VOLATILITY REGIMES IN STOCK MARKET LINKAGES

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Abstract

The paper examines the development of stock market linkages among CEE-3 (namely, the Czech, Hungarian, and Polish markets) and three stock market indices that represent the developed markets (i.e., MSCI Germany, the Dow Jones Euro Stoxx 50, and MSCI World). The stock market linkages are analyzed using the series constructed from differences between stock market index returns. Consequently, utilizing the Sansó, Aragó & Carrion-Silvestre, 2004 test and ICSS algorithm, we identify different volatility regimes for these series. Sudden changes in volatility occurred from 20 October 2002 to 14 December 2003 and they all led to a decrease in unconditional volatility, thus obtaining empirical evidence of possible increase in stock market linkages. These dates correspond to a period from Copenhagen summit, i.e. to a period, where there was little doubt, that CEE-3 countries will enter the European Union.

Key words: stock market linkages; stock market integration; volatility regimes; ICSS algorithm; CEE markets

JEL Code: C32, G01, G15

Introduction

Although the scale and approach toward privatization differs even between CEE-3 economies, the establishment[1] of stock markets in CEE-3 can be perceived as a byproduct of privatization in the early 90s. New stock markets attracted the interest of foreign investors, particularly after 1980s, after the US stock market crash in October 1987, as stock market linkages among developed countries increased considerably, thus providing lesser protection for international investors.

Still, until mid-90s, corporate governance and investor protection in CEE-3 countries may be regarded as underdeveloped. With European Union accession negotiations, the regulatory and legal framework improved, offering higher investor protection and, thus, relaxed investment barriers. In this paper, we explore, whether stock market linkages could be

[1] The CEE-3 stock markets have been functioning over two decades. The Warsaw stock exchange (WSE) was established on April 16, 1991; the Budapest stock exchange (BSE) was established on June 21, 1990; and the Prague stock exchange (PSE) was established on November 24, 1992. Note that these dates do not necessarily correspond to the first trading days.

subject to sudden changes, i.e. whether there are regimes of higher or lower stock market linkages. Contrary to the prevailing approach of dynamic conditional correlations (DCCs), we estimate stock market linkages simply as differences between returns of corresponding stock market indices. In line with the concept of σ-convergence, we are interested whether the unconditional volatility of the resulting series declined.

The remainder of the paper is organized as follows: in Section 1 we discuss the related literature of empirical studies examining CEE-3 stock markets. Section 2 describes the data and methodology, while Section 3 presents our empirical results. In the last section we provide concluding remarks.

1 Review of the related literature

Jochum, Kirchgässner & Platek (1999) scrutinized the effect of Asian and South American crisis (during 90s) on the dependence between CEE-3 and Russian stock markets with US stock market. Using daily closing prices from five stock market indices (WIG, BUX, PX50, ASP, and S&P 500), covering the period from 1 January 1995 through 21 September 1998, they compared the short and long-run dependence of markets before and during the crises. Bilateral co-integration analysis (Johansen test) suggested that before the crisis (dated to 1 September 1997), stable long-run relationship was present (WIG – S&P 500, BUX – S&P 500, PX50 – S&P 500), while during the crisis this relationship was disrupted. These findings suggest that already in late 90s, diversification opportunities in CEE-3 markets for international investors might have been limited. Somewhat contradictory findings were presented in Gelos & Sahay (2001). They observe changes in the co-movement of daily returns before and during several crisis periods of CEE-3, Russian and Asian stock markets and found, that during the Czech crisis[2], correlations between the Czech and Hungarian stock markets increased, although remained rather small. During the Asian crisis, hypothesis of no increase in correlations between Asian emerging market composite stock market index and CEE-3 stock market indices could not be rejected.[3] During the Russian crisis, the correlations between returns of CEE-3 stock market indices and Russian stock market have not increased as well.[4]

[2] Accompanied by the depreciation of the Czech koruna and stabilization package of the Czech government in June 1997. The period before the crisis corresponds to a sample from 1 June 1996 to 31 January 1997 and crisis period to a sample from 2 January 1997 to 15 June 1997.

[3] The period before crisis corresponds to a sample from 4 February 1997 to 1 July 1997 and crisis period to a sample from 2 July 1997 to 29 January 1998.

[4] The period before crisis corresponds to a sample from 31 January 1998 to 15 July 1998 and crisis period to a sample from 16 July 1998 to 15 October 1998.

As shown by Scheicher (2001), daily returns from a world equity portfolio (using FT/S&P Actuaries World Index as a proxy) had some predictive power towards returns of the Hungarian and Polish, but not the Czech stock market (using stock market indices from Clearing Houses and Exchange in Vienna), during the period from 1 January 1995 through 7 October 1997 (see Table 4 in Scheicher, 2001 with the estimates of the VAR-M-GARCH model). This suggests that international shocks are imported into CEE-3 stock markets. Thus, we may perceive this as an early evidence of stock market linkages between the two CEE markets and world equity portfolio. In the second half of the 90s, the development of the Czech stock market was considerably different from the one observed in other two CEE-3 markets. In 1993, 955 securities from the first wave of privatization were listed on the Prague stock exchange (PSE). In 1995 additional 674 securities emerged from the second wave of privatization.[5] This mass privatization resulted in a large number of listed companies but there was insufficient liquidity, and mistrusts among investors ("tunneling" by majority of shareholders). As a consequence, till 1997, more than three quarters of companies were already delisted.

Gilmore & McManus (2002) studied the presence of the stable long-run relationship between CEE-3 and the US S&P 500 index. Using bilateral co-integration tests (Johansen test) on weekly closing prices from 1 July 1995 to 1 August 2001, Gilmore & McManus (2002, Table 5) have found no evidence of a stable long-run relationship between any of the pair of S&P 500 and corresponding CEE-3 indices. Further on, they were unable to reject the hypothesis of no Granger causality from S&P 500 returns to respective CEE-3 stock market returns (see Table 7 in Gilmore & McManus, 2002). As argued in Voronkova (2004) the inability to find stable long-run correlations might be due to the presence of structural changes in the relationships between CEE-3 and developed stock markets. Similar conclusions may have been drawn already from results presented in Jochum, Kirchgässner & Platek (1999). Voronkova (2004) employed the Gregory-Hansen co-integration test, which allows taking into account various forms of structural changes. Stable long-run relationship was found among CEE-3 stock market indices for a series of daily closing prices from 7 September 1993 to 30 April 2002. In a bilateral setting, her results also indicated long-run relationship between WIG and S&P 500, WIG and DAX, WIG and CAC 40, BUX and DAX, BUX and CAC 40, and PX and CAC 40 (see Voronkova, 2004, Table 3–5).

On a sample of daily data from 2 October 2000 to 20 April 2007, Christiansen & Ranaldo (2009) used coexceedance (the joint occurrence of extreme returns in different

[5] The data were obtained from the homepage of the PSE: www.pse.cz.

markets) within ten CEE countries (i.e., new EU member states, which included the CEE-3) as a measure of stock market integration. Among other results, the authors found that the coexceedance in the ten CEE countries was associated with the coexceedance in the existing EU countries, which they interpreted as a sign of increased stock market integration. Pukthuanthong & Roll (2009) showed that using correlation based measures to assess stock market integration can have serious drawbacks. Instead, they measured stock market integration as a proportion of a country's stock market return that is explained by global factors. Their empirical analysis included the Czech, Polish, and Hungarian stock markets. Using daily data, Pukthuanthong & Roll (2009) found that until February 2008, the proportion of variance explained by global factors increased linearly (see their Table 3, p. 226). This pattern might be interpreted as evidence for a gradual increase in stock market integration.

Using weekly data from 3 October 1997 to 13 February 2009, Syllignakis & Kouretas (2011) found that during the recent financial crisis of 2007 – 2009, the correlation (between the CEE-3 countries and the German and US stock markets) increased from approximately 0.50 to 0.75. Subsequently, a positive relationship was found between the levels of the DCCs and the conditional volatility. Similarly, Gjika & Horvath (2013) used daily data covering the period from 20 December 2001 to 31 October 2011. They examined the time-varying correlations between the CEE-3 and the Eurozone (Stoxx 50), which was performed using the asymmetric DCC model framework. They found an increase in correlations as CEE-3 countries entered the EU (May 2004) while during the recent financial crisis these correlations remained at these high levels (approximately 0.60 – 0.70). Similarly as Syllignakis & Kouretas (2011), Gjika & Horvath (2013) showed that the levels of the DCCs can be linked to the volatility on the corresponding markets. Baumöhl (2013) applied an asymmetric DCC framework to estimate correlations between the CEE-3 and G7 stock markets and applied a smooth transition model to assess the speed and pattern of stock market co-movements.[6] In the case of the Czech stock market, the results suggest that the transition to higher co-movement began between the end of 2005 and first half of 2006, while the transition midpoints for the Hungarian and Polish markets seemed to overlap with the recent financial crisis.

[6] In fact, he estimated co-movements for Slovak stock market as well.

2 Data and methodology

2.1 Data

In this paper, we cover six stock market indices, namely Polish WIG 20 (WIG), Czech PX, Hungarian BUX, MSCI Germany (GER), Dow Jones Euro Stoxx50 (STX) and MSCI World (MSCI). Daily closing prices from 4 January 1999 to 28 September 2012 were obtained from the Thomson Reuters Datastream. CEE-3 indices are used in national currency to avoid the influence of exchange rate volatility. To mitigate non-synchronous trading effects, we used weekly returns. Let P_n be the closing price of a stock market index in given day $n = 1,2,...,N$. The weekly (continuous) returns S^A_t are then calculated as $ln(P^A_t/P^A_{t-1})$, where $P^A_t=n(t)^{-1}\sum_{i=1}^{n(t)}P_{t,i}$, and $n(t)$ is the number of days in a given week t.

2.2 Stock market linkages

We measure the stock market linkages using an approach originated in the literature on β- and σ-convergence. In the literature on stock market integration, these approaches are rarely used; see Babecký, Komárek, & Komárková (2013). In a time series framework, β-convergence can be used to measure, whether differences between stock market returns are declining. This is in line with the definition of convergence of Bernard & Durlauf (1996, p. 165): "*Countries i and j converge if the long-run forecasts of (log) per capita output for both countries are equal at a fixed time t.*". In our perspective, two stock markets converge in returns, if:

$$\lim_{n\to\infty} E\left(S^A_{i,t+n} - S^A_{j,t+n}\middle|\xi_t\right) = 0 \tag{1}$$

Where i and j represent different stock markets and ξ_t denotes all the information at time t. In a time series framework, σ-convergence can be used to measure, whether volatility of differences between stock market returns is declining. Volatility of these differences equaling zero suggest full synchronization of stock market returns.

With regard to stock market returns, σ-convergence might be of higher importance, as it measures the similarity of the distributions of stock market returns. In this paper, we utilize this concept of σ-convergence. Our series of interest is the demeaned difference between two stock market returns ($\varepsilon_{ij,t}$) and we are interested, whether the unconditional volatility of this series (estimated by squares of $\varepsilon_{ij,t}$, i.e. the square of the distance from fully synchronized returns) has changed:

$$v_{ij,t} = S^A_{i,t} - S^A_{j,t} \tag{2}$$

$$\varepsilon_{ij,t} = v_{ij,t} - \bar{v}_{ij} \tag{3}$$

2.3 Volatility regimes

We assume, that similarly as stock market returns, $\varepsilon^2_{ij,t}$ is clustered as there are periods of: (*a*) higher stock market co-movements, when global factors govern the evolution of stock market returns on both markets, and periods of (*b*) lower stock market co-movement, when local factors dominate the evolution of respective stock market(s). Such clustering of volatility can be estimated by using GARCH models. However, we are interested in the long-run changes in volatility, or more specifically in unconditional volatility. Accession into the European Union or prevailing slowdown of economic growth in Central Europe can induce sudden changes in the co-movement of stock market returns as well.

For the estimation of sudden changes in the unconditional co-movement of stock market returns, we utilized the ICSS (Iterated Cumulative Sum of Squares) algorithm of Inclán & Tiao (1994) and κ_2 statistics proposed by (Sansó, Aragó & Carrion-Silvestre, 2004). The test based on κ_2 may be applied to auto-correlated, non-normal, and conditionally heteroskedastic series. The proposed test statistics is defined as:

$$\kappa_2 = \sup_k \left| T^{-1/2} G_k \right| \tag{4}$$

where:

$$G_k = \hat{\omega}_4^{-1/2} \left(C_k - \frac{k}{T} C_T \right) \tag{5}$$

$$C_k = \sum_{t=1}^{k} \varepsilon^2_{ij,t}, k = 1,...,T \tag{6}$$

$$\hat{\omega}_4 = \frac{1}{T} \sum_{t=1}^{T} \left(\varepsilon^2_{ij,t} - \hat{\sigma}^2 \right)^2 + \frac{2}{T} \sum_{l=1}^{m} w(l,m) \sum_{t=l+1}^{T} \left(\varepsilon^2_{ij,t} - \hat{\sigma}^2 \right) \left(\varepsilon^2_{ij,t-l} - \hat{\sigma}^2 \right) \tag{7}$$

and:

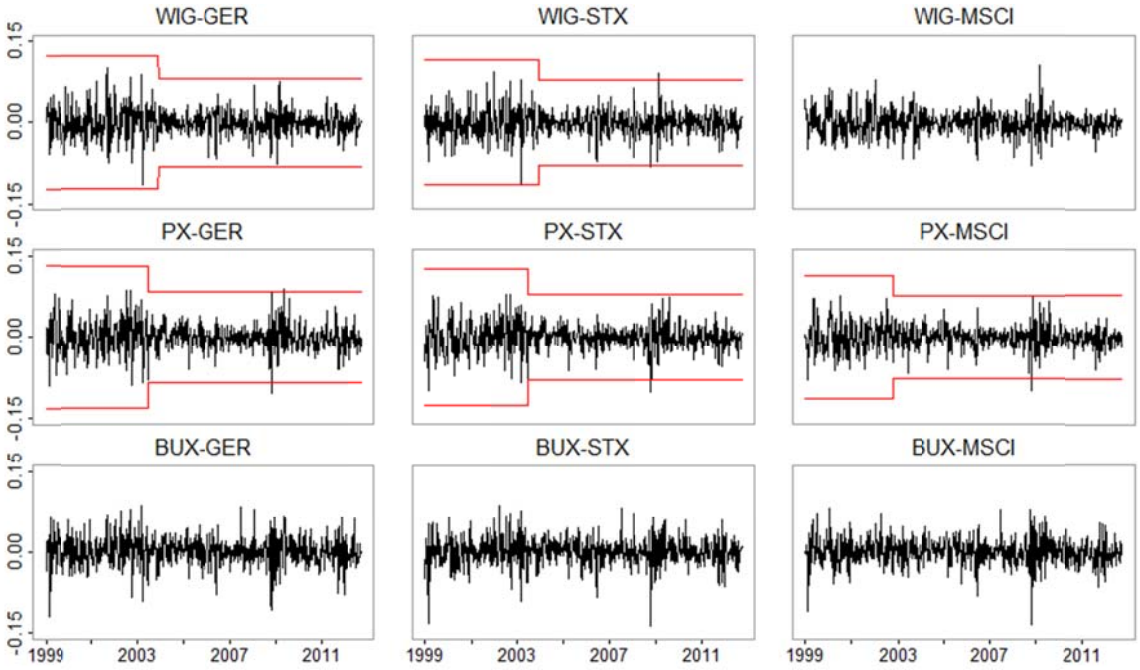
$$\hat{\sigma}^2 = \frac{1}{T} C_T \tag{8}$$

$w(l, m)$ are kernel weights. We used the standard Bartlett kernel weighting scheme defined as $w(l, m) = 1 - l/(m + 1)$, with m being the bandwidth parameter, which was estimated using the Newey-West automatic bandwidth procedure. The test statistic defined in (4) is used within the ICSS algorithm of Inclán & Tiao (1994, p. 916). Critical values for α = 0.05 were obtained from response surface regression reported in (Sansó, Aragó & Carrion-Silvestre, 2004).

3 Results

The demeaned return differences are depicted in Fig. 1 and basic statistics are provided in Tab. 1. Stock market linkages display some level of persistence in mean and volatility as well. One could argue that this autocorrelation and conditional heteroskedasticity is a manifestation of the short-run behavior of stock market co-movements, while unconditional volatility describes the long-run behavior of stock market co-movements.

Fig. 1: Demeaned return differences and volatility regimes



Source: own calculations
Notes: Volatility regimes are marked with the red lines, which correspond to +/- 4 standard deviations of return differences in a given regime.

Using the ICSS algorithm and κ_2 statistics, we have identified one sudden change in unconditional volatility for five series. Remarkably, all five sudden changes occurred within 60 weeks, from 20 October 2002 to 14 December 2003 and they all led to a decrease in unconditional volatility. The dates correspond to a period from Copenhagen summit in December 2002, where accession of new member states was announced, until late 2003, i.e. to a period, where there was little doubt, that CEE-3 countries will enter the European Union.

Tab. 1: Demeaned return differences: basic statistics

	WIG			PX			BUX		
	GER	STX	MSCI	GER	STX	MSCI	GER	STX	MSCI
std. dev.	0.0246	0.0236	0.0214	0.0258	0.0245	0.0221	0.0268	0.0258	0.0240
ACF(1)	0.1055	0.0910	0.1386	0.1705	0.1850	0.2129	0.0771	0.0710	0.1000
minLB (lag)	0.003(4)	0.002(4)	0.000(1)	0.000(1)	0.000(1)	0.000(1)	0.013(6)	0.004(2)	0.000(6)
$ACF^2(1)$	0.2643	0.1897	0.0939	0.2348	0.1933	0.1976	0.1697	0.1700	0.1987
$minLB^2$ (lag)	0.000(4)	0.000(26)	0.000(26)	0.000(4)	0.000(11)	0.000(6)	0.000(4)	0.000(10)	0.000(9)
JB (*p*-value)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Source: own calculations

Notes: "std.dev." – standard deviation; "ACF(1)" autocorrelation coefficient at lag 1; "minLB (lag)" – minimum *p*-value of the Ljung – Box test statistics (testing up to 26 lags) and the corresponding lag is in parenthesis; "$ACF^2(1)$" – autocorrelation coefficient of the squares of the series at lag 1; "$minLB^2$ (lag)" – minimum *p*-value of the Ljung – Box test statistics (testing up to 26 lags) on the squares of the series and the corresponding lag is in parenthesis; "JB (*p*-value)" – *p*-value of the Jarque – Bera normality test.

With an exception of WIG-MSCI, the decrease in volatility of return differences between emerging and developed stock markets was observed only for PX and WIG. No break was found for BUX. With regard to BUX, these results are still interesting as from Fig. 1 one could assume, that the volatility was not very high even before identified breaks found for other two CEE-3 markets. In fact, the unconditional standard deviation for the whole sample is only slightly higher for BUX than for PX and WIG return differences. This result is also in line with findings of Baumöhl & Lyócsa (2013), who have not found an increase in DCC between return of the BUX and the returns from developed markets, but at the same time, the average DCCs over the whole sample were only slightly lower than DCCs for PX and WIG.

Tab. 2: Identified breaks in unconditional volatility

	WIG	PX	BUX
GER	30.11.2003	22.6.2003	-
STX	14.12.2003	22.6.2003	-
MSCI	-	20.10.2002	-

Source: own calculations

Finally, Fig. 1 also suggests, that stock market linkages may have decreased between years 2007 and 2010. This can be seen from an increase in the volatility of the series during this period, which also covers the recent financial crisis and the start of the EU debt crisis. In this version of the paper we do not pursue this issue further, but note, that such finding is in contrast with almost all previous studies, which base their measure of market co-movement on correlations. These studies (e.g., Gijka & Horvath, 2013; Baumöhl & Lyócsa, 2013) report, that during the recent financial crisis, the stock market co-movement increased. Of course, our measure of stock market linkages is different as it measures a rather long-run behavior of stock market linkages and is also perhaps too simplistic, but it might also be that DCCs

models are extremely sensitive to outliers, i.e. presence of coexceedance. As a consequence, they might overestimate the overall stock market linkages.

Conclusion

We proposed a simple measure of stock market linkages, based on the concept of σ-convergence. This measure is the unconditional variance of the demeaned difference between two stock market returns. To measure changes in stock market linkages, we have used the ICSS algorithm of Inclán & Tiao (1994) and κ_2 statistics of (Sansó, Aragó & Carrion-Silvestre, 2004). Contrary to the prevailing approach in the literature (correlations), our approach does not consider short run dynamics of stock market linkages, but rather its long-run behavior (similarly as co-integration, but in a different way). Our approach should be also immune to the effects of contagion.

Using data from CEE-3 stock markets and three stock market indices from more developed markets, we found evidence, that the accession of Poland and the Czech Republic into the EU increased stock market linkages between their stock markets and developed stock markets, namely: PX-GER, PX-STX, PX-MSCI, WIG-GER, and WIG-STX. With regard to the stock market of Hungary, we have not found sudden changes in the unconditional volatility of return differences, but we argue, that the possible reason for this might be, that the stock market linkages were already higher before the late 2002 and 2003.

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