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Abstract

The growing interdependencies among capital markets are becoming significant factor affecting process of risk management both at macro and microeconomic level. Thus, the aim of the article is the analysis of interdependencies among capital markets of Germany, Poland and Baltic States. In order to measure the interdependencies DCC-GARCH model was applied. The research was conducted for the years 2004-2015. The capital market of Germany was taken as the one that has the biggest influence on the analysed Central and Eastern European markets. The conducted research enabled to determine the different nature of the interdependencies among the capital markets of Baltic States and Poland on one side and German capital market on the other side.

Key words

capital market, conditional variance, conditional correlation, DCC-GARCH model, integration

JEL Classification: G15, C58

1. Introduction

Last global financial crisis has confirmed the importance of interdependencies among economies. The interdependencies in real sphere can lead to transition of shocks in the case of all aspects of socio-economic life such as labour markets and human capital (Müller-Frączek & Pietrzak 2011; Gajdos, 2012; Wilk *et al*., 2013; Biczkowski *et al*., 2014; Pietrzak & Balcerzak 2016, Balcerzak, 2016a; Balcerzak & Pietrzak, 2016a; 2016b), sustainability of economies (Balcerzak & Pietrzak, 2016c; Pietrzak & Balcerzak, 2016b), international trading positions of countries and their technological potential (Balcerzak & Pietrzak, 2016c, Balcerzak, 2016b, Pietrzak & Łapińska, 2015; Vitunskiene & Serva, 2015; Łapińska, 2016), institutional order (Balcerzak, 2009; 2015; Balcerzak & Pietrzak, 2015a, 2015b, 2016d), and last but not least macroeconomic financial stability of countries (Mackiewicz-Łyziak, 2015; Balcerzak & Rogalska, 2016; Balcerzak *et al*., 2016). However, in recent decades the empirical research have confirmed that the most significant interdependencies among economies can be found in the case of capital markets (Forbes & Rigobon, 2002, Pericoli & Sbracia, 2003; Billio & Caporin, 2010, Fałdziński *et al.*, 2012; Heryán & Ziegelbauer, 2016; Pietrzak et al., 2017). As a result, the research devoted to the factors that can destabilise groups of capital markets and finding the transmission channels of potential disturbances is crucial for risk management (Baur, 2003; Corsetti *et al*., 2005; Engle 2009; Zinecker *et al*., 2016).

The main aim of the article is the analysis of interdependencies among capital markets of Poland, Baltic States and Germany. The research was conducted for the years 2004-2015. The

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first year of the study was chosen as it was the year of the biggest enlargement of the European Union, which significantly increased the interrelations among analysed economies. The last year of the research was restricted by the availability of data for the whole group of market indices. In order to verify the interdependencies DCC-GARCH model was applied.

In the research two hypotheses were proposed. According to the first one, there is a low level of interdependencies among capital markets of Baltic States and Germany. In the second hypothesis the existence of different mechanisms of reactions of capital markets of Baltic States and Poland to shocks coming from German market is assumed.

2. Methodology

An observation of periods of significantly increased and reduced volatility of capital markets prompted the researchers to introduce GARCH class models (Engle & Bollerslev, 1986). GARCH models allowed estimating the conditional variance for individual assets or indices. The methodology of GARCH models has been extended to the multi-dimensional case, which allowed inclusion of interdependencies among indices (Faldzinski & Pietrzak, 2015; Fałdziński *et al.*, 2016). DCC-GARCH model is an example of multi-dimensional model, which allows describing interdependencies between markets by estimating the conditional correlation (Engle 2002). In DCC-GARCH model the conditional variance depends on the lagged conditional variances and the square returns with the consideration of conditional means. In the case of a conditional correlation equation the standardized residuals from the variance equation and lagged conditional correlations make the describing variables. The estimation of the parameters of DCC-GARCH model can be done with application of the maximum likelihood method (Engle in 2002, 2009). In that case the two-step estimation method is the most commonly used. It assumes a separate estimation of the parameters of conditional variance equation and means. Then, on the basis of the obtained estimates of parameters, the parameters of conditional correlation equation are obtained (Fałdziński & Pietrzak, 2015). DCC-GARCH model can be written as follows:

$$\mathbf{Y_t} = \boldsymbol{\mu_t} + \boldsymbol{\eta_t}, \ \ \boldsymbol{\eta_t} \mid \mathrm{F}_{t-1} \sim t(0, \mathbf{D_t}\mathbf{R_t}\mathbf{D_t}, v), \tag{1}$$

$$\mathbf{D_t^2} = diag\{\mathbf{H_t}\}, \ \mathbf{H_t} = \mathbf{V_{t\text{-}1}}(\boldsymbol{\eta_t}), \ \mathbf{H_t} = \boldsymbol{\omega_i} + \boldsymbol{\alpha_i}\boldsymbol{\eta}^2_{\mathbf{i,t\text{-}1}} + \boldsymbol{\beta_i}\mathbf{H_{i,t\text{-}1}}, \ \boldsymbol{\varepsilon_t} = \mathbf{D_t^{-1}}\boldsymbol{\eta_t} \tag{2}$$

$$\mathbf{R_t} = diag\{\mathbf{Q_t}\}^{-1/2}\mathbf{Q_t}diag\{\mathbf{Q_t}\}^{-1/2}, \ \mathbf{Q_t} = \boldsymbol{\Omega} + \alpha\boldsymbol{\varepsilon}_{\mathbf{t\text{-}1}}\boldsymbol{\varepsilon}'_{\mathbf{t\text{-}1}} + \beta\mathbf{Q_{t\text{-}1}}, \ \boldsymbol{\Omega} = \bar{\mathbf{R}}(1-\alpha-\beta), \tag{3}$$

where: $\mathbf{Y_t}$ - the multivariate process of returns, $\boldsymbol{\mu_t}$ - the vector of conditional means of returns, $\mathbf{H_t}$ - the conditional variance matrix for *i*-th returns, $\mathbf{R_t}$ - the time-varying conditional correlation matrix, $\mathbf{V_{t\text{-}1}}(\boldsymbol{\eta_t})$ - the covariance matrix of the residuals $\boldsymbol{\eta_t}$, $\boldsymbol{\omega_i}, \boldsymbol{\alpha_i}, \boldsymbol{\beta_i}$ - the parameters of the conditional variance equation, α, β - the parameters of the conditional correlation equation, $\bar{\mathbf{R}} = \frac{1}{T}\sum_{i=1}^{T}\boldsymbol{\varepsilon_t}\boldsymbol{\varepsilon_t}'$ - the unconditional covariance matrix.

After estimating conditional correlation the next step in the research can be an analysis of order of integration for conditional correlation for pairs of selected indices. To measure the order of integration of stochastic processes in 1979 Dickey and Fuller proposed the unit root test DF. Its statistics is correct only if the stationary process is a AR(1) process (see Dickey & Fuller, 1979). Then, Phillips and Perron (1988) provided a method of solving the problem of autocorrelation of higher orders in the case of testing non-stationarity (see Phillips & Perron, 1988). They modified the DF statistics in such way that the autocorrelation of higher order does not affect the asymptotic distribution of the test statistic. In the first step of the procedure for the Phillips and Perron test it is assumed in the null hypothesis that the process is non-stationary of order 1 at least. Rejection of the null hypothesis results in the statement that the

process is stationary, ie. an integrated of order 0. In the case of the absence of evidence allowing rejecting the null hypothesis, the test is repeated for the first differences of the process. In the null hypothesis it is assumed that the process is non-stationary of order 2 at least, and in the alternative hypothesis that the process is non-stationary of order 1. Appling the test is continued until the rejection of the null hypothesis.

3. Analysis of interdependencies among markets of Lithuania, Latvia, Estonia, Poland and German capital market

In the conducted empirical research time series for five indices were uses: (OMX Riga, OMX Tallinn, OMX Vilnius, WIG and DAX). For all the indices a daily rates of return in the period 02.01.2004–02.0.2015 were assessed. The year 2004 was chosen because of the accession of the Baltic States and Poland to the European Union. This factor has influenced significantly the development of capital markets in these countries (Meluzin & Zineker, 2016) and could also affect the interdependences among the markets. Therefore, the research for this period seems to be justified by the existence of similar institutional conditions for the functioning of the capital markets of selected countries.

The study began by estimating parameters of DCC-GARCH model. For this purpose the maximum likelihood method with a conditional normal distribution was applied. In the first step separate estimation of the parameters of the conditional variance equation and means was performed, where AR(p)-IGARCH(p,q) model was assumed for all the indices. The analysis of the indices indicated a maximum degree of autoregression equal to one. In addition, preliminary estimation of the volatility models indicated IGARCH model the best fit for all the indices. Therefore, for all the indices the following specification of AR(1)-IGARCH (1,1) model was made:

$$\mathbf{y}_t = \gamma_0 + \gamma_1 y_{t-1} + \eta_t, H_t = \omega_0 + \alpha_1 \eta_{t-1}^2 + \beta_1 H_{t-1},$$

where the sum of parameters α_1 and β_1 equals to 1.

According to the two-step maximum likelihood method in the second step the parameters of the conditional correlation equation were estimated. The results are presented in Table 1. In the case of the conditional mean equations parametr γ_1 was statistically insignificant only for the German capital market. In the case of the conditional variance equations and conditional correlation in DCC-GARCH model for all the indices all the parameters α1 and β1 were statistically significant at the 5% significance level.

Table 1: The results of the estimation of the DCC-GARCH model

The conditional variance equation					
Parameter (stock index)	**Estimate**	**p-value**	**Parameter (stock index)**	**Estimate**	**p-value**
γ_0 (OMX RIGA)	0.058	~0.00	γ_0 (WIG)	0.085	0.005
γ_1 (OMX RIGA)	-0.094	~0.00	γ_1 (WIG)	0.071	~0.00
ω_1 (OMX RIGA)	0.015	0.061	ω_1 (WIG)	0.008	0.007
α_1 (OMX RIGA)	0.089	~0.00	α_1 (WIG)	0.074	~0.00
β_1 (OMX RIGA)	0,911	-	β_1 (WIG)	0.926	-
γ_0 (OMX TALLINN)	0.022	0.182	γ_0 (DAX)	0.081	~0.00

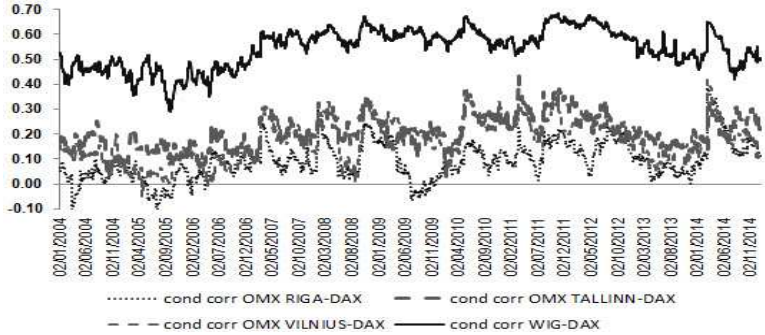
γ_1 (OMX TALLINN)	0.143	~0.00	γ_1 (DAX)	-0.007	0.707
ω_1 (OMX TALLINN)	0.013	~0.00	ω_1 (DAX)	0.018	0.006
α_1 (OMX TALLINN)	0.138	~0.00	α_1 (DAX)	0.109	~0.00
β_1 (OMX TALLINN)	0.862	-	β_1 (DAX)	0.891	-
γ_0 (OMX VILNIUS)	0.066	~0.00			
γ_1 (OMX VILNIUS)	0.138	~0.00	**The conditional correlation equation**		
ω_1 (OMX VILNIUS)	0.015	0.212	**Parameter**	**Estimate**	**p-value**
α_1 (OMX VILNIUS)	0.116	0.049	α	0.011	~0.00
β_1 (OMX VILNIUS)	0.884	-	β	0.977	~0.00

Source: own estimation.

DCC-GARCH model allows the measurement of the strength of interdependencies among analysed capital markets by means of the conditional correlations. The estimation of the parameters of DCC-GARCH model allowed to determine the value of the conditional correlation for the next pairs of indices. An analysis of the variability of conditional correlation over time allows to verify tendencies in the interdependences.

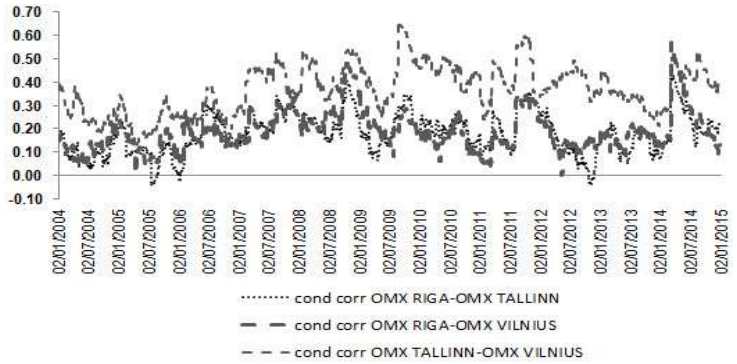
Figure 1 presents the conditional correlation among the DAX index and OMX Riga, OMX Tallinn, OMX Vilnius and WIG indices. The analysis of the correlations indicates that the interdependencies among the German capital market and the capital markets of the Baltic States are at a very low level. Thus, it can be said that since 2004 the shocks occurring on the German capital markets have been transferred to a low extant to the markets of Estonia, Latvia and Lithuania. However, in the case of Poland the interdependence with German capital market is at a much higher level. This means that the valuation of Polish index is largely dependent on the situation on the capital market in Germany.

Figure 1: The conditional correlation among chosen capital markets and market of Germany



On the other hand, Figure 2 presents the conditional correlations among indices of Baltic countries: OMX Riga, OMX Tallinn and OMX Vilnius. One can find weak interdependencies among the capital market of Latvia and the Estonian and Latvian markets. In the case of Estonian and Lithuanian capital markets the interdependencies are at a much higher level. The obtained results for the conditional correlations allowed to verify the hypothesis about the low level of interdependence among the markets of the Baltic Countries and the German capital market.

Figure 2: The conditional correlation among Baltic Countries capital markest



The values of the conditional correlations for the pairs of markets have been used to analyse integration. This allowed to verify the degree of integration of the interdependencies among pairs of selected markets. With application of Phillips-Perron test (Phillips & Perron, 1988) both the stationarity of the processes of conditional correlation I(0), and the integration of order one I(1) were established. The results of the Phillips-Perron test are shown in Table 2. In the case of the processes of conditional correlation for a pair of indices: OMX Riga and DAX, the test allowed to determine the integration of order zero. This means that the correlation process for a pair of indices OMX Riga and DAX is stationary. This stationarity may be the result of weak reaction of the Latvian market to shocks coming from other capital markets, including the capital market of Germany. Additionally, it is probable that if there are any reactions of the Latvian market, they do not case long term changes in the character of the interdependence. This can be confirmed by the values of conditional correlations, which for the pair of OMX Riga index with other indices are at much lower level in comparison to the values for other pairs of indices.

Table 2: The results of the integration analysis

Pair of indices	**Time series**	**Test statistics**	**p-value**	**Order of integration**
OMX Riga, DAX	Levels	-2.632	0.008	I(0)
	Differences	-	-	
OMX Tallinn, DAX	Levels	-1.298	0.1796	I(1)
	Differences	-52.947	~0.00	
OMX Vilnius, DAX	Levels	-1.691	0.086	I(0) for α=0.1 I(1) for α=0.05
	Differences	-52.746	~0.00	
WIG, DAX	Levels	-0.491	0.503	I(1)
	Differences	-52.321	~0.00	

Source: own estimation.

In the case of the processes of conditional correlations for pair of indices OMX Tallinn, DAX and WIG, DAX the test results indicate the integration of order one. For the process of the conditional correlation for a pair of indices OMX Vilnius and DAX one can find the integration of order one with 5% significance level. The increasing of the significance level to 10% results in rejecting the null hypothesis and the conclusion of integration of order zero. This means that other processes of conditional correlations are non-stationary in variance. The non-stationarity may be the result of strong reactions of the selected markets to shocks coming from the German capital market, which contribute to the long term changes in the levels of indices.

The results on the integration of processes of the conditional correlation enable to verify second hypothesis, which pointed to different reaction mechanism of Baltic States capital markets and Polish market to shocks coming from market of Germany.

4. Conclusions

The article concentrates on the problem of interdependencies among capital markets of Baltic States, Poland and Germany. The identification of interrelations among markets is a research problem, which is important form the perspective of risk management. Verifying the transmission channels of shocks between the markets is necessary for mitigating the costs of crisis situations.

In order to measure the interdependencies among selected markets DCC-GARCH model has been used. After estimation of the parameters of the model the conditional correlations showing the interrelationships among capital markets were obtained. The analysis allowed to conclude that there are very weak interrelationships among German capital market and the markets of the Baltic States. The study also allowed the identification of different mechanisms of formation of interdependences among German market and the capital markets in selected countries.

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