Are Volatility Transmissions between Stock Market Returns of Central and Eastern European Countries constant or dynamic? Evidence from MGARCH Models

Melik Kamışlı
Bilecik Şeyh Edebali University Bozüyük Vocational School, Department of Banking and Insurance, Bilecik, Turkey
melikkamisli@gmail.com

Serap Kamışlı
Anadolu University, Open Education Faculty, Eskişehir, Turkey
satbas@gmail.com

Mustafa Özer
Anadolu University, Faculty of Economics Administrative Sciences, Department of Economics, Eskişehir, Turkey
muozer@anadolu.edu.tr

Abstract
In this study, we try to identify the structure of conditional correlations between stock markets' returns of Central and Eastern European countries based on weekly data on stock market indexes of each nation in the sample over the period of 3rd week of September 2008 and 3rd week of August of 2015 by using Engle and Sheppard (2001) dynamic correlation model test. Based on our results, we observe that most of the conditional correlations between stock markets' returns of the nations are constant. Therefore, for modelling the volatility transmission between stock markets' returns of these nations, one has to use constant conditional correlation GARCH (CCC-GARCH) models over dynamic GARCH models. Also, this findings can provide useful information for the investors who are interested in investing money into the stocks of these markets, since having a constant conditional correlation between markets' returns can be taken as an indication of long term investments into these markets. Furthermore, the findings of the study have some implications about the selection of the stocks from the different markets based on the degree of the conditional correlation between markets.

Keywords: Volatility transmission, CCC-GARCH model, DCC-GARCH model, Engle and Sheppard test.

JEL classifications: C58, G11

Introduction

In this paper, we focus on analyzing the structure of conditional correlations among Central and Eastern European stock markets. It is widely believed that globalization has resulted in more integration of international financial markets and financial market participants are interested in knowing how shocks and volatility are transmitted across markets over time.

As stated in Walid et al. (2011), during the last two decades, emerging countries have experienced several crises, namely the stock market crash in 1987, the Asian currency crises in July 1997, the

Mexican currency crisis in 1994 and the subprime crisis of 2007–2008. Some of the key features of these "turbulent" episodes are large negative asset returns and high volatility and their effects have swiftly proliferated to other emerging economies. As Jayasuriya (2011) explained, global equity markets in general and regional markets in particular are often correlated with one another especially in times of financial crises when contagion and spillover effects are prominent.

Even in relatively calm periods, we may observe similar trending behavior across equity markets. As mentioned in Gupta and Guidi (2012), increased financial integration among stock markets in the world motivates international investors to look for new investment opportunities in order to improve risk adjusted returns for their portfolios. Stocks in different countries are exposed to different factors and as such by diversifying investments into international stocks investors get access to the factors that may not be represented in their domestic market.

A study of how interrelated equity markets are could provide useful insight for foreign investors who search for diversification opportunities abroad. This is because interlinkages of stock markets imply that markets tend to move together and, therefore, the potential gains from international diversification will be reduced. In fact, it is widely observed over the years that correlations among markets, both developed and developing, have increased due to reasons such as equity market liberalization policies and efficient information processing resulting from advancement in technology. Also, if a common group of investors' trade substantial amounts of money in two or more markets, their actions may lead to strong market correlations if investors engage in similar trade behavior.

Nevertheless, developing markets in emerging economies with relatively high and stable growth rates such as those in the East Asia and Pacific region and some markets in Central and Eastern Europe such as Turkey, Hungry, and Slovakia are often good choices for market participants looking to diversify their portfolios internationally. Therefore, foreign investor's interest is expected to be relatively high for these markets as the investment environment is often quite favorable for foreign participants. Therefore, the empirical study of volatility spillovers and the structure of conditional correlation across stock markets has been becoming interesting from the particular perspective of portfolio diversification and hedging strategies.

International stock market linkages have been extensively investigated on the grounds that the nature and extent of international linkages are most relevant to gauging the gains from international diversification of portfolio investments. While the earlier analyses have mainly focused on major developed markets, recent research has been extended to the linkages between emerging and developed markets on the understanding that benefits of international diversification rely increasingly on investment in emerging markets (Goetzmann et al. 2005).

Many developing economies have had policy changes to facilitate cross-country investment. Bekaert and Harvey (1997) show that such liberalizations policies often increase stock market correlation, a measurement of the extent of international linkages, decreasing the benefits of international diversification. Ng (2000), studies the market linkages between the six Pacific-Basin emerging economies and the US and Japan, finds that liberalization has an impact on the spillover effects from the US and Japan, but the effects vary from country to country and from event to event.

The volatility transmission mechanism across different markets are also studied by different articles including those by Hamao et al. (1990), King and Wadhwani (1990), Engle and Susmel (1993), King et al. (1994), Lin et al. (1994), Karolyi (1995) and Ramchand and Susmel (1998). However, most of these studies have focused on some specific financial markets. Booth et al. (1997) investigated volatility spillovers between Scandinavian stock markets. Kanas (1998) pointed out unidirectional and reciprocal volatility spillovers between major European countries. Christofi and Pericli (1999) and Chen et al. (2002) analyzed linkages between stock markets of Latin America. Fernandez-Izquierdo and Lafuente (2004) and In et al. (2001) examined volatility transmissions between Asian stock markets on the basis of Asian Crisis. As can be clearly seen from these studies, no serious work has been undertaken to study the structure of volatility transmission mechanism across stock markets in Central and Eastern Europe.

Knowing the structure of the conditional correlations, which is considered as a measure of the extent of market integration, across Central and Eastern European stock markets are important for financial participants especially when setting the optimal investment strategies and making the optimal portfolio allocation decisions, since different financial assets are traded based on these countries stock market's indexes. The purpose of this paper is to examine the structure of conditional correlations across the Central and Eastern European stock markets. In other words, the paper tries to explore whether the volatility spillovers are constant or dynamic across the pairs of stock markets under consideration. As mentioned in Majdoub and Mansour (2014), the empirical study of volatility spillovers is interesting from the particular perspective of portfolio diversification and hedging strategies. Indeed, as the empirical studies of Bekaert, et al. (2003) show that the international portfolio diversification is impaired by a high integration of international stock markets and correlated stock prices volatility. Therefore, to set the optimal investment strategies and construct the optimal portfolio, it is very important to start with determining whether conditional correlations among stock markets are constant and dynamic.

To do this, we carry out a test for constant versus dynamic correlation structure proposed by Engle and Sheppard (2001). Our findings suggest that most of the conditional correlations across the pairs of stock markets under consideration are constant. Therefore, for long-term investors in this countries have to take account of these findings when they construct their portfolios.

The layout of the paper is as follows. Section 2 describes the Constant and Dynamic Conditional Correlation Multivariate GARCH Models and Engle and Sheppard test. The description and study of data are given in Section 3. Section 4 discusses the test results and portfolio decisions and Section 5 concludes the empirical results.

The Constant and Dynamic Conditional Correlation Multivariate GARCH Models

Univariate autoregressive conditional heteroscedasticity (ARCH) and generalized ARCH (GARCH) models are commonly used to describe and forecast changes in volatility of (financial) time series. But, as mentioned in Arouri et al. (2011), when the objective is to investigate volatility interdependence and transmission mechanisms among different stock markets, multivariate setting such as the CCC-MGARCH model, the BEKK-MGARCH model or the DCC-MGARCH model are more relevant than univariate models.

The univariate GARCH models has been extended to multivariate GARCH recognizing that multivariate GARCH models are potentially useful developments regarding the parameterization of conditional cross-moments. Also, they allow to determine whether there is a volatility spillover from one investigated country to another. They measure time-varying conditional correlations across stock markets. They follow a univariate conditional volatility which can measure the short-run and long-run persistence of shocks to stock markets.

Different classes of MGARCH models have been proposed in the literature. They differ in the specification of the conditional variance matrix of a stochastic vector process. The Constant Conditional Correlation GARCH (CCC-GARCH) Model is developed by Bollerslev (1990) and based on the decomposition of the conditional standard deviations and correlations. In the CCC-GARCH model, the negative spillovers were ruled out by the assumption that all the parameters of the model are non-negative. Also, assuming that the correlations are constant makes the estimation of a large model possible and guarantees the positive definite estimator, by imposing the restriction of non-zero univariate conditional variance and full ranked correlation matrix. As mentioned in Chan et al. (2005), the CCC-GARCH model does not allow any volatility interdependencies across different markets and does not accommodate asymmetric behavior. But, the interactions between volatilities can be possible through contemporaneous constant correlation.

In the CCC-GARCH model, variances-covariances matrix $\mathrm{H_t}$ is assumed to be;

$$\{H_t\}_{ii} = h_{it}$$

$$\{H_t\}_{ij} = \sqrt{h_{ijt}} = p_{ij}\sqrt{h_{it}}\sqrt{h_{jt}} \quad i \neq j$$

$\mathrm{H_t}$ matrix is time-invariant and can be partitioned as;

$$\mathrm{H_t = D_t R D_t}$$

Where $\mathrm{D_t}$ is the $\mathrm{(NxN)}$ diagonal matrix that the diagonal elements are the conditional standard deviations, $\{H_t\}_{ij} = \sqrt{h_{ijt}}$ and R denote the matrix of conditional correlations with $(i,j)^{th}$ element being p_{ij} and $p_{ij} = 1$. Thus, the $(i,j)^{th}$ element of $\mathrm{H_t}$ is given as;

$$h_{ijt} = p_{ij}\sqrt{h_{iit}h_{jjt}}$$

To have a positive definite $\mathrm{H_t}$ for all t, each element of N conditional variances should be well defined and R has to be positive definite. Because of the diagonal structure, each variance behaves like a univariate GARCH model. In other words, the conditional variances of r_{it} processes, which is a certain linear combination of the vector of market returns, are similar to univariate GARCH(p,q) models (Chevallier, 2012).

$$h_t = \omega + \sum_{j=1}^{q} A_j r_{t-j}^2 + \sum_{j=1}^{p} B_j h_{t-j}$$

where ω is a Nx1 vector, A_j and B_j are diagonal NxN matrices, and $r_t^2 = r_t \otimes r_t$.
The bivariate CCC-GARCH model can be represented as follows:

$$\begin{bmatrix} h_{1t} \\ h_{2t} \end{bmatrix} = \begin{bmatrix} \omega_1 \\ \omega_2 \end{bmatrix} + \begin{bmatrix} \alpha_{11} & 0 \\ 0 & \alpha_{22} \end{bmatrix} \begin{bmatrix} \varepsilon_{1t-1}^2 \\ \varepsilon_{2t-1}^2 \end{bmatrix} + \begin{bmatrix} \gamma_1 \\ 0 \end{bmatrix} \begin{bmatrix} S_{t-1}^{-} \varepsilon_{1t-1}^2 \\ \varepsilon_{2t-1}^2 \end{bmatrix} + \begin{bmatrix} \beta_{11} & 0 \\ 0 & \beta_{22} \end{bmatrix} \begin{bmatrix} h_{1t-1} \\ h_{2t-1} \end{bmatrix}$$

To get a positive conditional variance in CCC-GARCH model, we simply assume that the coefficients of each equation satisfy the conditions derived in Nelson and Cao (1992) and Glosten et al. (1993).

As indicated in Kuper and Lestano (2007) and Gjika and Horvath (2013), since the assumption of CCC-GARCH model that the conditional correlations are constant may seem unrealistic in many empirical applications, Engle (2002) proposes the dynamic conditional correlation (DCC) model that is a direct generalization of the constant conditional correlation model of Bollerslev (1990) by making the conditional correlation matrix time dependent.

In DCC-GARCH model, time variant the conditional covariance matrix H_t can be decomposed as;

$$H_t = D_t R_t D_t$$

where R_t is the NxN time-varying correlation matrix and D_t is the NxN diagonal matrix of time-varying standard deviations from univariate GARCH models with $\sqrt{h_{it}}$ as the i_{th} element of the diagonal. The standard deviations in D_t are obtained from the following univariate GARCH (P,Q) process:

$$h_{it} = \omega_i + \sum_{p=1}^{P_i} \alpha_{ip} \varepsilon_{it-p}^2 + \sum_{q=1}^{Q_i} \beta_{iq} h_{it-q}$$

where α_{ip} represents the ARCH effects (or the short-run persistence of shocks to market return) and β_{iq} represents the GARCH effects (or the contribution of shocks to market return to long-run persistence).

When the conditions of non-negativity of the parameters and stationarity of the variances are satisfied, H_t will be positive definite for all t. The correlation dynamics can be written as follows:

$$Q_t = \left(1 - \sum_{m=1}^{M} \alpha_m - \sum_{n=1}^{N} \beta_n\right) \bar{Q} + \sum_{m=1}^{M} \alpha_n \left(\varepsilon_{t-m} \varepsilon_{t-m}'\right) + \sum_{n=1}^{N} \beta_n \, Q_{t-n}$$

$$R_t = Q_t^{*-1} Q_t Q_t^{*-1}$$

where $\varepsilon_t = D_t^{-1} r_t$ is the vector of standardized returns and $\bar{Q}$ is the unconditional covariance of the standardized residuals resulting from the first stage estimation and Q_t^* is a diagonal matrix composed of the square root of the diagonal elements of Q_t. The elements of R_t will be of the form, $p_{ijt} = q_{ijt} / \sqrt{q_{iit} q_{jjt}}$ where q_{ijt}, q_{iit} and q_{jjt} are the elements of Q_t corresponding to the indices. As mentioned Gjika and Horvath (2013), the covariance matrix H_t is positive definite as long as R_t is positive definite and the univariate GARCH models are correctly specified.

Furthermore, R_t is positive definite if and only if Q_t is positive definite.

Engle and Sheppard (2001) propose a test[1], which is a test for dynamic correlation model, to determine the nature of conditional correlations among the stock market indexes. Their test only requires consistent estimate of the constant conditional correlation, and can be carried out using a vector autoregression. The test for dynamic correlation model test the presence of dynamic correlation in the residuals of the DCC(1,1) MGARH model.

To carry out the Engle and Sheppard's test, first, we estimate the univariate GARCH model and obtain the standardized residuals for each series. Secondly, estimate the correlation of the standardized residuals, and jointly standardized the vector of univariate standardized residuals by the symmetric square root decomposition of $\bar{R}$. Thirdly, state the null and alternative hypotheses of the constant correlation against the alternative of dynamic conditional correlation as;

$$H_0: R_t = \bar{R} \quad \forall t \in$$
$$H_A: vech(R_t) = vech(\bar{R}) + \beta_1 vech(R_{t-1}) + \cdots + \beta_p vech$$

Under the null of constant correlation, the standardized residuals should be IID with the variance covariance matrix unit diagonal I_k. The artifcial regression will be a regression of the outer products of the residuals on a constant and lagged outer products. Let

$$Y_t = vech^u\left[\left(\bar{R}^{-1/2} D_t^{-1} \varepsilon_t\right)\left(\bar{R}^{-1/2} D_t^{-1} \varepsilon_t\right)' - I\right]$$

where $\left(\bar{R}^{-1/2} D_t^{-1} \varepsilon_t\right)$ is a kx1 vector of residuals jointly standardized under the null, and $vech^u$ is a modified vech which only selects elements above the diagonal. The vector autoregression is;

$$Y_t = \alpha + \beta_1 Y_{t-1} + \cdots + \beta_s Y_{t-s} + \eta_t$$

Under the null hypothesis, the constant and all the lagged parameters in the model should be zero. Therefore, rejection of the null of a constant correlation implies a dynamic structure. The test statistics has chi-square distribution with s+1 degrees o freedom.

Data and preliminary analysis

The data used in this study are weekly stock market indices in Central and Eastern European countries for the period from 3rd week of September 2008 to 3rd week of August of 2015. Since, according to Arouri et al. (2011), weekly data appear to capture the interactions among stock markets, we prefer to use weekly data. The data are extracted from DataStream. As suggested by Gupta and Guidi (2012), all indices are in domestic currency in order to avoid problems associated with transformation due to fluctuations in exchange rates.

[1] Obviously, there are some other tests for constant conditional correlations in MGARCH models. For further information see McCloud and Hong (2010).

Table 1: Descriptive statistics for weekly equity market returns

	Mean	Median	Maximum	Minimum	Std. Dev.	Skewness	Kurtosis	Jarque-Bera	ARCH
Greece(ATG)	-0.0045	-0.0004	0.1756	-0.2254	0.054	-0.3892	4.1281	28.26*	20.38*
Macedonia(MBI10)	-0.0028	-0.0019	0.1424	-0.2038	0.031	-0.9096	12.2711	1342.66*	7.08*
Slovenia(SBITOP)	-0.0019	-0.0017	0.0925	-0.1925	0.028	-1.3199	12.6715	1511.80*	16.65*
Croatia(CRBEX)	-0.0017	-0.0007	0.1419	-0.2948	0.032	-2.4105	27.7206	9541.65*	22.36*
Bulgaria(SOFIX)	-0.0017	-0.0002	0.1490	-0.2500	0.033	-1.6610	16.2590	2810.34*	32.23*
Serbia(BELEX15)	-0.0016	0.0006	0.1826	-0.2961	0.038	-1.1410	15.6467	2484.09*	24.28*
Slovakia(SAX)	-0.0016	0.0000	0.1225	-0.1515	0.026	-0.9782	9.6490	722.56*	0.14
Russia(IRTS)	-0.0015	-0.0001	0.3419	-0.2373	0.057	-0.1455	8.6624	483.56*	74.02*
Austria(ATX)	-0.0009	0.0018	0.1723	-0.3413	0.042	-1.8182	16.2486	2839.09*	4.70**
Czech Republic(PX)	-0.0008	0.0006	0.1557	-0.3045	0.036	-1.6105	19.0562	4033.81*	3.85***
Poland(WIG20)	-0.0003	0.0008	0.1601	-0.1664	0.032	-0.5206	7.8598	371.55*	66.35*
Latvia(OMXRGI)	0.0000	0.0007	0.1237	-0.1392	0.027	-0.8204	10.6114	911.90*	18.90*
Ukraine(UAX)	0.0002	-0.0025	0.2320	-0.2768	0.055	-0.2472	7.1241	259.51*	13.45*
Hungary(BUX)	0.0004	0.0005	0.1516	-0.2689	0.038	-1.0670	11.5228	1161.10*	11.71*
Lithuania(OMXVGI)	0.0008	0.0014	0.2483	-0.2076	0.030	0.0790	22.7551	5870.61*	2.79***
Romania(BETI)	0.0012	0.0017	0.1055	-0.3152	0.038	-2.4292	20.0677	4736.76*	2.71
Estonia(OMXTGI)	0.0016	0.0002	0.1597	-0.1542	0.032	-0.0892	9.6111	657.90*	4.26**
Turkey(XU100)	0.0020	0.0051	0.1576	-0.1927	0.038	-0.4992	5.9444	145.40*	37.23*

Table 1 provides wide range of descriptive statistics for all market returns. All market return series have small mean (less than 0.5% in absolute value) with a mixed sign. The stock market in Turkey has the highest average return (0.20%), followed by Estonia (0.16%). As indicated in Özer (2015), beginning in the early 2000's, net capital flows to Turkey increased substantially in line with the increasing current account deficits. Also, the abundant global liquidity and real interest rate differentials contributed to this development. As is explained in Clark et al. (2012) and Özer (2015), major developed country central banks have significantly increased the liquidity available in their economies. This has led to very low domestic interest rates and driven down world interest rates. The result has been a large investor appetite for relatively higher yielding assets in other parts of the world, particularly in countries with a sound macroeconomic environment and demonstrating strong economic performance such as Turkey. These factors have driven down the real interest rates that borrowers in these economies need to pay and have allowed Turkey to borrow abroad for investment and consumption relatively cheaply. FDI inflows, which are long-term and relatively stable, comprised a significant portion of capital inflows earlier in the decade. But, after 2004, the profile of net capital flows to Turkey changed dramatically. While in the mid-2000s flows were driven by large increases in FDI and other investment (largely loans to the non-banking sector), following the 2008/09 financial crisis flows shifted predominantly towards portfolio investment and FDI was more subdued. In the post crisis period there was a return to high "other investment" inflows (which are short-term in nature), driven by loans to the banking sector. In other words, after the 2008/09 financial crisis, shorter-term portfolio and other investments have become relatively more important. Thus, increasing investment of foreigners into stock market of Turkey (the portion of foreign investors in stock market of is approximately 65% as of end August 2015) caused the rise in stock prices.

Most of the stock markets of European Union member countries in the sample have negative average returns during examination period, mostly because of the effects of recent global crises and Eurozone turmoil.

The standard deviations of market returns are much greater than the means in absolute value, indicating that the means are not significantly different from zero (Ding and Vo (2012)). This is consistent with common knowledge that financial time series at this frequency usually follow a random walk. Russia market returns post the highest volatility (5.57%), followed just after Ukraine (5.47%) and Greece (5.44%). This high volatility of stock markets results from the that fact that there is an ongoing conflict between Russia and Ukraine which causes international investors flight from these countries, the sanctions imposed on Russia by international community and vulnerability of Russia stock market to global shocks. Also, because of the economic problems that Greece has been facing with as a result of the recent global economic crises and Eurozone turmoil, Greek default fear and pressure of the troika makes the Greece stock market more volatile. Slovakia has the lowest volatility (2.64%). Also, Russia has the highest spread ranging between – 0.24 and 0.34. Interestingly, Austria is ranked second with a spread ranging from −0.34 and 0.17. Ukraine is third ranked with a spread ranging from −0.28 and 0.23. This means that the Russia market undergoes large fluctuations compared to the other markets, seeing it has the most extreme values. Skewness coefficients are all negative except for Lithuania (OMXVGI). Kurtosis coefficients are significantly greater than three. In other words, the excess kurtosis for each is significantly positive, indicating that they have heavy tails relative to the normal distribution, which is also typical in these financial data. Skewness and kurtosis values indicate that the distributions of returns for all the market returns are negatively skewed and leptokurtic. These findings indicate that the distributions of almost all market return series are typically asymmetric, and that the probability of observing large negative returns is higher than that of a normal distribution. As a result, the Jarque–Bera test statistics (JB) clearly confirm the rejection of the null hypothesis of normality for all return series. Finally, we find strong evidence of ARCH effects for almost series considered except for Slovakia (SAX) and Romania (BETI), which thus supports our decision to employ a GARCH modeling approach to examining volatility transmission between oil and stock markets.

As is well known, asset allocation and risk assessment rely on the analysis of stock market correlations. In the context of the modern portfolio theory, diversification is considered as a powerful tool to reduce the risk of a portfolio associated with the volatility and covariability of its constituent assets. One way of implementing diversification is to allocate assets between various stock markets and/or industries. As mentioned in Yang et al. (2006), the correlation of market returns of different stock markets can be interpreted as an indicator of the comovement of markets. Thus, a higher positive correlation means a higher level of comovement between the markets which implies that it is more difficult to diversify portfolio risk by investing in these markets.

As we mentioned in introduction, due to the globalization, equity markets are often correlated with one another especially in times of financial turmoil. But correlations can also be high in calm periods too. We have in fact observed over the years that correlations among markets, both developed and developing, have increased due to reasons such as equity market liberalization policies and efficient information processing resulting from advancement in technology. If a common group of investors trade substantial amounts of money in two or more markets, their actions may lead to strong market correlations if investors engage in similar trade behavior. For example, trade decisions to buy or sell certain stock may often be synchronized for a common set of investors and their coordinated actions may even be intensified during global or regional shocks because of investor herd behavior. This intuition provides the basis for our idea that the behavior of a common group of investors may be an underlying factor for interlinkages identified in foreign equity markets where these investors actively engage in trading shares. Table 2 presents the unconditional correlations of market returns presented.

Table 2: Unconditional correlations of market returns

	ATG	ATX	BELEX15	BETI	BUX	CRBEX	IRTS	MBI10	OMXRGI	OMXTGI	OMXVGI	PX	SAX	SBITOP	SOFIX	UAX	WIG20	XU100
ATG	1.00																	
ATX	0.57	1.00																
BELEX15	0.27	0.29	1.00															
BETI	0.37	0.57	0.30	1.00														
BUX	0.40	0.57	0.16	0.47	1.00													
CRBEX	0.32	0.41	0.33	0.42	0.31	1.00												
IRTS	0.43	0.62	0.19	0.45	0.51	0.36	1.00											
MBI10	0.18	0.20	0.34	0.27	0.14	0.22	0.14	1.00										
OMXRGI	0.12	0.18	0.21	0.28	0.15	0.21	0.17	0.17	1.00									
OMXTGI	0.27	0.37	0.29	0.32	0.28	0.38	0.28	0.19	0.35	1.00								
OMXVGI	0.27	0.38	0.31	0.33	0.36	0.34	0.36	0.21	0.35	0.57	1.00							
PX	0.52	0.77	0.30	0.54	0.58	0.36	0.54	0.17	0.21	0.34	0.37	1.00						
SAX	0.06	0.04	0.09	0.08	0.05	0.06	0.01	0.06	0.03	0.15	0.18	0.08	1.00					
SBITOP	0.28	0.34	0.32	0.34	0.29	0.32	0.22	0.23	0.11	0.25	0.25	0.30	0.09	1.00				
SOFIX	0.20	0.25	0.27	0.24	0.25	0.24	0.22	0.18	0.18	0.22	0.29	0.28	0.06	0.22	1.00			
UAX	0.39	0.46	0.24	0.36	0.37	0.34	0.44	0.20	0.14	0.30	0.29	0.42	0.18	0.29	0.20	1.00		
WIG20	0.47	0.58	0.18	0.42	0.54	0.30	0.59	0.11	0.20	0.25	0.35	0.60	0.05	0.27	0.19	0.42	1.00	
XU100	0.41	0.50	0.09	0.32	0.46	0.26	0.49	0.08	0.11	0.23	0.24	0.45	0.06	0.20	0.11	0.28	0.50	1.00

Based on the unconditional correlations in Table 2, we can say that all the market returns are positively related to one another indicating that all the country stock markets have been moving in the same direction (up or down) during the sample period. The unconditional correlations vary substantially across markets: from 0.01 (Slovakia and Russia) to 0.77 (Czech Republic and Austria). But, on average, even though there are few high correlations, mostly between European member countries, such as Czech Republic, Austria, Greece, Hungary and Poland the values are weak for the other both member of European Union and non-member countries in the sample, such as Macedonia, Latvia, Bulgaria and Slovakia. The weak and positive values of correlations suggest that, in theory, that there is little short or long-term benefit to diversifying over across markets.

Results[2] and portfolio implications

In this section, we first try to examine the structure of conditional correlations across stock markets and then we discuss portfolio implications of the results.

The correlation analysis that we done above, is one of the most commonly used analysis to determine degree of integration across stock

[2] To shorten the article, only structure of the conditional correlations are given and the rest of the empirical results are not given. But, they are available upon request.

markets. But, since the traditional correlation analysis does not take into account of time varying structure of volatility, investors have to be careful about using this method especially the volatility of stock markets are high. Therefore, to capture the interactions among markets, one has to use the conditional correlation obtained from multivariate GARCH models. Also, since different financial assets are traded based on these market indexes, it is important for financial participants to understand the volatility transmission mechanism over time and across stock markets in order to make optimal portfolio allocation decisions.

Table 3 presents the structure of Conditional Correlations of markets' returns based on the Engle and Shepard test.

Table 3: The structure of conditional correlations of market returns

	ATG	ATX	BELEX15	BETI	BUX	CRBEX	IRTS	MBI10	OMXRGI	OMXTGI	OMXVGI	PX	SAX	SBITOP	SOFIX	UAX	WIG20	XU100
ATG	-																	
ATX	CCC	-																
BELEX15	CCC	CCC	-															
BETI	CCC	DCC	CCC	-														
BUX	CCC	DCC	CCC	DCC	-													
CRBEX	CCC	DCC	DCC	CCC	DCC	-												
IRTS	DCC	DCC	CCC	DCC	DCC	DCC	-											
MBI10	CCC	DCC	CCC	CCC	CCC	DCC	CCC	-										
OMXRGI	CCC	DCC	DCC	CCC	CCC	DCC	CCC	CCC	-									
OMXTGI	CCC	CCC	DCC	CCC	CCC	DCC	CCC	DCC	CCC	-								
OMXVGI	CCC	DCC	DCC	DCC	CCC	DCC	CCC	DCC	CCC	DCC	-							
PX	CCC	CCC	CCC	DCC	DCC	DCC	CCC	CCC	DCC	CCC	DCC	-						
SAX	CCC	DCC	CCC	CCC	DCC	CCC	DCC	CCC	CCC	CCC	CCC	CCC	-					
SBITOP	CCC	DCC	DCC	CCC	CCC	DCC	CCC	DCC	DCC	DCC	DCC	DCC	CCC	-				
SOFIX	CCC	DCC	DCC	DCC	CCC	DCC	CCC	DCC	DCC	DCC	DCC	DCC	CCC	DCC	-			
UAX	DCC	DCC	CCC	DCC	DCC	CCC	DCC	CCC	CCC	CCC	CCC	DCC	DCC	CCC	CCC	-		
WIG20	DCC	CCC	CCC	CCC	DCC	CCC	DCC	CCC	CCC	CCC	CCC	CCC	DCC	CCC	CCC	CCC	-	
XU100	DCC	CCC	CCC	CCC	DCC	CCC	DCC	CCC	CCC	CCC	CCC	DCC	DCC	CCC	CCC	CCC	DCC	-

According to results in Table 3, most of the conditional correlations between countries are constant (10 out of 18) implying that neither recent global crises nor Eurozone turmoil nor country specific developments haven't caused any structural shift in the volatility transmission between these countries. Therefore, we can suggest to the investors, who are especially intending to hold their portfolios for the long time and not intending to revise their positions based short-term developments, can include the lower correlated stocks from these markets. Conditional correlations obtained from CCC-GARCH models are given in Table 4.

Table 4: Estimated constant conditional correlations

	ATG	ATX	BELEX15	BETI	BUX	CRBEX	IRTS	MBI10	OMXRGI	OMXTGI	OMXVGI	PX	SAX	SBITOP	SOFIX	UAX	WIG20	XU100
ATG	-																	
ATX	0.58	-																
BELEX15	0.28	0.34	-															
BETI	0.40	0.61	0.35	-														
BUX	0.41	0.62	0.22	0.52	-													
CRBEX	0.31	0.47	0.40	0.49	0.40	-												
IRTS	0.44	0.61	0.25	0.45	0.54	0.40	-											
MBI10	0.23	0.30	0.33	0.34	0.27	0.34	0.22	-										
OMXRGI	0.17	0.26	0.22	0.31	0.22	0.27	0.28	0.19	-									
OMXTGI	0.28	0.45	0.30	0.44	0.36	0.42	0.36	0.27	0.44	-								
OMXVGI	0.25	0.38	0.28	0.30	0.34	0.36	0.37	0.25	0.43	0.56	-							
PX	0.52	0.79	0.34	0.59	0.65	0.45	0.55	0.25	0.26	0.41	0.35	-						
SAX	0.07	0.14	0.11	0.15	0.08	0.11	0.04	0.13	0.02	0.17	0.16	0.12	-					
SBITOP	0.32	0.40	0.34	0.39	0.35	0.43	0.28	0.27	0.18	0.30	0.21	0.37	0.13	-				
SOFIX	0.21	0.31	0.30	0.31	0.29	0.28	0.20	0.27	0.24	0.32	0.28	0.30	0.12	0.30	-			
UAX	0.40	0.46	0.25	0.41	0.40	0.39	0.48	0.28	0.17	0.32	0.24	0.44	0.22	0.35	0.26	-		
WIG20	0.48	0.60	0.24	0.45	0.60	0.34	0.60	0.17	0.26	0.33	0.32	0.63	0.09	0.30	0.20	0.43	-	
XU100	0.41	0.53	0.17	0.38	0.48	0.29	0.45	0.17	0.17	0.28	0.23	0.48	0.12	0.27	0.17	0.30	0.53	-

Based on the results in Table 4, roughly, we observe the same correlations across markets. However, there is a slight increase in the values of constant conditional correlations for almost all countries, except for Lithuania.

According to Gupta and Guidi (2012), in the context of the modern portfolio theory, the portfolio diversification could provide some benefits to an investor who include assets that have lower correlations in the portfolio knowing the fact that diversification is a powerful tool to reduce the risk of a portfolio. Main reason why people invest in portfolio is to seek to reduce risk associated with the volatility and covariability of its constituent assets. Best way to make an efficient diversification is to include the assets that have low and negative correlations. Also, as pointed out in Grubel (1968) and Levy and Sarnat (1970), incentives for investing into international markets result from lower correlations between asset returns as compared with that of the domestic assets. To reduce the risk of a portfolio through international diversification, investors need to know the interactions and volatility transmissions among stock markets. Recently, most of the investors believe that because of the increased integration of world stock markets, the correlations between the returns of the developed markets have increased. Therefore, investors looked at the emerging markets for exploiting benefits of international diversification in the belief that correlations both between developed markets and emerging markets and between the emerging markets will be lower. Interdependence (in diversification literature measured as correlations) among these markets may affect the scope for diversification possibilities. As Kearney and Lucey (2004) conclude, when correlations increase the apparent benefits of diversification into emerging markets potentially diminishes.

Some of the stock market investors prefer short-term investment and others don’t. Some of them try to enjoy making more profit from price fluctuations by constantly buying and selling the securities. For the investor especially intending to invest money into international stock markets, knowing whether there is constant and dynamic correlations between the markets becomes extremely important. If there is dynamic relation between the markets, investors should watch developments in the markets as well as dynamics of the relationship closely during the investment period. On the other hand, an investor, who is intend to make long-term investment and is not willing to make changes in his/her portfolio, has to pick stocks that have low and /or negative correlations to benefit from international diversification. Thus, based on the results of the study, it seems that these stock markets' interactions will help the investors who are planning to make long-term investment to reduce their risks by investing stocks of the markets in the sample countries.

Conclusion

This paper examined the structure of conditional correlations across stock markets of Central and Eastern European countries based on weekly data on stock market indexes of each nation in the sample over the period of 3rd week of September 2008 and 3rd week of August of 2015 by using Engle and Sheppard (2001) dynamic correlation model test.

Generally speaking, our results show that most of the conditional correlations among stock markets are constant, therefore, to model the volatility transmission between these stock markets, CCC-GARCH model should be preferred. Also, the findings of this study could be interpreted as saying that markets do interact with each other in terms of shocks and volatility. This finding points to the presence of cross-market hedging and sharing of common information by investors in these markets. This implies that the investors who are interested in long term investment on these markets should select stock from the markets that have constant conditional correlations. On the other hand, the investors who are interested in short term investment on these markets should focus on stocks from the markets that have dynamic conditional correlations.

Our findings have several economic and financial management implications. Firstly, portfolio managers and hedgers may be better able to understand the interlinkages between stock markets. Secondly, such results may be helpful for policy makers from a financial stability perspective, providing governments and central banks with insights into volatility spillovers between stock markets. Finally, results may also allow one to assess the level of emerging stock market informational efficiency.

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