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The Evolution of Financial Integration on Selected European Stock Markets: a Dynamic Principal Component Approach¹

Abstract

The goal of this paper is to recognize the dynamics of financial integration across the European stock markets over the last two decades. We investigate two groups of markets: (1) three developed European markets in the U.K., France, and Germany; and (2) three emerging Central and Eastern European markets in Poland, the Czech Republic, and Hungary (CEE–3). The evolution of the integration process is analyzed using a dynamic principal component approach. The index of integration serves as a robust measure of integration. The empirical results reveal that the dynamics of integration across the whole group of markets increased significantly following the CEEC–3's accession to the European Union. An inverted U-shape in the index of integration has been found in this case. Moreover, the average index of integration was significantly different during the Global Financial Crisis compared to the pre-crisis period.

Keywords: *European stock markets, dynamic principal component analysis, index of integration, Global Financial Crisis*

JEL: *C10, F36, F65, G01, G15, O52, O57*

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1. Introduction

The literature has shown that financial integration across stock markets is a crucial topic, owing to its many practical implications, especially in the context of international portfolio choice and diversification. According to the portfolio theory, the motivations and gains of international diversification rely on low correlations across equity markets in the world. The presence of a low correlation between foreign and domestic stock market returns allows an investor to smooth out portfolio risk without reducing portfolio expected return by adding foreign assets in the domestic portfolio. Unfortunately, a relatively high degree of financial integration is usually coupled with high cross-market correlations and therefore it might produce a substantial drop in cross-border portfolio diversification benefits.

It has been reported in the literature that the level of financial integration across markets varies over time. The evidence shows that capital markets are becoming increasingly integrated. The extent of international financial integration has important implications for economic theory and policy debates. Although integrated financial markets have easier access to foreign capital, they are more vulnerable to various global events, for example financial crises. Undoubtedly, the causes and consequences of the 2007–2009 Global Financial Crisis (GFC) have been strictly connected with international financial integration between markets. On one hand, the crisis transmission through financial and banking channels has been very rapid and substantial. Pisani-Ferry and Sapir (2010) stress that the European banks were particularly vulnerable given the high degree of internationalization in their activities, both within the euro area and outside. On the other hand, the degree of financial integration between the European financial markets (including the Central and Eastern European (CEE) emerging markets) increased substantially during such a critical event as the GFC. Another event that had a significant impact on the group of CEE markets was their accession to the European Union (EU) on the 1st of May 2004. Among other things, the so-called CEE–3 countries (that is Poland, the Czech Republic and Hungary)² were successful in the negotiations with the EU which led to them accessing the European Union. The financial integration between the emerging and developed European markets has critical implications for stock market comovements

As international market integration varies over time, the dynamics of this process merit deeper investigation. Therefore, the main goal of this paper is to recognize and assess the dynamics of financial integration processes across the European stock markets over the last two decades. The dynamic principal component analysis is applied to investigate the evolution of the integration process in a group

² A popular abbreviation for three biggest emerging European stock markets in Poland, Hungary and Czech Republic is the CEE–3 or the CEEC–3 (e.g. Olbryś, Majewska 2015a).

of markets. The index of integration (Volosovych 2011), which measures the proportion of total variation in individual stock index logarithmic returns explained by the first principal component, serves as a robust measure of integration.

The main contribution of this paper is twofold. Firstly, we explore whether the dynamics of financial integration processes across the groups of the European stock markets increased significantly during the GFC. The long-term sample period begins in October 1993 and ends in December 2015, and includes the 2007 U.S. subprime crisis period.³ The GFC period on the European developed and emerging stock markets have been formally assessed in papers (Olbrys, Majewska 2014; 2015a). In those studies, the Pagan and Sossounov (2003) method for statistical identification of market states was employed. The period from December 2007 to February 2009 was used as the common GFC period for the United Kingdom, France, Germany, and the U.S. (Olbrys, Majewska 2014), while October 2007 to February 2009 was confirmed as the common GFC period for Poland, the Czech Republic, Hungary, and the U.S. (Olbryś, Majewska 2015a). As Donadelli and Paradiso (2014) stress, a sub-period analysis allows us to examine whether the presence of crises affected the degree of equity market integration. Our empirical results revealed that the average index of integration was significantly different during the Global Financial Crisis compared to the pre-crisis period in both groups of markets. Secondly, we recognized that the dynamics of the financial integration process between the six European equity markets increased significantly after the CEEC-3 accession to the EU. An inverted U-shape in the index of integration has been found in the post-accession period.

To the best of our knowledge, no such research has been undertaken for the European stock markets thus far.

The remainder of this study is organized as follows. Section 2 presents a brief review of the literature concerning financial integration processes in the world, in the context of a dynamic approach. Section 3 specifies the methodological background of the dynamic principal component analysis and the index of integration. In Section 4, we present a data description and the empirical results concerning the dynamics of financial integration processes on the European stock markets. Section 5 recalls the main findings and presents conclusions.

³ The stock exchanges in Poland and Hungary began at the beginning of 1991, while the stock market in Prague was created in mid-1993. Therefore, the sample begins in October 1993.

2. Measuring Dynamics of Financial Integration on Stock Markets: Evidence in the Literature

There is no unanimity in the literature regarding the definition of integration. Bekaert et al. (2005) point out that integration can be regional or global. Beine et al. (2010) distinguish between trade and financial integration. Chambet and Gibson (2008) investigate whether the structure of emerging economies' trade policies influences the observed evolution of their levels of financial integration. The empirical results suggest that trade openness and financial integration are complementary rather than substitutes. Hardouvelis et al. (2006) assert that when stock markets are partially integrated, both global and local risk factors are priced. Bekaert and Harvey (1995) assume that markets are completely integrated if assets with the same risk have identical expected returns irrespective of the market. Risk refers to exposure to some common world factors. If a market is segmented from the rest of the world (which is the opposite of integration), its covariance with a common world factor may have little or no ability to explain its expected return. Intuitively, a quantitative measure of financial integration might be the proportion of an individual stock market return that can be explained by global factors. Pukthuanthong and Roll (2009) stress that although the degree of integration may seem intuitively apparent to many, quantitative measures of integration have not often agreed with the intuition.

The majority of researchers indicate that financial markets in the world exhibit time-varying integration. Obstfeld and Taylor (2003, p. 127) present a stylized view of capital mobility in modern history, 1860–2000. A figure of global capital market integration reveals the overall U-shaped trend line. Moreover, Donadelli and Paradiso (2014) indicate that markets do not necessarily follow identical dynamics and therefore one can observe three different financial integration patterns: (1) an increasing trend, (2) a J-shaped trend, or (3) a U-shaped trend.

Another issue is investigated by Bekaert et al. (2002). The authors recognize the problem of dating the integration of equity markets in the context of liberalization. They indicate that the market integration date is usually later than the official liberalization date announced by government decrees, albeit researchers often assume that the liberalization date is the market integration date. Moreover, de Jong and de Roon (2005) emphasize that most of the literature treats liberalization as a one-shot event, assuming that markets are completely segmented before the official liberalization date and perfectly integrated after that date. However, in reality the degree of segmentation or integration changes only gradually over time.

According to the literature, the evidence shows that growing international integration and globalization could lead to a progressive increase in cross-market correlations, especially in periods of high volatility (Longin, Solnik 1995, p. 6). Moreover, Longin and Solnik (2001) find that international stock market correla-

tions increase in bear markets, but not in bull markets. There are many studies analysing the evolution of stock market integration over time, using various methods based on correlations. For example, Büttner and Hayo (2011) analyse the determinants of stock market integration among the EU member states and apply bivariate DCC-MGARCH models to extract dynamic conditional correlations between the European markets. The authors stress that the impact of the European political and economic integration on European stock market integration has been studied more intensively. The empirical results reveal that in general the impact of the European political integration on financial market integration is stronger than the evidence for the influence of macroeconomic factors (see Büttner, Hayo 2011 and the references therein). Harkmann (2014) uses the DCC-GARCH methodology to investigate the impacts of the sovereign debt crisis on selected CEE stock markets. The results confirm that the DCCs increased between 2002 and 2012, which could be attributed to closer financial integration.

The evaluation of integration has been often carried out by applying tests interpreted as integration (globalization) tests in a group of stock markets. Integration has been evaluated by employing the equality tests of correlation matrices computed over non-overlapping subsamples: the pre-crisis and crisis periods (for example Longin, Solnik 1995; Chesnay, Jondeau 2001; Goetzmann et al. 2005; Brière et al. 2012; Olbryś, Majewska 2015b). The null hypothesis states that there is no integration effect during a crisis. To address this issue, different test statistics have been proposed in the literature, for example the Jennrich (1970) or the Larntz-Perlman (1985) tests. However, the robustness analysis reveals that the empirical results of integration effects are not homogeneous, and they are linked both to the integration test and data frequency (Olbryś, Majewska 2015b).

It is worth noting that the approach of measuring financial integration using correlations is often considered as questionable and has been amply discussed in the literature. Among others, Pukthuanthong and Roll (2009) point out that cross-country correlations, as the most widely used measures of integration, are flawed. The authors stress that the correlation across markets is a poor measure because even perfectly integrated markets can exhibit a weak correlation. This occurs whenever there are multiple global sources of return volatility and individual stock markets do not share the same sensitivities to all of them. Moreover, Carrieri et al. (2007) provide evidence on the impropriety of directly using stock market correlations of market-wide index returns as a measure of market integration. The authors stress that such an approach is problematic because it does not control for economic fundamentals within each country.

Volosovych (2011; 2013) emphasizes that various interpretational and statistical issues make the correlation coefficient an inadequate measure of integration. Firstly, the choice of the reference market might be problematic over a relatively long-term period. Secondly, the sample correlation is not a robust statistic in the presence of outliers or a heavy-tailed distribution. Thirdly, conclusions drawn

from correlations may be biased by the conditional heteroskedasticity of market returns. Forbes and Rigobon (2002) argue that correlation coefficients are conditional on market volatility. Furthermore, if the financial markets are affected by a global shock in a similar fashion, the cross-market correlations might be high even without significant integration. To avoid these problems, Volosovych (2011) proposes a methodology extending the classic principal component analysis (PCA) to capture the dynamics of financial integration processes.

3. Dynamic Principal Component Analysis

The classical Principal Component Analysis (PCA) has been employed in several studies, either by itself or to complement other techniques of measuring financial integration. For example, Nellis (1982) utilized PCA to investigate to what extent international financial integration has been enhanced as a result of the move to a floating exchange rate regime by the major industrialized countries in the early 1970s. Gagnon and Unferth (1995) used panel data techniques to estimate a common component to the ex post real interest rates of nine countries with liberal capital markets over 16 years. The authors conducted PCA and they found that the first principal component explains over 64 percent of the total variance, and it is clearly the world real interest rate, with nearly identical loadings on every country's real interest rate. Mauro et al. (2002) analysed yield spreads on sovereign bonds issued by emerging markets and they used a variety of statistical techniques, including PCA. The authors point out that there is a growing consensus in the literature⁴ that global economic integration reached a peak in the late nineteenth and early twentieth century, collapsed with the world wars and the intervening great depression, and gradually increased again after the collapse of the Bretton Woods system to attain levels similar to pre-1914. Bordo and Murshid (2006) applied PCA, among other methods, to compare the patterns in the transmission of shocks and currency crises during two periods of globalization: (1) the pre-WWI classical gold standard era, 1880–1914, and (2) the post-Bretton Woods era, 1975–2001. Their results suggest that financial market shocks were more globalized before 1914 compared to the present. Gilmore et al. (2008) examined comovements between developed European stock markets and three Central European countries (i.e. Poland, the Czech Republic and Hungary) and they applied dynamic PCA to explain the maximum variation in the set of market returns. Pukthuanthong and Roll (2009) investigated the issue concerning a global market integration and they employed the classic PCA to estimate a set of global factors with principal components. As proxies for glob-

⁴ For more details, see e.g. (Obstfeld, Taylor 2003).

al factors in a multi-factor model for 17 countries, the authors retained the first 10 principal components, which generally account for close to 90 percent of the total volatility in the covariance matrix. Subsection 3.1 presents a brief methodological background of the classical principal component approach.

3.1. Classical Principal Component Analysis (PCA) – Methodological Background

PCA is a non-parametric empirical methodology used to reduce the dimensionality of data and describe common features of a set of economic variables. The main idea of this procedure is to reduce the dimensionality of a data set consisting of a large number of interrelated variables, while retaining as much as possible of the variation present in the data. This is achieved by transforming, to a new set of variables, the principal components which are uncorrelated, and those which are ordered so that the first few retain most of the variation present in all of the original variables (Jolliffe 2002).⁵

Suppose that \mathbf{x} is a vector of p random variables, and that the variances of these variables and the structure of the covariances or correlations between them are of interest. The $\hat{\mathbf{O}}$ is a covariance (or correlation) matrix of elements of vector \mathbf{x} . The first step of PCA is to look for a linear function $\hat{\mathbf{a}}_1^T \mathbf{x}$ of elements of a vector \mathbf{x} (the first principal component) having maximum variance and given by equation (1):

$$\hat{\mathbf{a}}_1^T \mathbf{x} = \alpha_{11}x_1 + \alpha_{12}x_2 + \dots + \alpha_{1p}x_p = \sum_{j=1}^p \alpha_{1j}x_j, \quad (1)$$

where $\hat{\mathbf{a}}_1$ is a vector of p constants $\alpha_{11}, \alpha_{12}, \dots, \alpha_{1p}$. The next step is to look for a linear function $\hat{\mathbf{a}}_2^T \mathbf{x}$ (the second principal component), uncorrelated with $\hat{\mathbf{a}}_1^T \mathbf{x}$ and having maximum variance, and so on. The k -th derived variable is the k -th principal component and it is given by equation (2):

$$z_k = \hat{\mathbf{a}}_k^T \mathbf{x}, \quad k = 1, 2, \dots, p, \quad (2)$$

where $\hat{\mathbf{a}}_k$ is an eigenvector of $\hat{\mathbf{O}}$ corresponding to its k -th largest eigenvalue λ_k . Furthermore, if $\hat{\mathbf{a}}_k$ is chosen to have unit length, that is $\hat{\mathbf{a}}_k^T \hat{\mathbf{a}}_k = 1$, then $\text{var}(z_k) = \lambda_k$ (Jolliffe 2002, pp. 2–4).

⁵ For a brief history of PCA, see (Jolliffe 2002, pp. 6–9).

As for the notation (which is sometimes confusing), it is preferable to reserve the term ‘principal component’ for the derived new variable z_k and refer to $\hat{\mathbf{a}}_k$ as the vector of coefficients or loadings for the k -th principal component.

PCA is scale dependent. The principal components of a covariance matrix and those of a correlation matrix are different. In applied research, PCA of a covariance matrix is useful only if the variables are expressed in commensurable units. When variables are measured along different scales or variables’ standard deviations are different from each other, the variables with larger standard deviation might have a larger weight by construction. In such a case, it is advisable to calculate the components from the sample correlation matrix, which is analogous to standardizing all the variables prior to calculation (Jolliffe 2002, p. 21; Volosovych 2011).

3.2. Dynamic Principal Component Approach: The Index of Integration

As mentioned in the previous subsection, the goal of PCA is to capture most of the observed variability in the data in a lower-dimensional object, and thereby filter out noise. Volosovych (2011; 2013) stresses that very often a single component summarizes most of the variation of the original data. The author argues that the first principal component has a natural interpretation when PCA is applied to a comparable (such as price, return) series across markets. The proportion of total variation in individual returns explained by the first principal component serves as an index of integration. The main idea of a dynamic principal component approach is to estimate the index of integration over a long time period via rolling windows, which enables us to reveal important patterns and trends in financial integration processes.

Donadelli and Paradiso (2014) follow Volosovych (2011; 2013) and they employ the index of integration as a robust measure of the financial integration process in one global emerging region and three emerging sub-regions (Asia, Eastern Europe, Latin America). They divide the whole sample period into three specific sub-periods. The first period includes pre–2003 observations and is influenced by relevant international crises (that is the Asian and Russian crises). The second period includes 2003–2007 observations and is not contaminated by crises. The third period encompasses post–2007 data and it includes the GFC. The authors use the percentage of variance in equity excess returns explained by the first principal component. To obtain a dynamic integration index, they perform PCA in a rolling window framework. In their opinion, the choice of using the dynamic PCA approach is motivated by several factors, the most important of which is that this methodology is weakly affected by outliers and breaks in the series.

While in this research the dynamic index of integration is employed, it is worth mentioning that the nomenclature concerning a dynamic PCA is not unambiguous

and there exist alternative frameworks in the literature. For example, Sensoy et al. (2014) construct a financial fragility index by combining the methods of PCA and dynamic conditional correlations. The authors stress that their approach is a dynamic version of PCA.

4. Measuring Dynamics of Financial Integration in Selected European Stock Markets

The data consists of monthly logarithmic returns of six European stock market indexes (FTSE100, CAC40, DAX, WIG, PX, BUX), and the New York market index (S&P500). There are 267 monthly observations for each series for the long period beginning October 1993 and ending December 2015.

4.1. Preliminary Statistics

Table 1 presents brief information about the European stock market indexes employed in the study, in order of decreasing value of market capitalization at the end of 2015.

Table 1. The European stock market indexes used in the study

	Market	Market Cap., EUR billion, Dec 2015	Index
1	London	3009.528	FTSE100
2	Paris	1911.228	CAC40
3	Frankfurt	1781.586	DAX
4	Warsaw	127.769	WIG
5	Prague	23.323	PX
6	Budapest	16.344	BUX

Source: <http://sdw.ecb.europa.eu/>

Table 2 reports summarized statistics for the monthly logarithmic returns for the S&P500 and six European stock indexes: FTSE100, CAC40, DAX, WIG, PX, and BUX, as well as statistics testing for normality and interdependence.

Several results in Table 2 are worthy of comment. The measure for skewness shows that the return series are skewed, except for the WIG and BUX series. The measure for excess kurtosis shows that almost all series (except for the CAC40 series) are highly leptokurtic with respect to the normal distribution. The Doornik and

Hansen (2008) test rejects normality for each of the return series at the 5 percent level of significance. The Ljung-Box (1978) statistic at the lag $q \approx \ln T$, where T is the number of data points (Tsay 2010), calculated for the return series indicates the presence of significant linear dependencies in almost all cases, except for the PX series.

Table 2. Summarized statistics for monthly logarithmic returns for the U.S. and European stock market indexes used in the study

	Index	Mean	Standard deviation	Skewness	Excess kurtosis	Doornik-Hansen test	LB(6)
1	S&P500	0.006	0.043	-0.849 [0.000]	1.670 [0.000]	26.602 [0.000]	7.393 [0.286]
2	FTSE100	0.003	0.041	-0.693 [0.000]	0.674 [0.025]	21.833 [0.000]	5.689 [0.459]
3	CAC40	0.003	0.055	-0.535 [0.000]	0.466 [0.121]	12.494 [0.002]	5.521 [0.479]
4	DAX	0.006	0.063	-0.857 [0.000]	2.583 [0.000]	29.883 [0.000]	1.786 [0.938]
5	WIG	0.007	0.093	-0.261 [0.082]	4.603 [0.000]	108.594 [0.000]	4.950 [0.550]
6	PX	0.004	0.080	0.409 [0.007]	5.721 [0.000]	137.36 [0.000]	22.080 [0.001]
7	BUX	0.011	0.088	-0.191 [0.204]	5.608 [0.000]	145.914 [0.000]	3.518 [0.742]

Notes: This table is based on all sample observations during the period from October 1993 to December 2015. The test statistic for skewness and excess kurtosis is the conventional t -statistic. The Doornik-Hansen test (2008) has a χ^2 distribution if the null hypothesis of normality is true. Numbers in brackets are p -values. $LB(q)$ is the Ljung-Box (1978) statistic for returns, distributed as $\chi^2(q)$, $q \approx \ln T$, where $T=267$ is the number of data points.

Source: Authors' calculations.

Furthermore, we detected stationarity of the analysed series. We employed the ADF test (Dickey, Fuller 1981) and we proved that the unit-root hypothesis can be rejected for all series at 5 per cent significance level. However, according to the literature, dynamic PCA does not require stationarity of the data, e.g. (Gilmore et al. 2008, p. 613).

4.2. Empirical Evidence from the Index of Financial Integration

To recognize the evolution of financial integration processes across markets, we employed the dynamic principal component approach and computed the index of integration. This index measures the proportion of total variation in individual

stock index monthly logarithmic returns⁶ explained by the first principal component given by equation (1). The first principal component is estimated using a rolling window of 54 months.

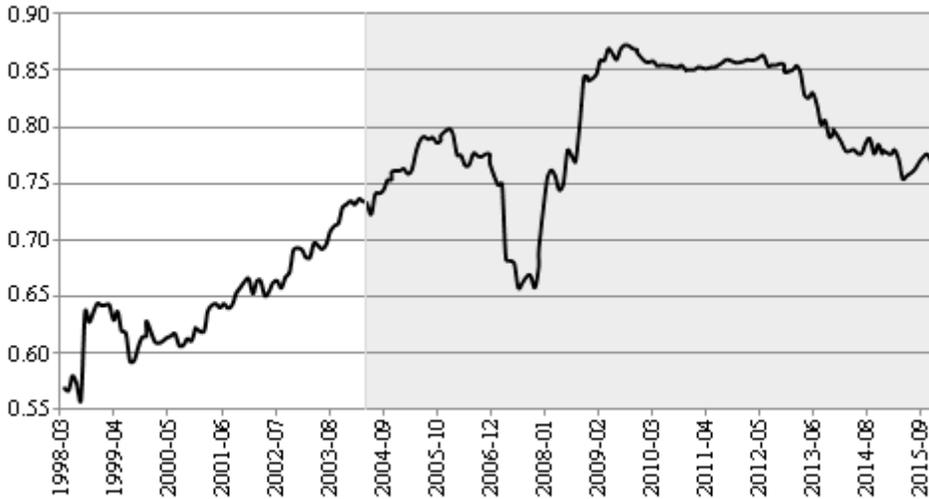


Figure 1. The dynamics of the integration index in the group of six European stock markets

Notes: Figure 1 reports the dynamics of the financial integration index across the group of six European stock markets in the whole sample period October 1993 – December 2015. A 54-months rolling window is used. The shaded vertical bar denotes the period after the CEEC–3 accession to the EU on the 1st of May 2004.

Source: Authors' calculations.

Figure 1 presents the dynamics of the financial integration process across the group of six European stock markets in the whole sample period from October 1993 to December 2015. The level of the index of integration is relatively high and it varies between 0.5575 (in July 1998) and 0.8721 (in August 2009). Moreover, one can observe that the most noticeable rise in the level of integration occurred not immediately after the CEEC–3's accession to the EU on the 1st of May 2004, but with a delay, in mid–2007. Besides, the integration index exhibits an inverted U-shaped trend in the post-accession period. This pattern is consistent with the literature and it reveals three specific phases. The first phase is characterized by a substantial increase in the degree of integration between international equity markets after a crucial event. The second phase relies on the relatively high cross-country integration observed in the period following the event. In this case it lasted between October 2008 and March 2013. The third phase indicates a sub-

⁶ We compute standardized monthly logarithmic returns by subtracting the average value of the returns from each single return for the sample period, and dividing it by the standard deviation.

sequent decrease in the level of integration over a long time after the event, and it begins in April 2013.

Table 3. Average index of financial integration in the group of six European stock markets

Period	Average index of financial integration
Before the CEEC-3 accession to the EU	0.647
After the CEEC-3 accession to the EU	0.799
Difference between two means (2) – (1)	0.151 [0.000]

Notes: The table is based on all sample observations during the period October 1993 – December 2015. To test for the significance of the difference between two means, the nonparametric permutation test is employed (Good 2005). The number in brackets is the p-value.

Source: Authors' calculations.

Table 3 reports the average level of the index of integration for the group of six European stock markets in the whole sample period October 1993 – December 2015. The research hypothesis that the average index of integration is significantly different after the CEEC-3's accession to the EU, compared to the period before the accession, is examined. A statistical test for the significance of the difference between two means is employed. The following hypotheses are tested:

$$\begin{aligned} H_0 : \mu_1 &= \mu_2 \\ H_1 : \mu_1 &\neq \mu_2 \end{aligned} \quad (3)$$

where μ_1 and μ_2 are the unknown expected values of the index of integration in two periods, and the null hypothesis states that two expected values are equal. We calculate nonparametric p -value using the permutation test. This methodology allows for non-normality of a distribution and it is proper in the small sample case (Good 2005). The obtained results presented in Table 3 show that the difference in means is statistically significant, that is the average index of integration across the whole group of six European stock markets increased significantly after the CEEC-3's accession to the EU, compared to the period before the accession.

Figures 2–3 report the dynamics of the financial integration processes in the group of three developed European stock markets and the U.S. market, as well as in the group of three emerging CEEC-3 stock markets and the U.S. market, respectively. Tables 4–5 present average values of the index of integration for both groups, respectively.

Figure 2 reveals that the major advanced European stock markets were rather highly connected during the period investigated. The level of the index of integration varies between 0.7288 (in March 1999) and 0.9328 (in January 2006). Moreover, it is worth observing that the level of integration in the whole group, including three developed and the U.S. markets, is visibly lower compared to the group excluding the U.S. market, and it varies between 0.7861 and 0.9525. This

evidence is rather consistent with the literature and it suggests a relatively strong integration among the major European economies.

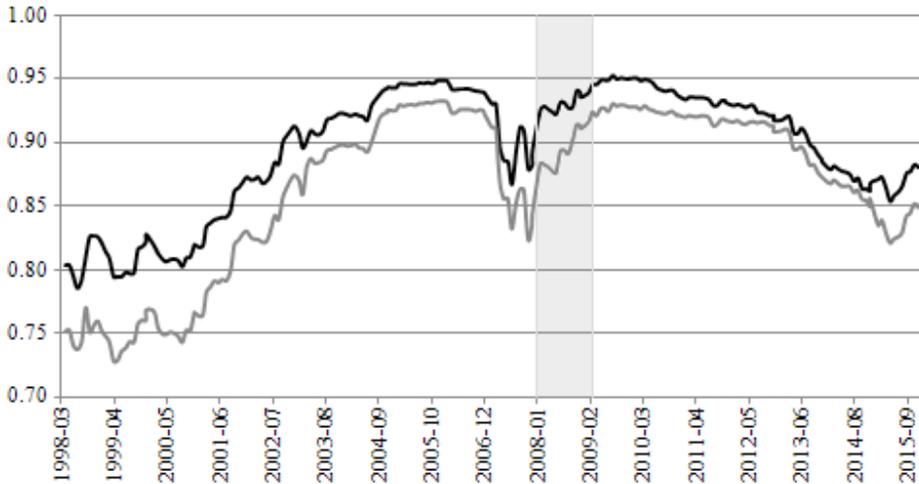


Figure 2. The dynamics of the integration index in the group of three developed European stock markets and the U.S. market

Notes: Figure 2 reports the dynamics of the financial integration index. A 54-months rolling window is used. The grey line defines the dynamics of the integration index computed across the group including three European stock markets and the U.S. market. The black line defines the dynamics of the integration index computed across the group including only three European stock markets. The whole sample period is October 1993 – December 2015. The shaded vertical bar denotes the common GFC period December 2007 – February 2009.

Source: Authors' calculations.

Table 4. Average index of financial integration in the group of three developed European stock markets and the U.S. market

Period	Average index of financial integration
Before the Global Financial Crisis	0.842
The Global Financial Crisis 12.2007 – 02.2009	0.894
Difference between two means (2) – (1)	0.052 [0.006]

Notes: The table is based on all sample observations during the period October 1993 – December 2015. To test for the significance of the difference between two means, the nonparametric permutation test is employed (Good 2005). The number in brackets is the p-value.

Source: Authors' calculations.

Table 4 presents the average level of the index of integration for the group of three developed European stock markets and the U.S. market in the whole sample period October 1993 – December 2015. The research hypothesis that the average index of integration was significantly different in the Global Financial Crisis

compared to the pre-crisis period is examined. The hypotheses (3) are tested using the permutation test. The empirical results show that the difference in means is statistically significant, i.e. the average index of integration was significantly different during the crisis period compared to the pre-crisis period (see Table 4).

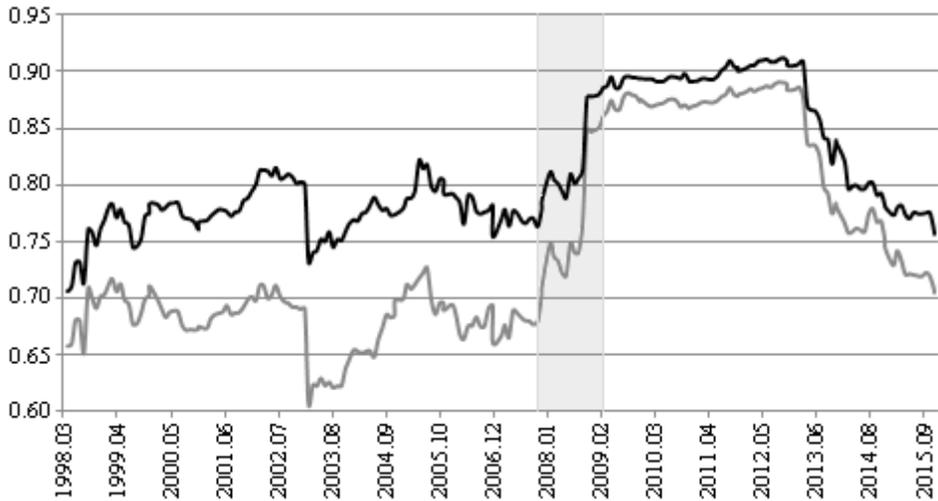


Figure 3. The dynamics of the integration index in the group of three emerging CEEC–3 stock markets and the U.S. market

Notes: Figure 3 reports the dynamics of the financial integration index. The grey line defines the dynamics of the integration index computed across the group including the CEEC–3 stock markets and the U.S. market. A 54-months rolling window is utilized. The black line defines the dynamics of the integration index computed across the group including only the CEEC–3 stock markets. The whole sample period is October 1993 – December 2015. The shaded vertical bar denotes the common GFC period October 2007 – February 2009.

Source: Authors' calculations.

Figure 3 shows that the level of integration in the group including the CEEC–3 and the U.S. markets is visibly lower than for the group of advanced markets. It varies between 0.6057 (in February 2003) and 0.8901 (in September 2012). However, as in Figure 2 one can observe that the level of integration in the whole group including three emerging and the U.S. markets is noticeably lower compared to the group excluding the U.S. market. In this case, it varies between 0.7063 and 0.9114. Moreover, the integration index exhibits an inverted U-shape during the crisis and post-crisis periods. This evidence is generally in accordance with the literature (for example Donadelli, Paradiso 2014). The inverted U-shaped pattern confirms the three phases observed in financial markets' integration. The first one is characterized by a massive increase in the degree of integration between international stock markets during the crisis (the so-called contagion effect). The second one indicates the relatively high cross-market integration observed in the period following the

shock (the so-called herding effect). The third phase could be explained as a subsequent decrease in the level of integration over a long time after the shock, and it starts on April 2013.

Table 5. Average index of financial integration in the group of three emerging CEEC–3 stock markets and the U.S. market

Period	Average index of financial integration
(1) Before the Global Financial Crisis	0.681
(2) The Global Financial Crisis 10.2007–02.2009	0.764
Difference between two means (2)–(1)	0.084 [0.000]

Notes: The table is based on all sample observations during the period October 1993 – December 2015. To test for the significance of the difference between two means, the nonparametric permutation test is employed (Good 2005). The number in brackets is the p-value.

Source: Authors' calculations.

Table 5 reports the average level of the index of integration for the CEEC–3 stock markets and the U.S. market in the whole sample period from October 1993 to December 2015. The research hypothesis that the average index of integration was significantly different during the Global Financial Crisis compared to the pre-crisis period is examined. The empirical results show that the difference in means is statistically significant, i.e. the average index of integration in this group of markets was significantly different in the crisis period compared to the pre-crisis period (see Table 5).

5. Conclusions

The purpose of this paper has been to recognize the dynamics of financial integration processes across the European stock markets over the last two decades. We investigated two groups of equity markets: (1) three largest developed European markets in the United Kingdom, France and Germany, and (2) three biggest emerging Central and Eastern European markets in Poland, the Czech Republic and Hungary (CEEC–3). The evolution of the financial integration process was explored using the dynamic principal component approach.

The empirical results confirm that the dynamics of integration processes are time-varying. Firstly, the results reveal that the average index of integration was significantly different during the Global Financial Crisis compared to the pre-crisis period, in both groups of markets. Secondly, there is no reason to reject the research hypothesis that the average index of integration across the whole group of six European stock markets increased significantly after the CEEC–3's acces-

sion to the EU, compared to the period before the accession. A visible inverted U-shaped pattern in the index of integration has been found in the post-accession period. Furthermore, as was implied from our dynamic principal component analysis, the degree of integration in the group of emerging markets was slightly lower than for advanced countries. Moreover, it was lower in both groups including the U.S. stock market compared to the groups excluding this market, respectively.

It is worthwhile to note that a high level of financial integration among the European stock markets could be a considerable impediment to international portfolio diversification, especially during crises. However, the results indicate that a certain solution to this problem might be to attach the American stock market instruments to the portfolio, as the level of financial integration in groups including the European and the U.S. stock markets is visibly lower.

Finally, we are aware that our analysis cannot provide definitive conclusions as to the dynamics of integration across the European countries. Therefore, a possible direction for further investigation would be to study the dynamics of integration processes in an alternative way, for example using a different measure of integration. Furthermore, the empirical results revealed that the level of integration in both groups of markets was rather high and persistent, not only during the Global Financial Crisis but also in a relatively long post-crisis period. This is a curious finding which is sometimes interpreted in the literature as the so-called 'herding effect' (for example Donadelli, Paradiso 2014). Nevertheless, in our opinion it requires further investigation in future research.

References

- Beine M., Cosma A., Vermeulen R. (2010), *The Dark Side of Global Integration: Increasing Tail Dependence*, 'Journal of Banking & Finance', 34.
- Bekaert G., Harvey C.R. (1995), *Time-Varying World Market Integration*, 'Journal of Finance', 1(2).
- Bekaert G., Harvey C.R., Lumsdaine R.L. (2002), *Dating the Integration of World Equity Markets*, 'Journal of Financial Economics', 65.
- Bekaert G., Harvey C.R., Ng A. (2005), *Market Integration and Contagion*, 'Journal of Business', 78(1).
- Bordo M.D., Murshid A.P. (2006), *Globalization and Changing Patterns in the International Transmission of Shocks in Financial Markets*, 'Journal of International Money and Finance', 25.
- Brière M., Chapelle A., Szafarz A. (2012), *No Contagion, Only Globalization and Flight to Quality*, 'Journal of International Money and Finance', 31(6).
- Büttner D., Hayo B. (2011), *Determinants of European Stock Market Integration*, 'Economic Systems', 35.
- Carrieri F., Errunza V., Hogan K. (2007), *Characterizing World Market Integration through Time*, 'Journal of Financial and Quantitative Analysis', 42(4).

- Chambet A., Gibson R. (2008), *Financial Integration, Economic Instability and Trade Structure in Emerging Markets*, 'Journal of International Money and Finance', 27.
- Chesnay F., Jondeau E. (2001), *Does Correlation Between Stock Returns Really Increase During Turbulent Periods?*, 'Economic Notes', 30(1).
- de Jong F., de Roon F.A. (2005), *Time-Varying Market Integration and Expected Returns in Emerging Markets*, 'Journal of Financial Economics', 78.
- Dickey D.A., Fuller W.A. (1981), *Likelihood Ratio Statistics for Autoregressive Time Series with a Unit Root*, 'Econometrica', 49(4).
- Donadelli M., Paradiso A. (2014), *Is there Heterogeneity in Financial Integration Dynamics? Evidence from Country and Industry Emerging Market Equity Indexes*, 'Journal of International Financial Markets, Institutions & Money', 32.
- Doornik J.A., Hansen H. (2008), *An Omnibus Test for Univariate and Multivariate Normality*, 'Oxford Bulletin of Economics and Statistics', 70, Supplement 1.
- Forbes K.J., Rigobon R. (2002), *No Contagion, Only Interdependence: Measuring Stock Market Comovements*, 'Journal of Finance', 57(5).
- Gagnon J.E., Unferth M.D. (1995), *Is There a World Interest Rate?*, 'Journal of International Money and Finance', 14.
- Gilmore C.G., Lucey B.M., McManus G.M. (2008), *The Dynamics of Central European Equity Market Comovements*, 'The Quarterly Review of Economics and Finance', 48.
- Goetzmann W.N., Li L., Rouwenhorst K.G. (2005), *Long-Term Global Market Correlations*, 'Journal of Business', 78(1).
- Good P. (2005), *Permutation, Parametric, and Bootstrap Tests of Hypotheses*, Springer Series in Statistics, Third Edition, New York, Springer.
- Hardouvelis G.A., Malliaropoulos D., Priestley R. (2006), *EMU and European Stock Market Integration*, 'Journal of Business', 79(1).
- Harkmann K. (2014), *Stock Market Contagion from Western Europe to Central and Eastern Europe During the Crisis Years 2008–2012*, 'Eastern European Economics', 52(3).
- Jennrich R.I. (1970), *An Asymptotic Chi-square Test for the Equality of Two Correlation Matrices*, 'Journal of the American Statistical Association', 65(330).
- Jolliffe I.T. (2002), *Principal Component Analysis*, Springer Series in Statistics, Second Edition, New York, Springer.
- Larntz K., Perlman M.D. (1985), *A Simple Test for the Equality of Correlation Matrices*, Technical Report No. 63, Department of Statistics, University of Washington.
- Ljung G., Box G.E.P. (1978), *On a Measure of Lack of Fit in Time Series Models*, 'Biometrika', 65(2).
- Longin F., Solnik B. (1995), *Is the Correlation in International Equity Returns Constant: 1960–1990?*, 'Journal of International Money and Finance', 14 (1).
- Longin F., Solnik B. (2001), *Extreme Correlation of International Equity Markets*, 'Journal of Finance', 56(2).
- Mauro P., Sussman N., Yafeh, Y. (2002), *Emerging Market Spreads: Then Versus Now*, 'Quarterly Journal of Economics', 117.

- Nellis J.G. (1982), *A Principal Components Analysis of International Financial Integration Under Fixed and Floating Exchange Rate Regimes*, 'Applied Economics', 14.
- Obstfeld M., Taylor A.T. (2003), *Globalization and Capital Markets*, [in:] Bordo M., Taylor A.T., Williamson J.G. (ed.), *Globalization in Historical Perspective*, Chicago, University of Chicago Press.
- Olbryś J., Majewska E. (2014), *Quantitative Identification of Crisis Periods on the Major European Stock Markets*, 'Pensee Journal', 76(1).
- Olbryś J., Majewska E. (2015a), *Bear Market Periods during the 2007–2009 Financial Crisis: Direct Evidence from the Visegrad Countries*, 'Acta Oeconomica', 65(4).
- Olbryś J., Majewska E. (2015b), *Testing Integration Effects Between the CEE and U.S. Stock Markets During the 2007–2009 Global Financial Crisis*, 'Folia Oeconomica Stetinensia', 15(1).
- Pagan A.R., Sossounov K.A. (2003), *A Simple Framework for Analysing Bull and Bear Markets*, 'Journal of Applied Econometrics', 18(1).
- Pisani-Ferry J., Sapir A. (2010), *Banking Crisis Management in the EU: An Early Assessment*, 'Economic Policy', 62.
- Pukthuanthong K., Roll R. (2009), *Global Market Integration: An Alternative Measure and its Application*, 'Journal of Financial Economics', 94.
- Sensoy A., Ozturk K., Hacıhasanoglu E. (2014), *Constructing a Financial Fragility Index for Emerging Countries*, 'Finance Research Letters', 11.
- Tsay R.S. (2010), *Analysis of Financial Time Series*, New York, John Wiley.
- Volosovych V. (2011), *Measuring Financial Market Integration over the Long Run: Is There a U-shape?*, 'Journal of International Money and Finance', 30.
- Volosovych V. (2013), *Learning about Financial Market Integration from Principal Components Analysis*, 'CESifo Economic Studies', 59(2).

Streszczenie

EWOLUCJA PROCESU INTEGRACJI WYBRANYCH EUROPEJSKICH RYNKÓW KAPITAŁOWYCH: ZASTOSOWANIE DYNAMICZNEJ ANALIZY GŁÓWNYCH SKŁADOWYCH

Celem pracy było badanie zmian poziomu integracji wybranych europejskich rynków kapitałowych na przestrzeni ostatnich dwudziestu lat. Analizie poddano dwie grupy rynków: (1) trzy rynki rozwinięte Wielkiej Brytanii, Francji i Niemiec, oraz (2) trzy rynki rozwijające się Europy Środkowo-Wschodniej w Polsce, Czechach i na Węgrzech. Ewolucja procesu integracji rynków została zbadana z wykorzystaniem dynamicznej analizy głównych składowych. Jako odporną miarę integracji zastosowano indeks integracji. Wyniki empiryczne potwierdziły, że poziom integracji wzrósł w sposób istotny po wejściu Polski, Czech i Węgier do Unii Europejskiej w 2004 r. Zaobserwowano wyraźny efekt odwróconego U na wykresie indeksu integracji w przypadku całej grupy badanych rynków. Ponadto stwierdzono, że średnia wartość indeksu integracji była istotnie wyższa w okresie Globalnego Kryzysu Finansowego w porównaniu z okresem przed kryzysem.

Słowa kluczowe: europejskie rynki kapitałowe, dynamiczna analiza głównych składowych, indeks integracji, Globalny Kryzys Finansowy