

Comovement Dynamics between Central and Eastern European and Developed European Stock Markets during European Integration and Amid Financial Crises – A Wavelet Analysis

Silvo Dajcman¹, Mejra Festic², Alenka Kavkler³

^{1,3} *University of Maribor*

Razlagova 14, 2000 Maribor

e-mail: silvo.dajcman@uni-mb.si, alenka.kavkler@uni-mb.si

²*Bank of Slovenia*

Slovenska 35, 1505 Ljubljana, Slovenia

e-mail: mejra.festic@bsi.si

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Stock market comovements between developed (represented in the article by markets of Austria, France, Germany, and the UK) and developing stock markets (represented here by three Central and Eastern European (CEE) markets of Slovenia, the Czech Republic, and Hungary) are of great importance for the financial decisions of international investors. From the point of view of portfolio diversification, short-term investors are more interested in the comovements of stock returns at higher frequencies (short-term movements), while long-term investors focus on lower frequencies comovements. As such, one has to resort to a time-frequency domain analysis to obtain insight about comovements at the particular time-frequency (scale) level. The empirical literature on the CEE and developed stock markets interdependence predominantly apply simple (Pearsons) correlation analysis, Granger causality tests, cointegration analysis, and GARCH modeling. None of the existent empirical studies examine time-scale comovements between CEE and developed stock market returns. By applying a maximal overlap discrete wavelet transform correlation estimator and a running correlation technique, we investigated the dynamics of stock market return comovements between individual Central and Eastern European countries and developed European stock markets in the period from 1997-2010. By analyzing the time-varying dynamics of stock market comovements on a scale-by-scale basis, we also examined how major events (financial crises in the investigated time period and entrance to the European Union) affected the comovement of CEE stock markets with developed European stock markets.

The results of the unconditional correlation analysis show that the developed European stock markets of France, the UK, Germany and Austria were more interdependent in the observed period than the CEEs stock markets. The later group of countries exhibited a lower degree of comovement between themselves as well as with the developed European stock markets during all the observed time period. The Slovenian stock market was the least correlated with other stock markets. By using the rolling wavelet correlation technique, we wanted to answer the question as to how the correlation between CEE and developed stock markets changed over the observed period. In particular, we wanted to examine whether major economic (financial) and political events in the world and European economies (the Russian financial crisis, the dot-com financial crisis, the attack on the WTC, the CEE countries joining the European union, and the recent global financial crisis) have influenced the dynamics of CEE stock market comovements with developed European stock markets. The results show that stock market return comovements between CEE and developed European stock markets varied over time scales and time. At all scales and during the entire observed time period the Hungarian and Czech stock markets were more interconnected to developed European stock markets than the Slovenian stock market was. The highest comovement between the investigated CEE and developed European stock market returns was normally observed at the highest scales (scale 5, corresponding to stock market return dynamics over 32-64 days, and scale 6, corresponding to stock market return dynamics over 32-64 and 64-128 days). At all scales the Hungarian and Czech stock markets were more connected to developed European stock markets than the Slovenian stock market. We found that European integration lead to increased comovement between CEE and developed stock markets, while the financial crises in the observed period led only to short-term increases in stock market return comovements.

Keywords: *Central and Eastern Europe, stock markets, financial crises, European Union, wavelets, commovement.*

Introduction

Stock market integration, stock market comovements, and return spillovers between developed and developing Central and Eastern European (CEE) stock markets are of great importance for the financial decisions of international investors. Increased comovements of stock market returns

may diminish the advantage of internationally diversified investment portfolios (Ling & Dhesi, 2010).

The most common method for measuring stock market comovements is linear correlation (Pearsons correlation coefficient). This is a symmetric, linear dependence metric (Ling & Dhesi, 2010) suitable for measuring dependence in multivariate normal distributions (Embrechts *et al.*, 1999).

But correlations may be nonlinear or time-varying (Xiao & Dhesi, 2010). Also, dependence between two stock markets as the market rises may be different than the dependence as the market falls (Necula, 2010). A better understanding of stock market interdependencies may be achieved by applying econometric methods. In the existing literature, the following methods are usually used to measure the level of stock market comovements: correlation coefficients (e.g. Koedijk *et al.*, 2002; Longin & Solnik, 1995), Vector Autoregressive (VAR) models (Malliaris & Urrutia, 1992; Gilmore & McManus, 2002), cointegration analysis (Gerrits & Yuce, 1999; Patev *et al.*, 2006), GARCH models (Tse & Tsui, 2002; Bae *et al.*, 2003; Cho & Parhizgari, 2008) and regime switching models (Garcia & Tsafack, 2009; Schwender, 2010). A novel, but very promising approach, is wavelet analysis.

Candelon *et al.* (2008) argued that comovement analysis should also consider the distinction between short- and long-term investors. From the point of view of portfolio diversification, short-term investors are more interested in the comovements of stock returns at higher frequencies (short-term movements), while long-term investors focus on lower frequencies comovements. As such, one has to resort to a time-frequency domain analysis to obtain insight about comovements at particular time-frequency (scale) level (Lee, 2004; Pakko, 2004; Rua & Nunes, 2009). In such a context, with both the time horizon of economic decisions and the strength and direction of economic relationships between variables that may differ according to the time scale of the analysis, a useful analytical tool may be represented by wavelet analysis (Pinho & Madaleno, 2009).

There are several studies using wavelet variance, wavelet correlation, and wavelet cross-correlation to investigate interdependence between economic (or financial) variables on different time scales (Kim and In 2005, In *et al.*, 2008, In and Kim 2006, Kim & In 2007, Gençay *et al.*, 2001a, Gallegati 2008, Conlon *et al.*, 2009, Ranta 2010, Zhou 2011). These studies confirm that interdependence between financial (or economic) variables is scale dependent, exhibiting different correlation structures at different time scales. There are no general conclusions about what scales exhibit the highest (positive) correlation: Gençay *et al.*, (2001a) found that the correlation between foreign exchange volatilities is the lowest for intra-day scales, the highest for a daily scale, and then reduces thereafter. Kim and In (2005) found a positive correlation between stock returns and inflation for the shortest scale (1 month) and for the longest scale (128 months), while a negative relationship is shown at the intermediate scales. Gallegati (2008) showed that the degree of correlation between stock returns and economic activity tends to be stronger at the intermediate and coarsest time scales than at the finest ones. Ranta (2010), investigating wavelet correlation among the major world stock indices DAX, FTSE 100, S&P 500, and Nikkei 225, found that the correlations of the S&P 500 with other indices increases from a daily time scale up to a scale of one week and then stops. The correlation between the Nikkei and the other indices peaks around a time scale of one month. Zhou (2011), investigating REIT stock markets, found that the

linkage among returns generally increases with the time scale. Ranta (2010) and Zhou (2011), using the MODWT running correlation technique, also showed that the return linkage between stock indices is time varying and its dynamics vary across scales.

The empirical literature on the CEE and developed stock markets interdependence predominantly apply simple (Pearson) correlation analysis (Serwa & Bohl 2005, Tudor 2010, Harrison & Moore 2009), Granger causality tests (Patev *et al.*, 2006, Horobet & Lupu 2009), cointegration analysis (Syllignakis & Kouretas 2006, Patev *et al.*, 2006), GARCH modeling (Scheicher 2001, Caporale & Spagnolo, 2010). None of the studies examine time-scale comovements between CEE and developed stock market returns.

Using MODWT, we aim to examine whether return comovement dynamics between the stock markets of three CEE countries (Slovenia, Hungary, and the Czech Republic) and developed European stock markets (Austria, France, Germany, and the UK) is time-varying. By analyzing the time-varying dynamics of stock market comovements on a scale-by-scale basis, we also examine how major events (financial crises in the investigated time period and entrance to the European Union) affected the comovement of CEE stock markets with developed European stock markets.

Description of the method

Wavelets mean small waves, whereas by contrast, sinus and cosinus are big waves. Wavelet by definition is any function that integrates to zero and is square-integrable. The wavelet transform is a mechanism that allows us to quantify how the averages of a time series over particular scales change from one interval of time to the next (Percival & Walden, 2000). These changes are quantified in wavelet coefficients, which form the bulk of any discrete wavelet transform.

Let¹ \mathbf{X} be an N dimensional vector whose elements represent the real-valued time series $\{x_t : t = 0, \dots, N-1\}$. For any positive integer, J_0 , the level J_0 MODWT of \mathbf{X} is a transform consisting of the $J_0 + 1$ vectors $\tilde{\mathbf{W}}_1, \dots, \tilde{\mathbf{W}}_{J_0}$ and $\tilde{\mathbf{V}}_{J_0}$, all of which have the dimension N . The vector $\tilde{\mathbf{W}}_j$ contains the MODWT wavelet coefficients associated with changes on the scale $\tau_j = 2^{j-1}$ (for $j = 1, \dots, J_0$), while $\tilde{\mathbf{V}}_{J_0}$ contains MODWT scaling coefficients associated with averages on the scale $\lambda_{J_0} = 2^{J_0}$. Based upon the definition of MODWT coefficients, we can write (Percival and Walden, 2000):

$$\tilde{\mathbf{W}}_j = \tilde{\mathbf{W}}_j \mathbf{X} \quad (1)$$

$$\tilde{\mathbf{V}}_{J_0} = \tilde{\mathbf{V}}_{J_0} \mathbf{X} \quad (2)$$

where $\tilde{\mathbf{W}}_j$ and $\tilde{\mathbf{V}}_{J_0}$ are $N \times N$ matrices. Vectors are denoted by bold fonts.

By definition, the elements of $\tilde{\mathbf{W}}_j$ and $\tilde{\mathbf{V}}_{J_0}$ are outputs obtained by filtering \mathbf{X} , namely

¹ Concepts and notations as in Percival and Walden (2000) are used.

$$\tilde{W}_{j,t} = \sum_{l=0}^{L_j-1} \tilde{h}_{j,l} X_{t-l \bmod N} \quad (3)$$

$$\tilde{V}_{j,t} = \sum_{l=0}^{L_j-1} \tilde{g}_{j,l} X_{t-l \bmod N} \quad (4)$$

for $t = 0, \dots, N-1$, where $\tilde{h}_{j,l}$ and $\tilde{g}_{j,l}$ are j th MODWT wavelet and scaling filters.

The MODWT treats the series as if it were periodic, whereby the unobserved samples of the real-valued time series $X_{-1}, X_{-2}, \dots, X_{-N}$ are assigned the observed values at $X_{N-1}, X_{N-2}, \dots, X_0$. The MODWT coefficients are thus given by:

$$\tilde{W}_{j,t}^\circ = \sum_{l=0}^{N-1} \tilde{h}_{j,l}^\circ X_{t-l \bmod N} \quad (5)$$

$$\tilde{V}_{j,t}^\circ = \sum_{l=0}^{N-1} \tilde{g}_{j,l}^\circ X_{t-l \bmod N}, \quad (6)$$

for $t = 1, \dots, N-1$; $\tilde{h}_{j,l}^\circ$ and $\tilde{g}_{j,l}^\circ$ are periodization of $\tilde{h}_{j,l}$ and $\tilde{g}_{j,l}$ to circular filters of length N . This periodic extension of the time series is known as analyzing time series $\{x_t\}$ using "circular boundary conditions" (Percival and Walden, 2000; Cornish *et al.*, 2006). There are $L_j - 1$ wavelet and scaling coefficients that are influenced by the extension ("the boundary coefficients"). The exclusion of boundary coefficients in the wavelet variance, wavelet correlation and covariance provides unbiased estimates (Cornish *et al.*, 2006).

Wavelet variance is defined for stationary and nonstationary processes with stationary backward differences. Considering only the non-boundary wavelet coefficient, obtained by filtering the stationary series with MODWT, the wavelet variance $v_X^2(\tau_j)$ is defined as the expected value of $\tilde{W}_{j,t}^2$. In this case $v_X^2(\tau_j)$ represents the contribution to the (possibly infinite) variance of $\{x_t\}$ at the scale $\tau_j = 2^{j-1}$ and can be estimated by the unbiased estimator (Percival and Walden, 2000, 306)

$$\hat{v}_X^2(\tau_j) = \frac{1}{M_j} \sum_{t=L_j-1}^{N-1} \tilde{W}_{j,t}^2 \quad (7)$$

where $M_j \equiv N - L_j + 1 > 0$ is the number of non-boundary coefficients at the j th level.

Given two stationary processes $\{x_t\}$ and $\{y_t\}$, an unbiased covariance estimator $\hat{v}_{X,Y}(\tau_j)$ is given by (Percival, 1995):

$$\hat{v}_{X,Y}(\tau_j) = \frac{1}{M_j} \sum_{t=L_j-1}^{N-1} \tilde{W}_{j,t}^{(X)} \tilde{W}_{j,t}^{(Y)} \quad (8)$$

where $M_j \equiv N - L_j + 1 > 0$ is the number of non-boundary coefficients at the j th level.

The MODWT correlation estimator for scale τ_j is obtained by making use of the wavelet cross-covariance and the square root of wavelet variances:

$$\hat{\rho}_{X,Y}(\tau_j) = \frac{\hat{v}_{XY}(\tau_j)}{\hat{v}_X(\tau_j) \hat{v}_Y(\tau_j)} \quad (9)$$

where $|\hat{\rho}_{X,Y}(\tau_j)| \leq 1$

Empirical results Data

Stock indices returns are calculated as differences of logarithmic daily closing prices of the stock indices $(\ln(P_t) - \ln(P_{t-1}))$, where P is an index closing price on trading day t or previous trading day $t-1$. The following indices are considered: LJSEX (Slovenia), PX (Czech Republic), BUX (Hungary), ATX (Austria), CAC40 (France), DAX (Germany), and FTSE100 (Great Britain). The first day of observation is April 1, 1997, the last day May 12, 2010. Days of no trading on any of the observed stock markets were left out. The total number of observations amounts to 3,060 days. Data sources of LJSEX, PX, and BUX indices are their respective stock exchanges; data source of ATX, CAC40, DAX, and FTSE100 indices is Yahoo Finance.

Table 1 presents some descriptive statistics of the data. Jarque-Bera test rejects the hypothesis of normally distributed observed time series, all indices are asymmetrically (left) distributed around the sample mean, kurtosis is greater than with normally distributed time series.

Stationarity of stock index return time series was tested using Augmented Dickey-Fuller (ADF) and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) tests, proving that all return time series are stationary (results can be obtained from the authors). Next, the most common method of measuring stock market comovements, i.e. a linear correlation (Pearson's correlation coefficient), was calculated. Table 2 presents the unconditional correlation (Pearson's correlation coefficient) results.

As results in table 2 indicate, the stock markets of France, the UK and Germany were the most interdependent. This is a common finding in existing literature (e.g. Serwa & Bohl, 2005; Harrison & Moore, 2009). The highest comovement is observed between the French and UKs stock market returns, with a correlation coefficient of 0.871. The CEEs stock markets exhibited a lower degree of comovement between themselves as well as with the developed European stock markets during the observed time period. Among the observed stock indices, the Slovenian stock market is the least correlated with other stock markets. The PX index seems to comove the most with the ATX, BUX, and FTSE100. The BUX is slightly less correlated with other observed stock indices than the PX. The highest comovement of BUX is observed with the PX, DAX, and ATX.

Wavelet correlation analysis results

The MODWT transformation of the indices return series is performed by using a Daubechies least asymmetric filter with a wavelet filter length 8 (LA8). This is a common wavelet filter in other empirical studies on financial market interdependencies (Gençay *et al.*, 2001b; Ranta 2010).

Table 1

Descriptive statistics for stock index return time series

| | Min | Max | Mean | Std. deviation | Skewness | Kurtosis | Jarque-Bera statistics |
|---------|---------|--------|-----------|----------------|----------|----------|------------------------|
| LJSEX | -0.1285 | 0.0768 | 0.0003521 | 0.01062 | -0.87 | 20.19 | 38,073.93*** |
| PX | -0.199 | 0.2114 | 0.0002595 | 0.01667 | -0.29 | 24.62 | 59,654.93*** |
| BUX | -0.1803 | 0.2202 | 0.0004859 | 0.02021 | -0.30 | 15.90 | 21,260.91*** |
| ATX | -0.1637 | 0.1304 | 0.0002515 | 0.01558 | -0.40 | 14.91 | 18,153.48*** |
| CAC40 | -0.0947 | 0.1059 | 0.0001206 | 0.01628 | 0.09 | 7.83 | 2,982.52*** |
| DAX | -0.0850 | 0.1080 | 0.0002071 | 0.01756 | -0.06 | 6.58 | 1,635.47*** |
| FTSE100 | -0.0927 | 0.1079 | 0.0000774 | 0.01361 | 0.09 | 9.30 | 5,069.61*** |

Note: The significance level of rejecting the null hypothesis of the Jarque-Bera test (i.e. the sample data come from a normal distribution with unknown mean and variance) are denoted the following way: *** indicate that the null hypothesis is rejected at the 1% significance level, ** indicate that the null hypothesis is rejected at the 5% significance level and * indicate that the null hypothesis is rejected at the 10% significance level.

Source: Own calculations.

Table 2

Unconditional correlation coefficients for the stock index returns

| | LJSEX | PX | BUX | ATX | CAC40 | DAX | FTSE100 |
|---------|-------|-------|-------|-------|-------|-------|---------|
| LJSEX | 1 | | | | | | |
| PX | 0.306 | 1 | | | | | |
| BUX | 0.244 | 0.551 | 1 | | | | |
| ATX | 0.308 | 0.597 | 0.504 | 1 | | | |
| CAC40 | 0.202 | 0.516 | 0.481 | 0.627 | 1 | | |
| DAX | 0.210 | 0.469 | 0.519 | 0.560 | 0.799 | 1 | |
| FTSE100 | 0.211 | 0.527 | 0.494 | 0.635 | 0.871 | 0.740 | 1 |

Note: Pearson's correlation coefficient is calculated. All correlation coefficients are significantly different from zero at a 1% significance level.

Source: Own calculations.

The wavelet coefficients W_1 to W_6 correspond to changes in averages over physical scales of $\tau_j = 2^{j-1}$ days, while the scaling coefficient V_6 corresponds to the averages of the index return series over the scale of $\lambda_{J_0} = 2^{J_0}$ (Percival and Walden, 2000). To achieve an optimal balance between sample size and the length of the filter, the maximum number of levels that we use in the decomposition is 6 ($J_0 = 6$). Scale 1 measures the dynamics of returns over 2-4 days, scale 2 over 4-8 days, scale 3 over 8-16 days, scale 4 over 16-32 days, scale 5 over 32-64 days, and scale 6 over 64-128 days.

Unbiased estimates for wavelet correlations are achieved by considering only non-boundary coefficients. There are 2,619 MODWT wavelet coefficients not affected by the boundary condition. A major drawback of using a higher maximum number of levels in the MODWT decomposition is losing sample size. As we also want to include the period after the start of the global financial crisis (from September 16, 2008 onwards), we decided not to take a J_0 value greater than 6. To examine if the wavelet correlation is time-varying, a rolling correlation (that is, a correlation computed in moving windows) was calculated. Using this approach, the correlation between the two stock indices return series for the time t was calculated from w observations (where w is the size of the window), centered around the time t . The window was rolled forward one day at a time, resulting in a time series of wavelet correlations. This way we obtained $N-w$ correlation coefficients. This window size of $w=200$ days was chosen (as in Ranta (2010)) to capture enough data points to obtain reasonable estimates for higher scales. By using this technique, we want to answer the question as to how the correlation between CEE and developed stock

markets changed over the observed period. In particular, we want to examine whether major economic (financial) and political events in the world and European economies (the Russian financial crisis, the dot-com financial crisis, the attack on the WTC, the CEE countries joining the European union, and the recent global financial crisis) have influenced the dynamics of CEE stock market comovements with developed European stock markets. The results are graphically presented in figures 1-4².

Wavelet rolling correlations exhibit high volatility, as evident from figures 1-4, thus indicating that correlation is not just scale dependent, but also time dependent. Similar results but for other stock markets and methods of research, were also obtained by Hue *et al.* (2008), Ranta (2010), and Zhou (2011). The first four scales exhibit relatively similar time dynamics (volatility) paths, whereas scale 6, presenting low frequency (long investment horizon) dynamics, exhibits a more independent time path.

At all scales (that is for diverse investment horizons) the Hungarian and Czech stock market returns were more correlated to developed European stock markets return dynamics than the Slovenian stock market returns. This finding can be attributed to the fact that the Czech and Hungarian stock markets have attracted many foreign

² In the figures, the Russian financial crisis (outbreak on August 13, 1998) is denoted by RFC, the Dot-Com crisis (the date, March 24, 2000, is taken as the outbreak of the crisis, when the peak of S&P500 was reached, before the dot-com crisis began) is denoted by DCC. The attack on WTC in New York (September 11, 2001) is denoted by WTC, the entrance to European Union (May 1, 2004) is denoted by EU and the outbreak of the global financial crisis (September 16, 2008) by GFC. The vertical lines indicating major event are drawn at 100 days (half the window length) before the actual date of the event, as due to the construction characteristics of rolling correlation coefficient the effect of the event should start to show up in the graph 100 days before the actual time of event.

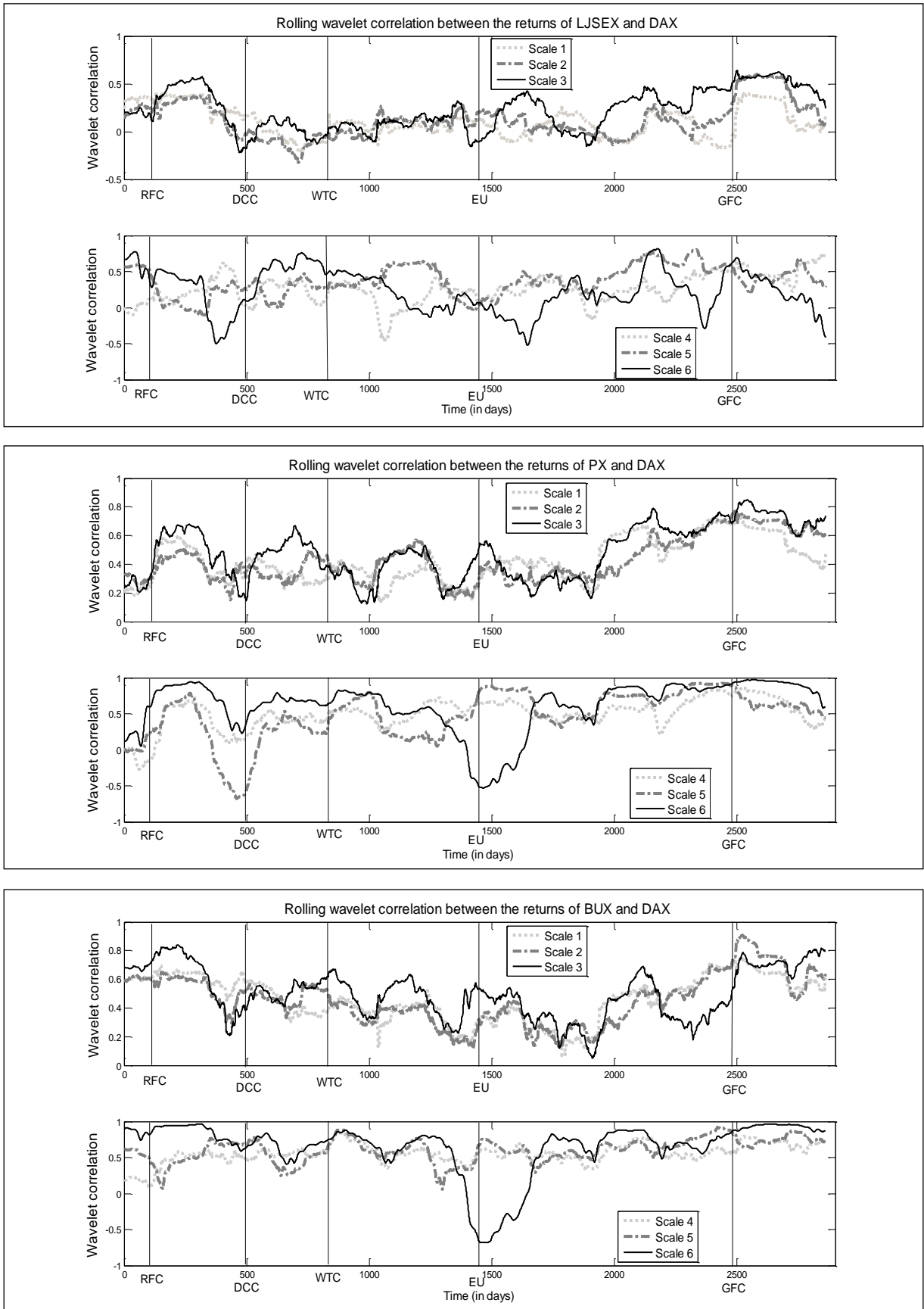


Figure 1. Rolling wavelet correlation between the CEE and the German stock market returns

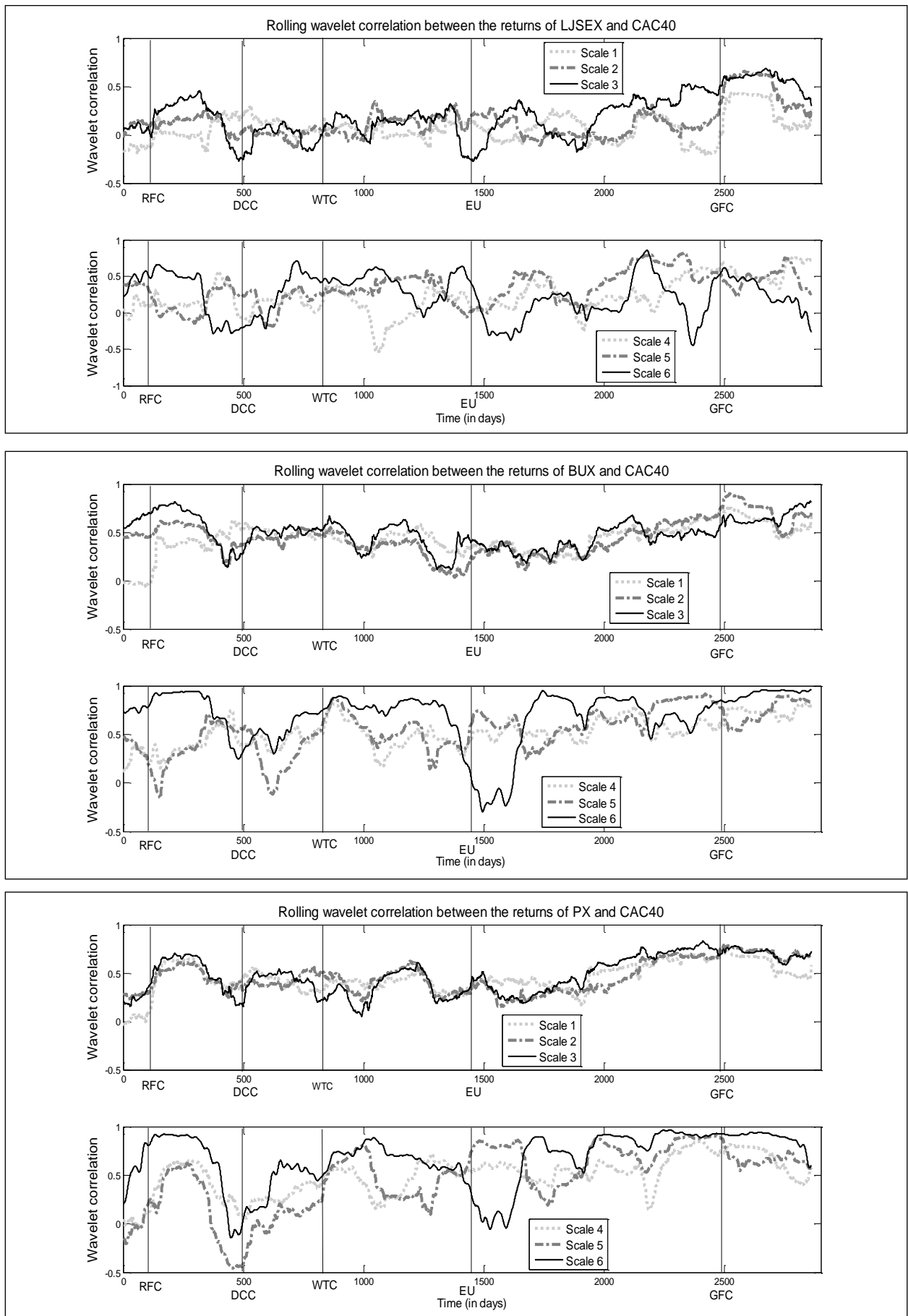


Figure 2. Rolling wavelet correlation between the CEE and the Austrian stock market returns

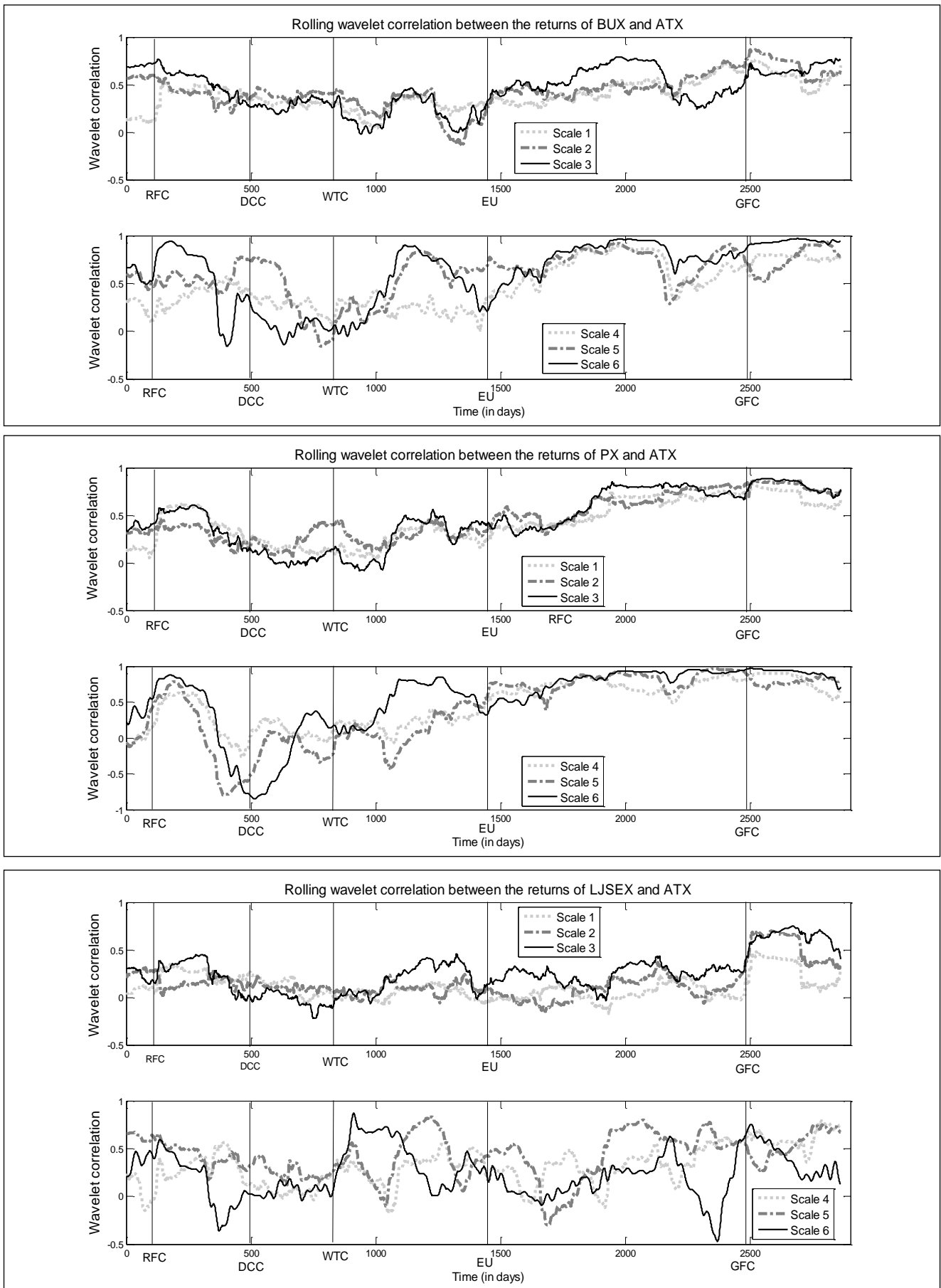


Figure 3. Rolling wavelet correlation between the CEE and the French stock market returns

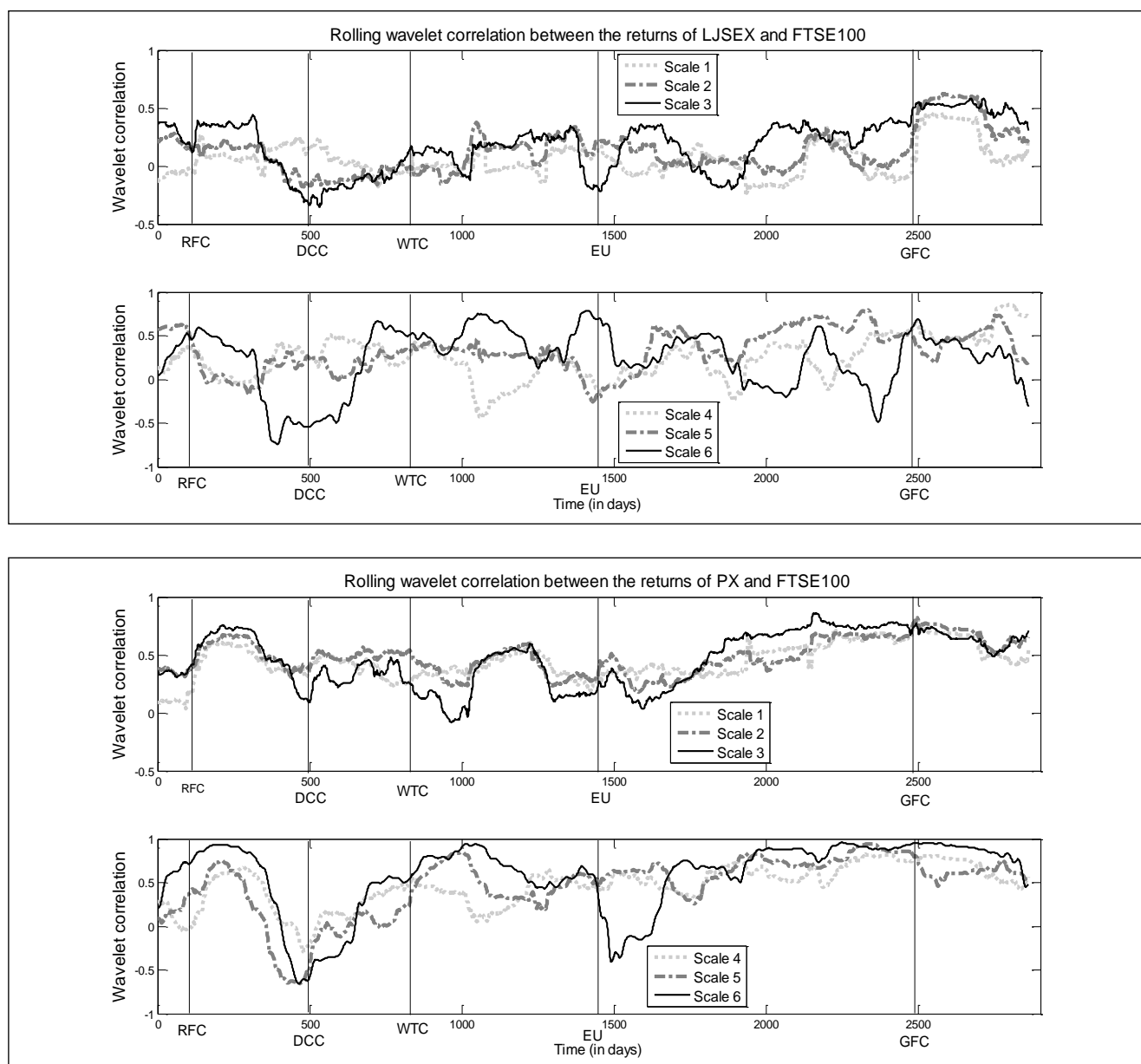


Figure 4. Rolling wavelet correlation between the CEE and the UK stock market returns

investors (Caporale and Spagnolo, 2010) while the, Slovenian stock market has struggled to do so. Further, the liquidity of shares listed on the Ljubljana stock exchange is significantly smaller than on the Prague and Budapest stock exchanges³, which according to a recent study of Didier et al. (2011) can lead to a smaller comovement with foreign stock markets.

Since joining the European Union, the correlation of CEE stock markets with the developed European stock markets has increased. The result was expected, as there is plenty of evidence that European integration should've lead to the increasing interdependence of financial

markets⁴. Our research shows that this holds true for shorter investment horizons, corresponding to shorter wavelet scales, as well as longer investment horizons, corresponding to higher wavelet scales.

The financial market crises covered by our study (the Russian financial crisis, dot-com, and global financial crisis) were observed to have a short lasting (of about 100-400 days) effect on stock markets comovements. We found that at the start of the financial market turmoil the comovement of the CEE's stock markets with developed European stock markets normally increases, while after a period of 100-400 days reduces. This is particularly

³ Market capitalization of the companies listed at the Ljubljana stock exchange at the end of year 2010 was 6,994 million EUR and the yearly turnover (stock trading activity) was 457 million EUR. The Budapest stock exchange capitalization was 20,888 million EUR and turnover 20,000 million EUR. Stock market capitalization of the Prague stock exchange was 31,265 million EUR and the yearly turnover reached 15,400 million EUR.

⁴ Empirical studies of the effects of European integration on interdependence of the developed European stock markets, that confirm this finding, are e.g. Koch and Koch (1991), Kasa (1992), Longin and Solnik (1995) and Bessler and Yang (2003). For the CEE stock markets, this was confirmed by the studies of Syllignakis and Kouretas (2006), Harrison and Moore (2009), Allen *et al.* (2010), Caporale and Spagnolo (2010).

apparent at the shorter time scales (scales 1, 2, and 3). Similarly to our study, but only for daily returns, Patev *et al.* (2006) also found evidence of only short-term effects on increased stock market comovements of CEE stock markets with developed stock markets.

The global financial crisis (the collapse of Lehman Brothers, on September 16, 2008 is taken as the major event that transmitted the financial crisis from the US to world financial markets) had a major impact on Slovenian and Hungarian stock market comovement with developed European stock markets, especially for short investment horizons (scales 1, 2, and 3). The interconnection of CEE with developed European stock markets for the whole observed period (1997-2010) was the highest during the period between the end of 2008 and the first half of 2009. Similar to previous financial crises, the strength of comovement reduced afterwards, but it reduced more for the LJSEX and BUX indices than for the PX.

Conclusions

Stock market comovement dynamics between developed stock markets (represented in this paper by the Austrian, French, German, and UK markets) and developing stock markets (represented by three CEE markets: Slovenia, the Czech Republic, and Hungary) is of great importance for the financial decisions of international investors. We argued that a comovement analysis should consider the distinction between short- and long-term investors. From the point of view of portfolio diversification, short-term investors are more interested in the comovements of stock returns at higher frequencies (short-term movements), while long-term investors focus on lower frequencies comovements. We used MODWT tools to investigate multiscale comovement dynamics

between investigated stock markets. In the empirical part of the paper we first applied the unconditional (Pearson's) correlation analysis and found, that on average the investigated developed stock market exhibited a higher comovement between themselves than CEE's stock markets exhibited between themselves as well as with the developed European stock markets. Among the observed stock indices, the Slovenian stock market was least correlated with other stock markets.

Next we applied a rolling wavelet correlation technique and showed that stock market return comovement between CEE and developed European stock markets in the period 1997-2010 varied over time and over time scales. The highest comovement between the investigated stock market returns is normally achieved at the highest scales (scale 5, corresponding to stock market return dynamics over 32-64 days, and scale 6, corresponding to stock market return dynamics over 32-64 and 64-128 days). At all scales the Hungarian and Czech stock markets were found to be more connected to developed European stock markets than the Slovenian stock market. This can be attributed to the fact that the Czech and Hungarian stock markets have attracted foreign investors and their stock market being more liquid than the Slovenian stock market.

The financial market crises covered by our study (the Russian financial crisis, dot-com and global financial crisis) were observed to have a short-lasting (of about 100-400 days) effect on stock markets comovements. An important implication of our study is that foreign investors in CEE stock markets should investigate wavelet scale correlations between the stock markets that correspond to their investment horizons.

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Silvo Dajcman, Mejra Festic, Alenka Kavkler

Bendrų veiksmų tarp Centrinės ir Rytų Europos bei išsivysčiusių Europos biržų dinamika Europos integracijos metu ir finansinių krizių metu: bangų teorijos analizė

Santrauka

Bendras akcijų rinkų judėjimas tarp išsivysčiusių (Austrija, Prancūzija, Vokietija ir JK biržos) ir besivystančių akcijų rinkų (trijų Centrinės ir Rytų Europos šalių: Slovėnijos, Čekijos respublikos ir Vengrijos) yra labai svarbus tarptautinių investuotojų finansiniams sprendimams. Trumpalaikiai investuotojai yra labiau suinteresuoti dažnesne rinkos bendro judėjimo apyvarta (trumpalaikiu judėjimu), nei ilgalaikiai investuotojai. Pastarieji sutelkia dėmesį į ne tokį dažną bendrą judėjimą. Norint suprasti bendrą judėjimą tam tikruose laiko dažnumo lygiuose (skalėse), reikia panaudoti laiko dažnumo srities analizę. Dažniausiai naudojamas akcijų rinkos įvertinimo metodas yra *linijinė koreliacija* (Pearson koreliacijos koeficientas). Tai simetriška, linijinė metrika, tinkanti priklausomybei įvertinti įvairiai kintančiuose standartiniuose išsidėstymuose. Tačiau nustatyta, kad koreliacijos gali būti nelinijinės arba kintančios tam tikrą laiką. Dviejų akcijų rinkų priklausomybė viena nuo kitos priklauso nuo rinkos augimo ir kritimo. Empirinėje literatūroje, nagrinėjančioje Centrinės ir Rytų Europos bei išsivysčiusių akcijų rinkų tarpusavio priklausomybę, dažniausiai taikoma paprasta (Pearson) koreliacijos analizė, Granger priežastingumo tyrimai, Bendros integracijos analizė ir GARCH modeliavimas. Nė vienas iš jau esančių empirinių darbų netiria laiko skalių bendro judėjimo tarp Centrinės ir Rytų Europos bei išsivysčiusių akcijų rinkų apyvartą.

Taikant maksimalaus dubliavimo pavienio bangelės pakeitimo koreliacijos įvertinimą ir nenutrūkstamos koreliacijos metodą, buvo iširta akcijų rinkos apyvartos bendro judėjimo dinamika tarp atskirų Centrinės ir Rytų Europos šalių ir Europos išvystytų akcijų rinkų 1997-2010 m. laikotarpiu. Analizuojant akcijų rinkos bendro judėjimo kitimo dinamiką remiantis skale, buvo tirta, kaip svarbiausi įvykiai (finansinės krizės tyrimo laikotarpiu ir įstojimo į Europos Sąjungą metu) paveikė Centrinės ir Rytų Europos akcijų rinkų ir Europos išsivysčiusių akcijų rinkų bendrą judėjimą.

Remiantis ekonometrine metodika, buvo pateikta tam tikra apyvartos „laiko serijas“ apibūdinanti statistika (buvo nagrinėta tokių kasdiniinių akcijų indeksų apyvarta: LJSEX (Slovėnijoje), PX (Čekijos respublikoje), BUX (Vengrijoje), ATX (Austrijoje), CAC40 (Prancūzijoje), DAX (Vokietijoje), ir FTSE100 (Didžiojoje Britanijoje)). ADF ir KPSS testai patvirtino, kad „laiko serijos“ yra stacionarios.

Pearson (besąlyginės) koreliacijos rezultatai rodo, kad išsivysčiusių Europos šalių: Prancūzijos, JK, Vokietijos ir Austrijos akcijų rinkos stebėjimo metu tarpusavyje buvo labiau susijusios. Centrinės ir Rytų Europos akcijų rinkų bendrasis judėjimas tarpusavyje buvo mažesnis, panašiai kaip ir su Europos išsivysčiusiomis akcijų rinkomis. Slovėnijos akcijų rinka buvo mažiausiai koreliuota su kitomis akcijų rinkomis.

Naudojant svyruojančios bangelės koreliacijos metodą, buvo siekiama atsakyti, kaip koreliacija tarp Centrinės ir Rytų Europos bei išsivysčiusių šalių akcijų rinkų pasikeitė stebėjimo laikotarpiu. Ypač svarbu buvo nustatyti ar svarbiausi ekonominiai finansiniai ir politiniai įvykiai pasaulyje ir Europos šalyse (Rusijos finansinė krizė, dot-com finansinė krizė, Pasaulinio prekybos centro „ataka“, Centrinės ir Rytų Europos šalių prisijungimas prie Europos Sąjungos, paskutinė pasaulinė finansinė krizė) paveikė Centrinės ir Rytų Europos akcijų rinkos bendro judėjimo su Europos išsivysčiusiomis akcijų rinkomis dinamiką. Naudojant šį metodą, koreliaciją tarp dviejų akcijų indeksų apyvartos serijų laikui t buvo apskaičiuota iš w stebėjimų (kur w yra ekrano dydis dienomis), sukaupia apie laiką t . Ekranas buvo pakreiptas laike viena diena į priekį, dėl to susidarė laiko serijų bangelė koreliacijos. Tokiu būdu mes gavome $N-w$ koreliacijos koeficientus. 200 dienų Ekranas dydis buvo tikrinamas norint sukaupti pakankamai duomenų, kad būtų galima gauti patikimus įvertinimus aukštesnėms skalėms.

Svyruojančios bangelė koreliacijos analizės rezultatai rodo, kad akcijų rinkos apyvartos bendras judėjimas tarp Centrinės ir Rytų Europos ir Europos išsivysčiusių akcijų rinkų keitėsi laiko skalėse ir tam tikru laiku. Viso stebėjimų laikotarpio metu, visose skalėse Vengrijos ir Čekijos akcijų rinkos buvo daugiau tarpusavyje susijusios su Europos išsivysčiusiomis akcijų rinkomis, nei Slovėnijos akcijų rinka. Aukščiausias bendras judėjimas tarp tirtų Centrinės ir Rytų Europos bei Europos išsivysčiusių akcijų rinkų apyvartą dažniausiai buvo pasiektas aukščiausiose skalėse (skalė 5, atitinkanti akcijų rinkos apyvartos dinamiką per 32-64 dienų, ir skalė 6, atitinkanti akcijų rinkos apyvartos dinamiką per 32-64 ir 64-128 dienų). Visose skalėse Vengrijos ir Čekijos akcijų rinkos buvo labiau susietos su Europos išsivysčiusiomis akcijų rinkomis negu Slovėnijos akcijų rinka. Paaiškėjo, kad Europos integracija turėjo nemažą reikšmę didesniajam bendram judėjimui, o finansinės krizės stebėjimo metu (Rusijos finansinė krizė, dot-com, ir pasaulinė finansinė krizė) tai buvo tik trumpalaikė (maždaug 100-400 dienų trukmės) įtaka akcijų rinkų bendram judėjimui. Buvo nustatyta, kad rinkos finansinės sumaišties pradžioje Centrinės ir Rytų Europos akcijų rinkų bendras judėjimas su Europos išsivysčiusiomis rinkomis dažniausiai padidėdavo, o po 100-400 dienų laikotarpio sumažėdavo. Tai buvo labai aiškiai matyti trumpesnėse laiko skalėse (skalės 1, 2, ir 3, atitinkančios 2-4 dienas, 4-8 dienas ir 8-16 dienų).

Pasaulinė finansinė krizė didžiausią įtaką padarė Slovėnijos ir Vengrijos akcijų rinkų bendram judėjimui su išsivysčiusios Europos akcijų rinkomis, ypač trumpalaikių investicijų diapazone (skalės 1, 2, ir 3). Aukščiausias tarpusavio ryšys tarp Centrinės ir Rytų Europos bei Europos išsivysčiusių akcijų rinkų per visą stebėtą laikotarpį (1997-2010 metais) buvo nuo 2008 metų pabaigos iki 2009 metų pirmojo pusmečio. Panašiai buvo su ankstesnėmis finansinėmis krizėmis, vėliau bendro judėjimo stiprumas mažėjo, tačiau LJSEX ir BUX indeksams jis sumažėjo daugiau, negu PX.

Raktažodžiai: *Centrinė ir Rytų Europa, akcijų rinkos, finansinės krizės, Europos Sąjunga, bangelės, bendras judėjimas.*

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