Chapter

Stock Markets of the Visegrad Countries after Their Accession to the European Union

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Abstract

In this chapter, interlinkages between stock markets in CEE-4 countries and capital markets in developed countries are analyzed. Changes of variance on stock markets in Poland, the Czech Republic, Slovakia, and Hungary are identified. Differences among countries are analyzed. Capital markets of these countries are compared in terms of market efficiency. Moreover, co-movements of stock markets in Visegrad countries with capital markets in developed countries are studied. Different specifications of multivariate GARCH models are studied. Asymmetric GARCH-BEKK model and Asymmetric Generalized Dynamic Conditional Correlation model are considered.

Keywords: stock markets, Visegrad countries, market efficiency, multivariate GARCH, shocks' transmission

1. Introduction

The Visegrad countries are the four Central European Countries (referred to as the CEE-4 henceforth)—Czech Republic, Poland, Slovakia, and Hungary. These countries joined the European Union (EU) in spring 2004, and three of them are still (January 2020) committed to adopting the euro at some point. At the early stages of transformation, their stock markets were relatively poorly integrated with the stock markets of the EU countries (the so-called old EU countries). This is due to the shorter history of the free-market economy in Poland, Hungary, and the Czech Republic. Low level of correlation between rates of return on stock market indexes in CEE-4 countries and rates of return on stock market indexes of industrialized economies resulted in considering assets from post-communist economies in investors' portfolios (e.g., see [1, 2]). The accession of Poland, Hungary, and the Czech Republic to the EU on May 1, 2004 attracted the interest of numerous investors who had not earlier invested in these countries due to political, corporate governance, and liquidity risks (see [3]). In particular, the Slovakian stock market was strongly integrated with capital markets of developed economies due to the country's participation in the Exchange Rate Mechanism 2 (ERM2 henceforth) and euro adoption in 2009 (see [4]). A significant increase in the level of integration resulted in a decrease in the benefits from using the portfolio diversification strategy.

During the US subprime crisis, a significant increase in correlations between stock markets in CEE-3 countries and capital markets in developed economies was observed (see [5]). In particular, correlation between shocks in the Slovakian stock market and shocks in industrialized countries was very large. The outbreak of the euro area sovereign debt crisis resulted in a slight decrease in the level of correlation between stock markets in CEE-4 countries and mature capital markets. However, rates of return in the German stock market still strongly affected the rates of return in the Polish, Hungarian, Czech, and Slovakian stock market. After the introduction of the Outright Monetary Transactions program (OMT henceforth), the sensitivity of the stock market returns in Poland, the Czech Republic, and Hungary to external shocks decreased significantly. This phenomenon was not observed in the case of Slovakia, which is a member of the euro area.

Nevertheless, we still think that we can contribute to this body of literature. Previous studies devoted to the analysis of the performance of stock markets in Poland, the Czech Republic, Slovakia, and Hungary compared sensitivity of these markets to external and internal shocks in a priori defined subperiods. In most cases, the Winkler's [6] periodization of the global financial crisis was used. In this research study, we identify days of statistically significant breakpoints on the basis of the method proposed by Inclan and Tiao [7]. Stock markets of Poland, the Czech Republic, Slovakia, and Hungary are compared with regard to timing of significant breakpoints. Moreover, efficiency of stock markets in CEE-4 countries is compared across subperiods and across markets. Sensitivity of stock markets to external shocks is compared in the context of the volatility transmission and linkages between rates of return. Differences between resistance to shocks from the United States and Germany (main economy of the European Union) are analyzed as well. The obtained differences between Slovakia and noneuro-area member states should provide recommendations for policy makers of Poland, the Czech Republic, and Hungary in the context of the future accession of these countries to the euro area.

This chapter has the following structure. In Section 2, the literature review is provided. In Section 3, the methodology is presented. In Section 4, findings from the empirical research are presented and discussed. The last section concludes the study.

2. Literature review

Poor integration of capital markets in Poland, the Czech Republic, Hungary, and Slovakia in the twentieth century resulted in low level of interest in sensitivity of these markets to external shocks in academic literature. These stock markets were previously analyzed in the context of portfolio diversification opportunity (see, e.g., [1, 2]). The very low degree of global integration of capital markets of Central and Eastern European countries in the pre-accession period was identified, among others, by Mateus [8], Maneschiold [9], and Nielsson [10]. An analysis of the sensitivity of the CEE-3 stock markets to global shocks during the dotcom crisis, which was conducted by Bein and Tuna [11], has indicated their calmness and excluded possibility of their significant reaction to negative news.

After announcement of the CEE-4 countries' EU membership, all stock markets in the region started to show similar level of volatility reactions to both negative and positive news that had the same magnitude. This finding has been interpreted as an increase in confidence for international investors after the announcement of the accession of countries of the Central and Eastern Europe to the European Union (see [12]). The accession of Poland, the Czech Republic, Hungary, and Slovakia to the EU on May 1, 2004, attracted the interest of many investors who had earlier refrained from buying assets of these countries due to corporate governance, political, and liquidity risks (see, e.g., [13–15]). An increase in the level of integration resulted in a significant decrease in the benefits from using the portfolio diversification strategy (see [16]).

The impact of the subprime crisis on the performance of stock markets in CEE-4 countries has been broadly discussed in the economic literature. Very significant transmission of shocks to CEECs' stock markets during the subprime crisis was identified in numerous research studies (see, e.g., [17–19]). As Syllignakis and Kouretas [13] suggested, the contagion transmission from the major stock markets to capital markets of the CEECs in the period of financial turmoil as well as during the subprime crisis was due to increased financial liberalization and increased participation of foreign investors in these markets.

In turn, studies devoted to the role of the sovereign debt crisis in shaping stock market prices in the Central and Eastern Europe seem to be rare. The analysis of dynamic correlation coefficients conducted by Bein and Tuna [11] indicates that during the euro-area sovereign debt crisis, stock markets in the analyzed region have been highly correlated with the finance-led markets of GIIPS (Greece, Italy, Ireland, Portugal, and Spain) as well as with stock markets of the EU3 (France, Germany, and the United Kingdom). Moreover, significant spillover effect from capital markets of Italy, Ireland, Portugal, and Spain to stock markets of the Central and Eastern European countries has been identified. Differences in the level of reaction of stock markets in CEE-4 countries during the euro area sovereign debt crisis have been noticed as well. Due to the fact that Slovakia was a member of the euro area in 2010–2011, stock market in this country reacted stronger to positive and negative shocks. Moreover, the Polish stock market has shown a significantly higher level of conditional correlation than the Czech Republic and Hungary. Some results in the literature devoted to the sensitivity of capital markets in Visegrad countries to external shocks have pointed out their asymmetric reaction (see, e.g., [18, 20]). This finding has been interpreted as a problem of information asymmetry and the presence of agents with superior knowledge [21].

As Grabowski [20] and Moagar-Poladian et al. [22] have noticed, in the period of financial stability (2013–2019) in the case of Poland, the Czech Republic, and Hungary, the sensitivity of the stock market returns to external shocks became meaningfully weaker. In the case of the Slovakian stock market, drop in the level of integration was smaller (see, e.g., [23]). Moreover, after 2012, the evolution of the stock market indices in the CEE-4 countries has followed different paths. As a result of the lower level of market uncertainty, volatility spillovers have weakened. A within-group integration of stock markets of the CEE-4 countries has decreased significantly. Opportunities for portfolio diversification have increased with discrepancies between market returns observed after 2012 (see. [20]).

3. Methodology

In order to identify different states of stock markets, the methodology proposed by Inclan and Tiao [7] and Inclan et al. [24] should be used. On the basis of the following statistics,

$$IT = D_{k*}\sqrt{T/2} \tag{1}$$

moments of significant changes in the unconditional variance were identified. In formula (1), the number of observations denoted by T and D_{k*} is defined as follows:

$$D_{k*} = \max_{k} |D_k|, \tag{2}$$

where

$$D_k = \frac{C_k}{C_T} - \frac{k}{T}, \tag{3}$$

C_k is the cumulative sum of squares.

Market efficiency belongs to the most important features describing financial markets in the area of information processing mechanisms. According to the concept introduced by Fama [25], on informationally efficient market prices always fully reflect the available information. As a result, it is not possible to achieve permanently superior returns on the basis of publicly available information, and the changes in financial asset prices are random. There are three main statistical methods of testing efficiency (autocorrelation test, runs test, and the test for the presence of unit root).

Testing the autocorrelation is based on the autocorrelation of the kth-order (ACF) coefficient, which is defined as follows:

$$\hat{\rho}_k = \frac{\sum_{t=k}^{T}(r_t - \bar{r})(r_{t-k} - \bar{r})}{\sum_{t=1}^{T}(r_t - \bar{r})^2}, \tag{4}$$

where r_t denotes a rate of return of a financial instrument. The lack of autocorrelation of the first order does not preclude the existence of autocorrelation of higher orders (see [26, 27]). Since the autocorrelation coefficients of higher order ignore the information provided by the observations between the first and last one in the period, analysis of capital market efficiency is conducted within the framework of the statistical analysis of the partial autocorrelation coefficients (PACFs).

The second method of testing efficiency is based on the run tests. The null hypothesis says that the changes of prices of securities are random. The test statistic is as follows:

$$U = \frac{K - E(\tilde{K})}{S(\tilde{K})}, \tag{5}$$

where K denotes count of empirical runs, $E(\tilde{K})$ denotes expected number of runs, while $S(\tilde{K})$ denotes standard deviation of the number of runs. If we consider two series (e.g., negative and non-negative), then the expectation and variance are calculated as follows:

$$E(\tilde{K}) = \frac{2n_1n_2 + n}{n}, \tag{6}$$

$$S^2(\tilde{K}) = \frac{2n_1n_2(2n_1n_2 - n)}{(n-1)n^2}, \tag{7}$$

where n_1 and n_2 denote the numbers of different types of series, and n is the total number of series. If we consider three series (e.g., negative, zero, and positive), then the expectation and variance are calculated as follows:

$$E(\tilde{K}) = n + 1 - \frac{\sum_{j=1}^{3} n_j^2}{n}, \tag{8}$$

$$S^2(\tilde{K}) = \frac{\sum_{j=1}^{3} n_j^2\left(\sum_{j=1}^{3} n_j^2 + n + n^2\right) - 2n\sum_{j=1}^{3} n_j^3 - n^3}{(n^2-1)n}, \tag{9}$$

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where n_1 , n_2, and n_3 denote the numbers of different types of series, and n is the total number of series.

The statistic (2) is normally distributed with 0 mean and standard deviation 1.

In order to test whether the series if securities follow random walk, the variance ratio tests (see [28]) are used. This test is based on the assumption that the variance of increments in a random walk is linearly independent. Variance ratio statistics are calculated as follows:

$$VR(k) = \frac{S^2(r_t + r_{t-1} + \dots + r_{t-k+1})}{k * S^2(r_t)}. \tag{10}$$

In order to verify, whether the RW1 (assumption that increments of analyzed process are independent and identically distributed) null hypothesis is valid, the following statistic is used:

$$M_1(k) = \frac{VR(k) - 1}{\sqrt{\phi(k)}}, \tag{11}$$

where

$$\phi(k) = \frac{2(2k-1)(k-1)}{3kT}. \tag{12}$$

In order to verify, whether the RW3 (it is assumed that the process has dependent but uncorrelated increments), the following statistic is used:

$$M_2(k) = \frac{VR(k) - 1}{\sqrt{\phi^*(k)}}, \tag{13}$$

where

$$\phi^*(k) = \sum_{j=1}^{k-1} \left[\frac{2(k-j)}{k}\right]^2 \delta_j \tag{14}$$

and

$$\delta_j = \frac{\sum_{t=j+1}^{T} (r_t - \bar{r})^2 (r_{t-j} - \bar{r})^2}{\left[\sum_{t=1}^{T} (r_t - \bar{r})^2\right]^2}. \tag{15}$$

Both statistics $M_1(k)$ and $M_2(k)$ follow standard normal distribution. If the null hypothesis is rejected, the analyzed time series is not random walk, and the capital market is not efficient (see, e.g., [29]).

In order to analyze sensitivity of stock markets to external shocks, the following bivariate VAR(p)-AGDCC-GARCH(1,1) models (see [30]) will be considered:

$$\boldsymbol{r}_t = \sum_{i=1}^{p} \boldsymbol{\Pi}_i \boldsymbol{r}_{t-i} + \boldsymbol{\varepsilon}_t, \tag{16}$$

$$E\left(\boldsymbol{\varepsilon}_t \boldsymbol{\varepsilon}_t^T\right) = \boldsymbol{H}_t, \tag{17}$$

where $\boldsymbol{r}_t$ is the following vector of rates of return on stock market indices:

$$\boldsymbol{r}_t = \left[r_t^{VIS} \quad r_t^{DEV} \right]^T$$

r_t^{VIS} denotes the rate of return on stock market index in a Visegrad country (VIS=PL,CZ,HU,SK), and r_t^{DEV} denotes the rate of return on a mature stock market index (DEV = DE,US). The covariance matrix is decomposed as follows:

$$\boldsymbol{H}_t = \boldsymbol{D}_t \boldsymbol{R}_t \boldsymbol{D}_t, \tag{18}$$

where the matrix $\boldsymbol{D}_t$ consists of squared roots of variances of shocks:

$$\boldsymbol{D}_t = diag\left[\sqrt{h_t^{VIS,VIS}} \quad \sqrt{h_t^{DEV,DEV}} \right]. \tag{19}$$

These variances of shocks are modeled according to the following GARCH(1,1) model:

$$h_t^{n,n} = \alpha_{0,n} + \alpha_{1,n} \left(\varepsilon_{t-1}^n \right)^2 + \beta_{1,n} h_{t-1}^{n,n}, n = VIS, DEV. \tag{20}$$

Correlations between shocks change in time and depend on negative and positive shocks in the following way:

$$\boldsymbol{R}_t = (diag(\boldsymbol{Q}_t))^{-1/2} \boldsymbol{Q}_t (diag(\boldsymbol{Q}_t))^{-1/2}, \tag{21}$$

where

$$\boldsymbol{Q}_t = \left(1 - \tilde{\alpha}_1 - \tilde{\beta}_1\right)\overline{\boldsymbol{Q}} + \tilde{\gamma}_1\left(\overline{\boldsymbol{Q}} - \overline{\boldsymbol{Q}}^-\right) + \tilde{\alpha}_1 \boldsymbol{u}_{t-1}\boldsymbol{u}_{t-1}^T + \tilde{\beta}_1 \boldsymbol{Q}_t + \tilde{\gamma}_1 \boldsymbol{u}_{t-1}^-\left(\boldsymbol{u}_{t-1}^-\right)^T. \tag{22}$$

The elements of vector $\boldsymbol{u}_t$ are defined as follows:

$$u_t^n = \frac{\varepsilon_t^n}{\sqrt{h_t^{n,n}}}, \tag{23}$$

where n = VIS,DEV and $\boldsymbol{u}_{t-1}^-$ consists of zero-threshold standardized errors, while the matrices $\overline{\boldsymbol{Q}}$ and $\overline{\boldsymbol{Q}}^-$ denote the unconditional covariance matrices of vectors $\boldsymbol{u}_{t-1}$ and $\boldsymbol{u}_{t-1}^-$, respectively.

As a robustness check, parameters of the asymmetric VAR(p)-GARCH-BEKK model (see [30]) will be estimated. In this model, the covariance matrix evolves according to the following formula:

$$\boldsymbol{H}_t = \boldsymbol{C}\boldsymbol{C}^T + \boldsymbol{A}\boldsymbol{\varepsilon}_{t-1}\boldsymbol{\varepsilon}_{t-1}^T\boldsymbol{A}^T + \boldsymbol{B}\boldsymbol{H}_{t-1}\boldsymbol{B}^T + \boldsymbol{D}\boldsymbol{\xi}_{t-1}\boldsymbol{\xi}_{t-1}^T\boldsymbol{D}^T, \tag{24}$$

4. Results and discussion

In the empirical research, we use daily data covering period from May 2004 to December 2019. Logarithmic rates of return on WIG (acronym of the Warsaw Stock Index in Polish), BUX (acronym of the Budapest Stock Index in Hungarian), PX (acronym of the Prague Stock Exchange in Czech), SAX (acronym of the Slovakian Stock Index in Slovakian), DAX (acronym of the German Stock Index in German language), and S&P500 (Standard and Poor's 500) are used.

In the first step, the methodology proposed by Inclan and Tiao [7] and Inclan et al. [24] is used in order to identify dates of significant changes in the unconditional variance for Poland, the Czech Republic, Hungary, and Slovakia (**Table 1**).

Results of the analysis indicate that significant changes in volatilities of the rates of return were observed in similar days in all markets. Significant breakpoint in variance during the financial turmoil and short before the Lehman Brothers bankruptcy is in line with expectations. The second breakpoint date is observed during the euro area sovereign debt crisis. However, in the case of Slovakia, a significant change was observed short before the announcement of the OMT program. Difference between Slovakia and noneuro-area members does not come as a surprise, since the performance of financial markets in Slovakia was strongly linked to the situation in the euro area. The announcement of the OMT program turned out to have the long-term impact on markets in the euro area, so the obtained result confirms findings of other studies (see [31, 32]). Moreover, short after the Brexit referendum, significant breakpoint in variance is observed. This result confirms findings obtained by Kurecic and Kokotovic [33], who have also noticed a significant increase in volatility on stock markets after this event. Results of the British referendum could provide information about a threat of an illiberal turn all over the world. As a result, level of trust in financial markets decreased significantly, which was reflected by the appearance of the home bias phenomenon. All in all, in the case of all four countries, four in terms of volatility four states can be distinguished.

In the next step, hypothesis concerning efficiency of stock markets is verified on the basis of three methods for all four subperiods and four countries. Results of verification for Poland are presented in **Table 2**. Results of verification for the Czech Republic are presented in **Table 3**. Results of verification for Hungary and Slovakia are presented in **Tables 4** and **5**.

Results from **Tables 2–5** indicate that stock markets in four analyzed countries were efficient in most of analyzed subperiods. However, in some cases, conclusions depend on the used methodology. The lowest level of efficiency was observed during the subprime crisis in the United States. This result is not surprising, since after the Lehman Brothers bankruptcy, very large panic on stock markets was observed. As a result of this panic, efficiency of financial markets decreased significantly. Some studies set hypothesis that the phenomenon of I(2)-ness of prices of financial instruments in crisis periods exists (see, e.g., [34]). Inefficiency of stock markets in the crisis period may confirm validity of this hypothesis. It turns out that stock markets of countries of the Central and Eastern Europe differ with regard to efficiency. For example, after the Lehman Brothers bankruptcy, stock markets in Hungary and Poland turned out to be inefficient, while the H0 hypothesis about efficiency was not rejected in the case of Slovakia and the Czech Republic. Differences across subperiods suggest that it is difficult to infer about efficiency in the

Country	Poland	Czech Republic	Hungary	Slovakia	Event
Dates of breakpoint in variances	2008-09-12	2008-09-04	2008-09-12	2008-09-12	The US subprime crisis
	2011-12-21	2011-12-23	2012-01-23	2012-07-23	The euro area sovereign debt crisis
	2016-06-27	2016-07-18	2016-06-29	2016-06-28	The Brexit referendum

Table 1.
Results of the analysis of breakpoints in variance.

Description of subperiod	Dates	Variance ratio test	Autocorrelation function	Run test
Before the subprime crisis	2004-05-03 to 2008-09-12	0.9833	0.362	0.44
Subprime crisis and the euro area sovereign debt crisis	2008-09-15 to 2011-12-21	0.0488	0.012	0.64
Calming down after crisis and before the Brexit referendum	2011-12-22 to 2016-07-27	0.9715	0.306	0.76
The last period after the Brexit referendum	2016-07-28 to 2019-12-30	0.7031	0.248	0.96
P *values of statistical tests are provided.*				

Table 2.
Results of testing efficiency of the Polish stock market.

Description of subperiod	Dates	Variance ratio test	Autocorrelation function	Run test
Before the subprime crisis	2004-05-03 to 2008-09-04	0.9050	0.403	0.64
Subprime crisis and the euro area sovereign debt crisis	2008-09-05 to 2011-12-23	0.9785	0.717	0.31
Calming down after crisis and before the Brexit referendum	2011-12-24 to 2016-07-18	0.6140	0.071	0.64
The last period after the Brexit referendum	2016-07-19 to 2019-12-30	0.7835	0.367	0.45
P *values of statistical tests are provided.*				

Table 3.
Results of testing efficiency of the Czech stock market.

Description of subperiod	Dates	Variance ratio test	Autocorrelation function	Run test
Before the subprime crisis	2004-05-03 to 2008-09-12	0.3055	0.079	0.24
Subprime crisis and the euro area sovereign debt crisis	2008-09-15 to 2012-01-23	0.0211	0.003	0.13
Calming down after crisis and before the Brexit referendum	2012-01-24 to 2016-06-29	0.8756	0.005	0.88
The last period after the Brexit referendum	2016-06-30 to 2019-12-30	0.4549	0.274	0.20

Table 4.
Results of testing efficiency of the Hungarian stock market. P *values of statistical tests are provided.*

whole period, and some financial markets may be efficient in one period and inefficient in the other one.

In the last step, financial markets of the four analyzed countries are compared with regard to sensitivity to shocks from Germany and the United States. Multivariate GARCH models take into account time-varying volatilities. Therefore, division into subperiods according to **Table 1** is not necessary. In turn, analysis will be conducted in three large subperiods:

Description of subperiod	Dates	Variance ratio test	Autocorrelation function	Run test
Before the subprime crisis	2004-05-03 to 2008-09-12	0.3055	0.079	0.24
Subprime crisis and the euro area sovereign debt crisis	2008-09-15 to 2012-01-23	0.0211	0.003	0.13
Calming down after crisis and before the Brexit referendum	2012-01-24 to 2016-06-29	0.8756	0.005	0.88
The last period after the Brexit referendum	2016-06-30 to 2019-12-30	0.4549	0.274	0.20

Table 5.
Results of testing efficiency of the Slovakian stock market. P *values of statistical tests are provided.*

- before the Lehman Brothers bankruptcy,
- between the Lehman Brothers bankruptcy and before the announcement of the OMT program, and
- after the announcement of the OMT program.

Table 6 presents estimates of parameters reflecting impact of rates of return for developed markets on the rates of return for Visegrad stock markets, while the table average values of correlations

Results of the analysis indicate the strength of the impact of developed stock markets on Visegrad stock markets differed across subperiods (**Table 7**). The strongest linkages were observed in the crisis period. Between 2008 and 2012, shocks generated by stock markets in Visegrad countries were strongly correlated with shocks generated by stock markets in Germany and the United States. A significant drop in comovements of stock markets in Poland, the Czech Republic, Hungary, and capital markets of Germany and the United States was observed after the announcement of the OMT program. In the stable period, investors got knowledge which classes of assets were riskier or safer. Moreover, the illiberal turn in the Central and Eastern Europe could have impact on sensitivity of stock markets in Poland, the Czech Republic, and Hungary on external shocks (see, e.g., [35]) In the case of the correlation between shocks associated with SAX and DAX, a decrease in correlation was not so large, which should be attributed with participation of

	WIG	BUX	PX	SAX
First subperiod				
DAX	0.549	0.705	0.237	0.187
S&P500	0.313	0.743	0.226	0.278
Second subperiod				
DAX	0.643	0.792	0.289	0.367
S&P500	0.421	0.851	0.113	0.389
Third subperiod				
DAX	0.439	0.266	0.125	0.191
S&P500	0.206	0.299	0.098	0.235

Table 6.
Impact of rates of return of developed markets on rates of return of Visegrad countries.

	WIG	BUX	PX	SAX
First subperiod				
DAX	0.378	0.316	0.104	0.156
S&P500	0.279	0.178	0.373	0.211
Second subperiod				
DAX	0.511	0.489	0.723	0.375
S&P500	0.194	0.347	0.851	0.413
Third subperiod				
DAX	0.208	0.278	0.176	0.364
S&P500	0.386	0.198	0.251	0.278

Table 7.
Correlations between shocks generated.

Slovakia in the euro area. However, rates of return on WIG and BUX turned out to be more sensitive to changes in rates of return on DAX in particular in years 2004–2012. This may be due to large interactions between Germany and two economies of the Central and Eastern Europe (Polish economy and Hungarian economy).

5. Conclusions

In this chapter, the performance of stock markets in Visegrad countries after their EU accession was studied. Results of the analysis indicate that there were differences between the performance of the Slovakian stock market and the performance of noneuro-area member states. In the case of all four markets, three significant breakpoints in variance were identified. These breakpoints reflect the beginning of the US subprime crisis, the end of the euro area sovereign debt crisis and, the results of the Brexit referendum.

Stock markets in the CEE-4 countries turned out to be informationally efficient in three of four subperiods. Hypothesis about informational efficiency was rejected only in the case of Poland and Hungary and in the crisis period. In the case of the Czech and Slovakian stock market, there were no grounds to reject hypothesis about their efficiency. Results of three statistical tests confirmed it.

Stock markets in Poland and Hungary were more sensitive to changes of rates of return on DAX. However, in the stable period after 2012, correlation between shocks generated by Poland, the Czech Republic, and Hungary and shocks generated by Germany was much weaker than in earlier years. Integration of the Slovakian stock market with capital markets of developed economies did not decrease in the post-crisis period.

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