Eş-entegrasyon yöntemi kullanılarak belirlenmeye çalışılmıştır. Johansen Eşbütünleşme testine göre ele alınan borsalar arasında uzun dönemli bir ilişki olduğu tespit edilmiştir. Borsalar arasındaki oynaklık değişkenliği VAR (1) -M-GARCH-BEKK modeliyle incelenmiştir. Elde edilen bulgular sonucunda, Türkiye (BIST-100)'in koşullu varyansı, kendi kısa dönem şokları ve uzun dönem oynaklıkları ile Polonya ve Macaristan borsalarının kısa dönem şokları ve uzun dönem oynaklıklarından etkilenmektedir. Ayrıca, Türkiye'nin koşullu varyansı, Romanya borsasının uzun dönem oynaklığından etkilenmektedir.

Anahtar Sözcükler: *Borsa, Oynaklık Geçişkenliği, Romanya, Polonya, Türkiye, Macaristan, Ukrayna, VAR-GARCH, BEKK.*

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INTRODUCTION

Economic globalization and technological developments have indicated that the national economies should be evaluated as a whole as well as being handled individually. Especially after the collapse of the Berlin Wall, along with the integration movements in Europe and America, the economies became a whole and intense interactions started in the countries. The intense interaction in the economies could be seen in the real and financial markets of the countries so that one country affects other countries easily (Bala, Takimoto, 2017; Coudert *vd.*, 2015; Hemche *vd.*, 2016; Kenourgios, Dimitriou, 2015), even creating economic crises. In this case, East Asian crisis (Li, Giles, 2015) and 2008 financial crisis shown as examples.

Following the economic and financial crises, investors did not reduce their investments in developing and developing countries, and even in the 2008 financial crisis, there was a $ 616 billion investment flow to developing countries, according to the International Finance Corporation report (Balli *vd.*, 2015). Despite many factors, the high growth rates of the countries and the increase in their share in the global economy attract investors to developing countries (Demiralay, Bayraci, 2015). In this context, it turns out that financial investors need to diversify portfolios. Because developing countries have higher volatility and higher profits. Therefore, it will be beneficial for investors to find out the existence and the magnitude of the volatility and volatility transmission between the markets.

In the financial literature, volatility transitions among the financial markets of developing countries has recently begun. In the literature, there is a high concentration on developing country markets to developing countries to investigate the transmission of markets (Adrangi *vd.*, 2014; Cardona *vd.*, 2017; Chan-Lau, Ivaschenko, 2003; Chuliá *vd.*, 2017; Demiralay, Bayraci, 2015; Fink, Schüler, 2015; John Wei *vd.*, 1995; Lahrech, Sylwester, 2011; Li, Giles, 2015; Miyakoshi, 2003; Verma, Ozuna, 2007; Wang, Wang, 2010). On the other hand, there has been a recent increase in the studies on the transitivity of the financial markets of countries within a certain geography (Arouri *vd.*, 2010; Cardona *vd.*, 2017; Darrat *vd.*, 2000; Demiralay, Bayraci, 2015; Güloğlu *vd.*, 2016; Lahrech, Sylwester, 2011; Marashdeh, 2005; Verma, Ozuna, 2007). The paper for BRICS (Ahmad *vd.*, 2013; Bhar, Nikolova, 2009; Gilenko, Fedorova, 2014; Hammoudeh *vd.*, 2013; Mensi *vd.*, 2017a; Mensi *vd.*, 2017b; Mensi *vd.*, 2016) and CIVETS (Korkmaz *vd.*, 2012) defined by financial institutions also increased. However, in the literature, no studies is found for the countries located in Central and Eastern Europe and the Black Sea countries.

This study examined the volatility transmisson between the countries in Central (Poland) and Eastern Europe (Hungary and Romania) and Black Sea coast (Ukraine and Turkey (BIST-100)). The work is expected to contribute to financial literature in many ways. Firstly, this study is the first study to examine the transmission between financial markets of Central and Eastern Europe and Black Sea countries. Secondly, measuring the volatility using VAR-BEKK-GARCH enriches the analysis. Finally, it is expected that portfolio diversification will lead to diversification of investors portfolio by revealing the correlation between aforementioned markets.

This study consists of 4 parts including the introduction section. Empirical methods and data sets are introduced in the section 2. In the following section, the empirical results reported. In the last section provides some concluding remarks and policy recommendations.

The Econometric Method and Data

In this study BEKK-GARCH (1,1) method developed by Engle, Kroner (1995) is used to examine the volatility transmission between stock markets (Gilenko, Fedorova, 2014; Huang, Kuo, 2015; Li, Giles, 2015).

The mean equations (VAR (1)) in the model are as follows equation (1):

$$R_{t+1} = \mu + \Phi R_t + \varepsilon_{t+1}$$
$$\varepsilon_{t+1} = H_{t+1}^{1/2} \eta_{t+1} \qquad (1)$$

where $R_{t+1} = \left[R_{t+1}^{Pol} \ R_{t+1}^{Bud} \ R_{t+1}^{Bist} \ R_{t+1}^{Ukr} R_{t+1}^{Rom} \right]'$ denotes the stock returns[1], Φ shows 4x4 matrix estimated parameters of the lag variables found in the mean equations. The algebraic representation of the BEKK-GARCH (1,1) model is like the following eq. (2):

$$H_{t+1} = CC' + A\varepsilon_t \varepsilon_t' A' + BH_t B' \qquad (2)$$

In Eq. (2), H is the 5x5 variance-covariance matrix; C is the 5x5 upper triangular constant matrix. The matrix A and B show the estimators expressing the effects of short-run shocks and long-run volatilities, respectively. The matrix form of eq. (2) is like eq (3) below:

$$H_{t+1}=CC'+\begin{pmatrix} a_{11} & a_{12} & a_{13} & a_{14} & a_{15} \\ a_{21} & a_{22} & a_{23} & a_{24} & a_{25} \\ a_{31} & a_{32} & a_{33} & a_{34} & a_{35} \\ a_{41} & a_{42} & a_{43} & a_{44} & a_{45} \\ a_{51} & a_{52} & a_{53} & a_{54} & a_{55} \end{pmatrix}\varepsilon_t\varepsilon' \begin{pmatrix} a_{11} & a_{21} & a_{31} & a_{41} & a_{51} \\ a_{12} & a_{22} & a_{32} & a_{43} & a_{52} \\ a_{13} & a_{23} & a_{33} & a_{43} & a_{53} \\ a_{14} & a_{24} & a_{34} & a_{44} & a_{54} \\ a_{15} & a_{25} & a_{35} & a_{45} & a_{55} \end{pmatrix}+\begin{pmatrix} b_{11} & b_{12} & b_{13} & b_{14} & b_{15} \\ b_{21} & b_{22} & b_{23} & b_{24} & b_{25} \\ b_{31} & b_{32} & b_{33} & b_{34} & b_{35} \\ b_{41} & b_{42} & b_{43} & b_{44} & b_{45} \\ b_{51} & b_{52} & b_{53} & b_{54} & b_{55} \end{pmatrix} H_{t-1} \begin{pmatrix} b_{11} & b_{21} & b_{31} & b_{41} & b_{51} \\ b_{12} & b_{22} & b_{32} & b_{43} & b_{52} \\ b_{13} & b_{23} & b_{33} & b_{43} & b_{53} \\ b_{14} & b_{24} & b_{34} & b_{44} & b_{54} \\ b_{15} & b_{25} & b_{35} & b_{45} & b_{55} \end{pmatrix} \quad (3)$$

The analytical forms of the conditional variances of each of the returns of the matrix given by eq. (3) are as in eq. (4) below:

$$\begin{aligned} h_{jj,t+1} &= c_{jj}^{*}+\left(a_{j1}^{2}\varepsilon_{1,t}^{2}+2a_{j1}a_{j2}\varepsilon_{2,t}\varepsilon_{1,t}+2a_{j1}a_{j3}\varepsilon_{3,t}\varepsilon_{1,t}+2a_{j1}a_{j4}\varepsilon_{4,t}\varepsilon_{1,t}+2a_{j1}a_{j5}\varepsilon_{5,t}\varepsilon_{1,t}\right) \\ &+\left(a_{j2}^{2}\varepsilon_{2,t}^{2}+2a_{j2}a_{j3}\varepsilon_{3,t}\varepsilon_{2,t}+2a_{j2}a_{j4}\varepsilon_{4,t}\varepsilon_{2,t}+2a_{j2}a_{j5}\varepsilon_{5,t}\varepsilon_{2,t}\right)+\left(a_{j3}^{2}\varepsilon_{3,t}^{2}+2a_{j3}a_{j4}\varepsilon_{4,t}\varepsilon_{3,t}+2a_{j3}a_{j5}\varepsilon_{5,t}\varepsilon_{3t}\right) \\ &+\left(a_{j4}^{2}\varepsilon_{4,t}^{2}+2a_{j4}a_{j5}\varepsilon_{5,t}\varepsilon_{4t}\right)+(a_{j5}^{2}\varepsilon_{5,t}^{2})+\left(b_{j1}^{2}h_{11,t}+2b_{j1}b_{j2}h_{21,t}+2b_{j1}b_{j3}h_{31,t}+2b_{j1}b_{j4}h_{41,t}+2b_{j1}b_{j5}h_{51,t}\right) \\ &+\left(b_{j2}^{2}h_{22,t}+2b_{j2}b_{j3}h_{32,t}+2b_{j2}b_{j4}h_{42,t}+2b_{j2}b_{j5}h_{52,t}\right)+\left(b_{j3}^{2}h_{33,t}+2b_{j3}b_{j4}h_{43,t}+2b_{j3}b_{j5}h_{53,t}\right) \\ &+\left(b_{j4}^{2}h_{44,t}+2b_{j4}b_{j5}h_{54,t}\right)+(b_{j5}^{2}h_{55,t}) \\ & j=1,2,...,5 \end{aligned} \quad (4)$$

The estimation of the BEKK-GARCH model is performed by the quasi-maximum likelihood (QML) method. Because of the fact that it is in non-linear form, marginal effects must be measured. Therefore, the delta method is used to measure marginal effects and standard errors in this study. The daily data for the period 2011: 01-2016:12 are used to examine the volatility between the stock markets obtained from DATASTREAM. Series during the period of 20011-2016 is given in Figure 1. Analyzes in the study series realized based on first day of the series.

Figure 1. Stock Market

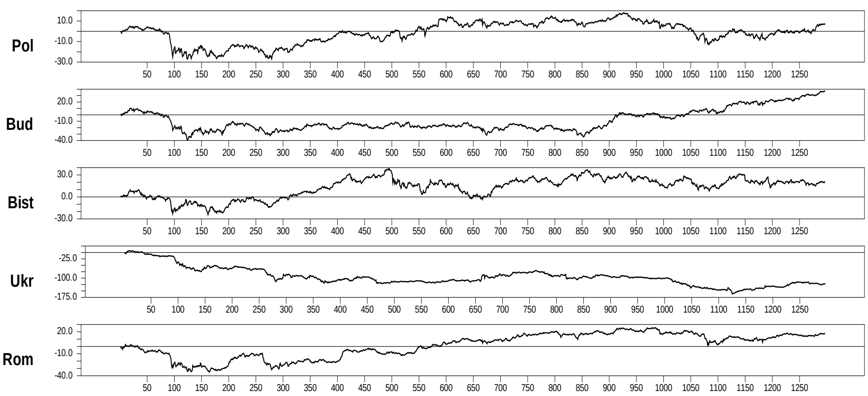


Figure 2. Commodity Price Levels Over Time

When the series are carefully examined, it is worth noting that the series may be co-integrated. In Table 1, some descriptive statistics and the ADF test results are given.

Table 1. Descriptive Statistics and Unit Root Test Results

Statistics	Pol	Bud	Bist	Ukr	Rom
Mean	0.005	0.028	0.016	-0.093	0.013
Std. Dev.	1.086	1.269	1.529	2.017	1.026
Skewness	-0.786	-0.263	-0.717	-0.281	-0.661
Kurtosis	4.310	2.420	4.218	8.441	9.173
Jarque-Bera	1137.06***	331.42***	1072.35***	3865.21***	4638.51***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
LB-Q (12)	27.350***	13.470	20.786**	24.623***	28.632***
	(0.00)	(0.33)	(0.05)	(0.01)	(0.00)
ARCH-LM (12)	11.012***	10.283***	4.239***	5.834***	7.247***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
ADF	-2.492	-1.665	-2.701	-2.286	-2.598

*Note: ***, ** and * represent 1%, 5% and 10% statistical level, respectively. All series represent returns of each variable.*

In Table 1, the Hungarian stock market has the highest average return. This stock market is followed by Turkish, Romanian and Polish stock markets respectively. On the other hand, the Ukrainian stock market has negative return, which can be due to an economic crisis and a conflict with Russia. When the standard deviations of the series are analysed, it is seen that Ukraine has the highest volatility. Ukraine and Turkey are followed by Hungary. In the Turkish case, it can be said that the terrorist incidents (Algan *vd.*, 2017) are very effective as well as the recent economic and political developments. In the literature, there are many studies on the terrorist incidents that have been seen on the financial sector (Abadie, Gardeazabal, 2008; Arin *vd.*, 2008; Balcilar *vd.*, 2016; Chen, Siems, 2004; Drakos, 2004; Gupta *vd.*, 2016). Skewness coefficients of the return series are less than 0, which means that the series are left-skewed. In addition, the kurtosis coefficients indicate that the series exhibit a leptokurtic (fat-tail) distribution, suggesting that the ARCH effect may be present in the series. The Jarque-Bera statistic obtained from the skewness and kurtosis coefficients also shows return series are not normally distributed. According to the Ljung-Box statistical, only autocorrelation is observed in Hungarian stock market. Finally, the ADF unit root test proposed by Dickey, Fuller (1979) is applied to determine the stationarity of the series. According to the unit root test, the series are found to be stationary at level of I(1).

Empirical Findings

In the previous section, the series are stationary at I (1) that reveals the possibility of cointegration between the series. Figure 1 shows intuitively the presence of cointegration relations in the series. Determining to cointegration relationship between series Johansen, Juselius (1990) is used Johansen, Juselius (1990) test is sensitive to the lag length. That is why the optimal length is determined (k = 1) according to the Schwartz information criterion. According to the cointegration test, the series are found cointegrated at the level of significance of 10%. In the literature, many studies suggested cointegration relation between the stock markets (Arshanapalli *vd.*, 1995; Chien *vd.*, 2015; Click, Plummer, 2005; Darrat *vd.*, 2000; Kasa, 1992; Marashdeh, 2005; Mollah, Mobarek, 2016; Voronkova, 2004; Yang *vd.*, 2014). Long-run relationships among the stock market make it necessary to reveal volatility pass-through. The volatility transmission among stock markets is determined by using VAR (1) -BEKK-GARCH (1,1) model. The results are presented in Table 2.

Table 2. Volatility Spillover of BEKK-MVGARCH Model

Returns Estimate	**Pol**	**Bud**	**Bist**	**Ukr**	**Rom**
Conditional mean equation					
Constant	0.025	0.042	0.050	**-0.081****	0.033
	(1.093)	(1.418)	(1.336)	(-2.176)	(1.518)
$ar(1)_{1i}$	**0.066*****	-0.035	**0.071***	0.019	0.015
	(2.437)	(-1.095)	(1.654)	(0.483)	(0.607)
$ar(1)_{2i}$	0.002	**0.04 6***	-0.022	0.001	0.023
	(0.104)	(1.764)	(-0.646)	(0.050)	(1.278)
$ar(1)_{3i}$	0.006	0.000	**-0.052****	**-0.047****	**0.030****
	(0.369)	(0.032)	(-1.972)	(-1.922)	(1.938)
$ar(1)_{4i}$	**-0.034*****	**-0.036*****	-0.018	-0.009	-0.011
	(-2.695)	(-2.476)	(-0.967)	(-0.329)	(-0.996)
$ar(1)_{5i}$	**0.073*****	**0.066****	**0.126*****	0.031	**0.076*****
	(2.765)	(2.098)	(3.235)	(0.726)	(3.075)
Conditional variance-covariance equation					
c_{1i}	**0.260*****				
	(8.301)				
c_{2i}	**-0.100****	**0.113****			
	(-2.329)	(2.134)			
c_{3i}	**-0.481*****	**0.147***	0.026		
	(-8.189)	(1.668)	(0.216)		
c_{4i}	0.015	**-0.609*****	-0.065	0.004	
	(0.177)	(-11.493)	(-0.376)	(0.018)	
C_{5i}	0.067	0.020	-0.005	0.000	0.000
	(1.489)	(0.632)	(-0.170)	(0.009)	(0.000)
a_{1i}	**0.078*****	**0.096*****	**0.364*****	0.063	**0.142*****
	(2.469)	(3.971)	(10.361)	(1.125)	(5.239)
a_{2i}	0.029	**0.158*****	**0.139*****	**-0.168*****	0.023
	(0.998)	(7.532)	(3.977)	(-3.064)	(1.005)
a_{3i}	0.009	**-0.027*****	**-0.255*****	-0.002	**0.046*****
	(0.527)	(-1.815)	(-10.683)	(-0.070)	(2.974)
a_{4i}	0.013	-0.008	-0.000	**0.614*****	0.021
	(0.909)	(-0.468)	(-0.017)	(17.433)	(1.357)
a_{5i}	0.036	0.027	-0.044	0.086	**0.089 *****
	(1.290)	(1.225)	(-1.273)	(1.588)	(3.201)
b_{1i}	**0.831*****	**-0.035****	**0.071****	**-0.099***	**-0.143*****
	(29.165)	(-1.982)	(1.950)	(-1.700)	(-7.026)
b_{2i}	**0.037*****	**0.978*****	**-0.064*****	**0.111*****	0.013
	(2.479)	(119.381)	(-3.270)	(3.033)	(1.352)
b_{3i}	**0.121*****	0.019	**0.899*****	**0.103*****	**0.102*****

	(8.429)	(1.421)	(33.154)	(2.637)	(6.329)
b_{4i}	0.012	0.012	0.011	**0.765*** **	0.005
	(1.345)	(1.340)	(1.010)	(32.810)	(0.566)
b_{5i}	0.001	**-0.020** **	**-0.113*** **	-0.039	**0.955*** **
	(0.058)	(-2.279)	(-5.405)	(-1.269)	(70.695)
Diagnostic tests					
Q(6)	5.607	3.684	9.834	10.065	4.678
	(0.468)	(0.719)	(0.131)	(0.121)	(0.585)
Q(12)	7.539	11.566	11.430	19.397	9.918
	(0.819)	(0.481)	(0.492)	(0.079)	(0.623)
$Q^2(6)$	17.691***	3.902	3.414	6.923	18.861***
	(0.007)	(0.689)	(0.755)	(0.327)	(0.004)
$Q^2(12)$	23.310**	9.284	5.347	9.177	21.612**
	(0.025)	(0.678)	(0.945)	(0.687)	(0.042)
MV Q (6)		155.750			
		(0.357)			
MV Q (12)		273.996			
		(0.856)			
MV Q^2 *(6)*		225.876***			
		(0.000)			
MV Q^2 *(12)*		338.466***			
		(0.062)			
LM test on std. residuals(6)		2137.20***			
		(0.000)			
LM test on std. residuals(12)		3841.88***			
		(0.000)			
LM test on std. seq. residuals(6)		3201.94***			
		(0.000)			
LM test on std. seq. residuals(12)		4265.67***			
		(0.000)			
LogL			-10022.836		
Wald test for all cross-volatility coefficients (H_0:a_{ij}=b_{ij}=0, i≠j)					
Chi-sq				662.545***	
				(0.000)	
Wald test for cross-volatility coefficients on each variable (H_0:a_{ij}=b_{ij}=0, i≠j)					
Chi-sq	270.253***	65.592***	120.826***	20.958***	50.654***
	(0.000)	(0.000)	(0.000)	(0.007)	(0.000)

*Note: *, ** and *** are statistically significant at 1%, 5% and 10% respectively. Q and Q^2 are statistics of Ljung-Box for the null hypothesis of no autocorrelation for a series in question on standardized and standardized squared residuals, respectively. MV Q-statistic and MV Q^2-statistic are Hosking's multivariate portmanteau Q-statistics. The LM-statistic tests a set of series for multivariate ARCH effects.*

On the Table 2, according to the mean equation coefficients Polish stock market return is negatively affected by the one-period lagged effect of Ukrainian stock market, while being positively affected by the one-period lagged of the Romanian stock market. Hungarian stock market is positively affected by the one-period lagged of Romanian stock market, while Ukrainian stock market negatively effects Hungarian stock market. Turkish stock market returns are positively affected by Polish and Romanian stock market returns. Romanian stock market returns are positively affected by the Turkish stock market. This is an important finding in revealing that there is close interaction between two stock markets.

VAR (1) -BEKK-GARCH (1,1) models are obtained by using the maximum likelihood method and then the delta method is applied to make interpretations of the conditional variances of the equation. Because, as can be seen from eq.4, the model is quadratic and unit effects need to be revealed. Eq.5 gives short-run shocks and eq. 6 gives long-run volatility affecting the conditional variance of each country's stock.

$$\begin{aligned}
h_{Pol,t} &= (0.078\varepsilon_{Pol,t-1} + 0.029\varepsilon_{Bud,t-1} + 0.009\varepsilon_{Bist,t-1} + 0.013\varepsilon_{Ukr,t-1} + 0.036\varepsilon_{Rom,t-1})^2 \\
h_{Bud,t} &= (0.096\varepsilon_{Pol,t-1} + 0.158\varepsilon_{Bud,t-1} - 0.027\varepsilon_{Bist,t-1} - 0.008\varepsilon_{Ukr,t-1} + 0.0276\varepsilon_{Rom,t-1})^2 \\
h_{Bist,t} &= (0.364\varepsilon_{Pol,t-1} + 0.139\varepsilon_{Bud,t-1} - 0.255\varepsilon_{Bist,t-1} - 0.000\varepsilon_{Ukr,t-1} - 0.0446\varepsilon_{Rom,t-1})^2 \\
h_{Ukr,t} &= (0.063\varepsilon_{Pol,t-1} - 0.168\varepsilon_{Bud,t-1} - 0.002\varepsilon_{Bist,t-1} + 0.614\varepsilon_{Ukr,t-1} + 0.086\varepsilon_{Rom,t-1})^2 \\
h_{Rom,t} &= (0.142\varepsilon_{Pol,t-1} + 0.023\varepsilon_{Bud,t-1} + 0.046\varepsilon_{Bist,t-1} + 0.021\varepsilon_{Ukr,t-1} + 0.089\varepsilon_{Rom,t-1})^2
\end{aligned} \tag{5}$$

Conditional variance of the Polish stock market is not statistically affected by its short-run shocks, while its own long-run volatility effects positively (0.690). Thus, the vast majority of the uncertainty arises from its long-run volatility. On the other hand, the conditional variance of the Polish stock market is significantly affected by the short-run shocks directly or indirectly (covariance) occurring in other stock markets. The long-run covariance between Hungary and Poland (0.062) increases uncertainty in the Polish stock market. Interestingly, long-run covariance between Polish and Turkish stock markets (0.201) cause high amount uncertainty in Polish stock market. It can be argued that this is due to the fact that Poland and Turkey are located in the same class (financial deepness) and the opening of stock markets at the same time frame. Poland stock market is not directly or indirectly affected by the Ukrainian and Romanian stock markets supports the result obtained for Poland and Turkey (financial deepness).

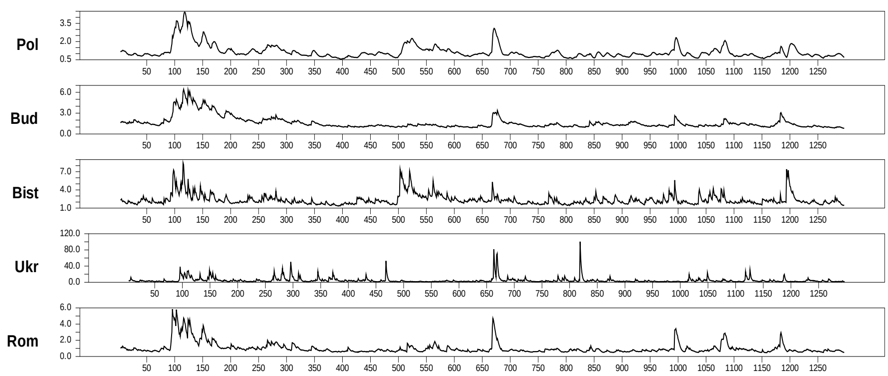
Hungarian stock market is affected by its short-run shock (0.025) and its long-run volatility (0.958). Good (bad) news occurring its own market decrease (increase) uncertainty in Hungarian stock market. Long-run volatility of Hungarian stock market creates more uncertainty rather than short-run shocks. On the other hand, the long-run covariance between the Polish-Hungarian and Romanian-Hungarian stock markets [(-0.069) and (-0.039)] reduces the uncertainty in the Hungarian stock market. Short-run shocks occurring from Turkish stock market affect indirectly (-0.008) the long-run conditional variance of the Hungarian stock market.

On the other hand, short-run shocks in Polish stock market (0.133) and long-run covariance (0.128) between Turkish and the Polish stock market (0.128) positively affect Turkey's conditional variance. At the same time, the long-run volatility of the Romanian stock market affects positively (0.001) the conditional variance of Turkish stock market.

$$
\begin{aligned}
h_{Pol,t} &= (0.831h_{Pol,t-1} + 0.037h_{Bud,t-1} + 0.121h_{Bist,t-1} + 0.012h_{Ukr,t-1} + 0.001h_{Rom,t-1})^2 \\
h_{Bud,t} &= (-0.035h_{Pol,t-1} + 0.978h_{Bud,t-1} + 0.012h_{Bist,t-1} + 0.012h_{Ukr,t-1} - 0.020h_{Rom,t-1})^2 \\
h_{Bist,t} &= (0.071h_{Pol,t-1} - 0.064h_{Bud,t-1} + 0.899h_{Bist,t-1} + 0.011h_{Ukr,t-1} - 0.1136h_{Rom,t-1})^2 \\
h_{Ukr,t} &= (-0.099h_{Pol,t-1} + 0.111h_{Bud,t-1} + 0.103h_{Bist,t-1} + 0.765h_{Ukr,t-1} - 0.039h_{Rom,t-1})^2 \\
h_{Rom,t} &= (-0.143h_{Pol,t-1} + 0.013h_{Bud,t-1} + 0.102h_{Bist,t-1} + 0.005h_{Ukr,t-1} + 0.955h_{Rom,t-1})^2
\end{aligned} \tag{6}
$$

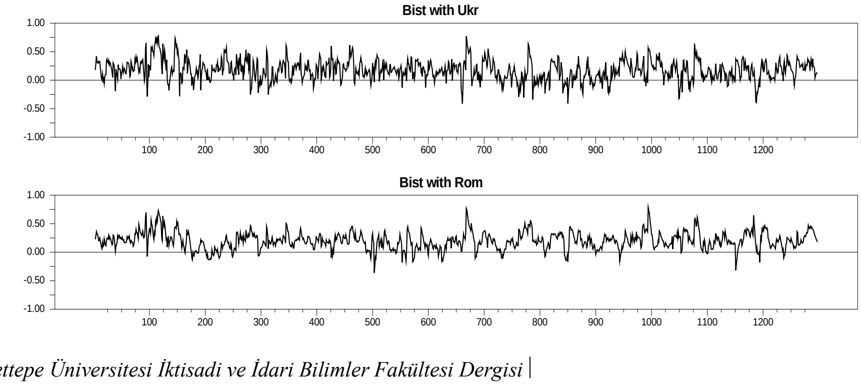
The conditional variance of the Romanian stock market is positively affected by short-run covariances between Polish-Turkish (0.013), Polish-Romanian (0.025) and Turkish-Romanian (0.008), while being directly affected by short-run shocks of Poland stock market (0.020).

Figure 2. Own Volatilities



BEKK-GARCH model's nonstationary is due to the conditions of$\varepsilon^2_{a,t} + h_{a,t} <1$ and $|\varepsilon^2_{a,t} * \varepsilon^2_{b,t} + h_{a,t} * h_{b,t}| <1$. BEKK-GARCH model is nonstationary as $\varepsilon^2_{Rom,t} + h_{Rom,t}=0.696<1$, $\varepsilon^2_{Bud,t} + h_{Bud,t}=0,981<1$, $\varepsilon^2_{Bist,t} + h_{Bist,t}=0.873<1$, $\varepsilon^2_{Ukr,t} + h_{Ukr,t}=0.962<1$, $\varepsilon^2_{Rom,t} + h_{Rom,t}=0.919<1$ and $|\varepsilon^2_{Pol,t} * \varepsilon^2_{Bud,t} * \varepsilon^2_{Bist,t} * \varepsilon^2_{Ukr,t} * \varepsilon^2_{Rom,t} + h_{Pol,t} * h_{Bud,t} * h_{Bist,t} * h_{Ukr,t} * h_{Rom,t}|=0.533<1$. Figure 2 shows the own volatilities of stock markets.

Figure 3. Conditional Correlations Between Stock Markets



The time-varying correlation coefficients between the series derived from the VAR (1) -BEKK GARCH (1,1) model are calculated. These correlation coefficients are found to be average 0.495 for Polish and Hungarian stock exchanges, 0.444 for Polish and Turkish stock exchanges, 0.314 for Polish and Ukrainian, and 0.313 for Polish and Romanian stock exchanpes. At the same time, correlations between Hungarian and Turkish, Hungarian-Ukrainian and Hungarian-Romanian are found to be 0.327, 0.227 and 0.303, respectively. Time-varying correlations between Turkish-Ukrainian and Turkish-Romanian are found to be 0.175 and 0.200 respectively. Finally, the correlation between the Ukrainian and Romanian stock exchanges is found to be 0.228. The correlation coefficients between the stock markets are given in Figure 3, 4 and 5.

Figure 4. Conditional Correlations Between Stock Markets

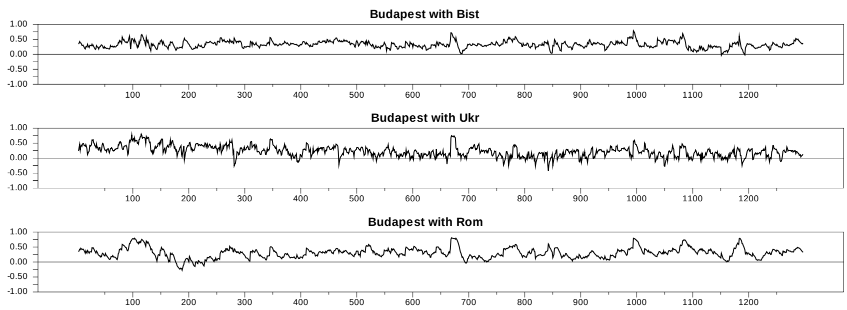
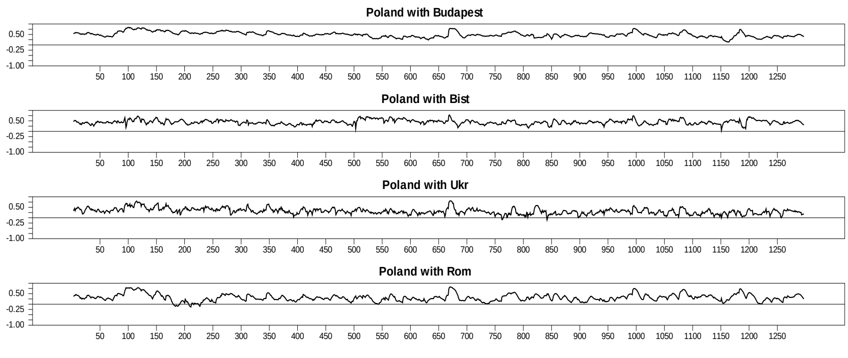


Figure 5. Conditional Correlations Between Stock Markets



CONCLUSION

In this study, the volatile transmission between Poland, Hungary and Romania stock markets located in Central and Eastern Europe and Turkey and Ukraine on the Black Sea cost are examined by BEKK-GARCH during period of 2011: 01-2016: 12.

As a result of the ADF unit root test, stock market is found to be stationary at I (1) level. This result indicated that series may be cointegrated. Johansen, Juselius (1990) cointegration test is applied and the series are found to be cointegrated. Then volatility transmission is examined for cointegrated series.

According to the results, Poland is affected indirectly by the Hungarian stock market, as well as by its own long-run volatility and Turkey's short-run shocks, while it is not directly or indirectly affected by short-run shocks of other markets including its own short-run shocks. On the one hand, the Hungarian stock market is directly and indirectly influenced by its own and the Polish stock market in the short-run. In addition, short-run shocks between Polish and Turkish stocks markets reduce the volatility in the Hungarian stock market. Long-run covariance between Hungarian and Romanian stock markets is reduced the volatility of Hungarian stock market. The Turkish stock market is directly and indirectly influenced by short-run shocks from the Polish and Hungarian stock markets as well as its own short-run shocks. In addition, the Romanian stock market directly and indirectly affects the Turkish stock market in the long-run. Ukrainian stock market is directly affected its short-run, indirectly the Hungary stock market in short-run. In the long run, the covariance between Polish and Ukrainian stock market and the covariance between Turkish and Hungarian stock markets affect the Ukraine stock market. Finally, Romanian stock market is directly affected by the Poland stock market and indirectle affected by the Turkish stock market in the short-run. In the long-run, the Polish and Turkish stock exchanges directly and indirectly affect the Romanian stock market. Finally, the majority of volatility in the country's stock markets is due to long-run volatility in its own stock market.

According to the empirical findings, there are direct and indirect relations between stock markets of the 5 countries. In this regards, these stock markets should be closely monitored by researchers and investors. In particular, the Polish and Turkish stock markets are in a dominant position influencing the stock markets of the countries under consideration. Undoubtedly, these two stock markets are more developed than the other countries in the sense of financial depth. In this context, financial agreements between the countries will contribute regional economy. This will reduce financial volatility and attract more investors to these countries.

FOOTNOTES

[1]Each return calculated as $R_{i,t+1} = 100 * \ln\left(\frac{P_{i,t+1}}{P_{i,t}}\right)$.

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