DE GRUYTER OPEN

Folia Oeconomica Stetinensia
DOI: 10.1515/foli-2015-0024

WYDZIAŁ NAUK EKONOMICZNYCH I ZARZĄDZANIA
UNIWERSYTET SZCZECIŃSKI

TESTING INTEGRATION EFFECTS BETWEEN THE CEE AND U.S. STOCK MARKETS DURING THE 2007–2009 GLOBAL FINANCIAL CRISIS

Joanna Olbryś, Ph.D.

Białystok University of Technology
Faculty of Computer Science, Department of Theoretical Computer Science
Wiejska 45A, 15-351 Białystok, Poland
e-mail: j.olbrys@pb.edu.pl

Elżbieta Majewska, Ph.D.

University of Białystok
Faculty of Mathematics and Informatics, Institute of Mathematics
Department of Applied Mathematics
K. Ciołkowskiego 1M, 15-245 Białystok, Poland
e-mail: elam@math.uwb.edu.pl

Received 15 September 2014, Accepted 27 April 2015

Abstract

The main goal of this paper is to explicitly test a research hypothesis that there was no integration effect among the U.S. and the eight Central and Eastern European (CEE) stock markets during the 2007–2009 Global Financial Crisis (GFC). As growing international integration could lead to a progressive increase in cross-market correlations, the evaluation of integration was carried out by applying equality tests of correlation matrices computed over non-overlapping subsamples: the pre-crisis and crisis periods, in the group of investigated markets. The crisis periods are formally established based on a statistical method of dividing market states into bullish and bearish markets. The sample period May 2004–April 2014 includes the 2007 U.S. subprime financial crisis. The robustness analysis of the integration tests with respect to various data frequencies is provided. The empirical results are not homogeneous and they depend both on the integration test and data frequency. Consequently, it is not possible to conclude whether integration between the investigated markets is present.

JEL Classification: C10, F36, F65, G01, G15, O52.

Keywords: stock market, financial crisis, cross-market correlations, integration.

Introduction

The eight Central and Eastern European (CEE) emerging markets joined the European Union (EU) on the 1 May 2004. These countries, in the order of decreasing population size are: Poland, Czech Republic, Hungary, Slovakia, Lithuania, Latvia, Slovenia and Estonia. The CEE economies are interesting in many respects, especially in the context of the influence of the 2007 U.S. subprime crisis.

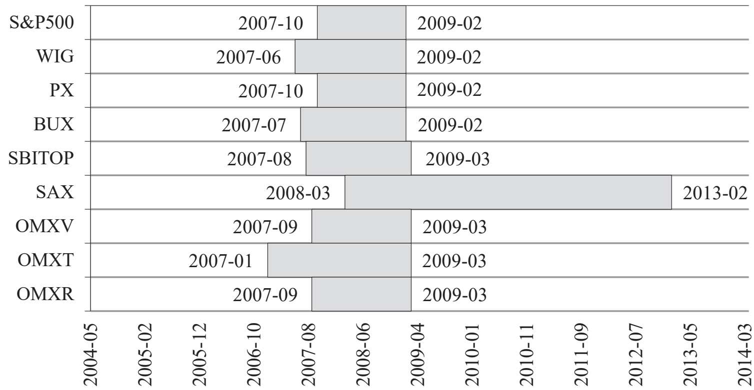
The aim of this paper is to explicitly test the research hypothesis that there was no integration effect among the U.S. and the CEE stock markets during the 2007–2009 Global Financial Crisis. According to the literature, evidence shows that growing international integration could lead to a progressive increase in cross-market correlations (Longin, Solnik, 1995). Therefore, the evaluation of integration was carried out by applying equality tests of correlation matrices computed over non-overlapping subsamples: the pre-crisis and crisis periods, in the group of investigated stock markets. Moreover, the robustness analysis of integration tests with respect to various data frequencies is provided. The sample period begins with the CEE accession to the EU on the 1 May 2004, and ends on April 30, 2014, and it includes the 2007 U.S. subprime crisis. The crisis periods on the CEE equity markets are established and based on the paper (Olbrys, Majewska, 2014b), in which these periods are formally detected using a statistical method of dividing market states into bullish and bearish markets (Pagan, Sossounov, 2003). A direct identification of crises is performed on the eight CEE stock markets, and, for comparison, on the U.S. market. The results confirm October 2007–February 2009 as the common period of the recent global financial crisis, except for Slovakia (Olbrys, Majewska, 2014b). The robustness analysis reveals that the empirical results are not homogeneous and they depend both on the integration test and data frequency. Unfortunately, this evidence makes it impossible to decide for or against integration among the U.S. and the CEE stock markets during the recent global crisis. The result is novel and, to the best of our knowledge, has not been discussed in the literature. Due to the importance of the problem, a possible direction for further investigation would be to test the integration effect applying other methods, e.g. international asset pricing models (Bekaert et al., 2005; Hardouvelis et al., 2006; Bekaert et al., 2014).

The remainder of the study is organized as follows. Section 2 presents a brief literature review concerning the influence of the 2007 U.S. subprime crisis on the CEE stock markets. In Section 3, we provide a brief analysis of the effect of increasing cross-market correlations in down markets, in the context of integration. In Section 4, we present data description and empirical results on the main indexes of the CEE and U.S. stock markets. Section 5 recalls the main findings and concludes.

1. The 2007–2009 financial crisis in the U.S. and CEE stock markets

The influence and consequences of the 2007 U.S. subprime crisis for developed and emerging stock markets in the world have been amply reported in the literature. As the goal of this paper is an investigation of integration effects in the CEE equity markets during the recent Global Financial Crisis, we focused our analysis of previous literature on studies related mostly to European economies. According to the literature, e.g. (Calomiris, 2009; Brunnermeier, 2009; Claessens et al., 2010), the recent crisis timeline, from the U.S. perspective, was marked by four major events: (1) the increase in subprime delinquency rates in the spring of 2007, (2) the liquidity crunch in late 2007, (3) the liquidation of Bear Stearns in March 2008, and (4) the failure of Lehman Brothers in September 2008. The U.S. economy officially entered recession following a peak in December 2007. The crisis began in the U.S., but initially it did not affect the CEE markets to the same extent. Claessens et al. (2010) identified five groups of countries based on the date they were affected by the crisis. They asserted that Latvia and Estonia slipped into recession in 2008Q1, Hungary in 2008Q2, together with the major Western European countries, i.e. the U.K., France and Germany, Lithuania and Slovenia in 2008Q3, while Poland and the Czech Republic entered recession in 2008Q4. Slovakia slipped into recession with a delay, in 2009Q1. The Baltic region stock markets were among the most affected by the crisis. Lane and Milesi-Ferretti (2011) showed that Lithuania, Latvia, and Estonia entered the group of the "Top 5" crisis countries in the world. Marer (2010) analysed the CEE economies among other Eastern European countries in the context of commonalities and differences during the recent financial crisis. He pointed out that the global crisis hit the most vulnerable economies (i.e. Hungary and the Baltic States) immediately and hard, while the less vulnerable countries (i.e. Poland, the Czech Republic, Slovenia and Slovakia) were less affected.

As a matter of fact, there is no agreement in determining the global crisis period among the researchers. In particular, there is no unanimity about the pre-, post-, and crisis periods, e.g. (Pisani-Ferry, Sapir, 2010; Mishkin, 2011; Dooley, Hutchison, 2009; Calomiris et al., 2012; Bartram, Bodnar, 2009; Olbrys, Majewska, 2013). Therefore, as mentioned in the Introduction, in our research the crisis periods in the CEE stock markets are formally established based in the paper (Olbrys, Majewska 2014b), in which the Pagan-Sossounov (2003) method for statistical identification of market states is employed. According to the literature, a direct identification of



May 2004–April 2014. The crisis periods are:
(1) 10.2007–02.2009 (S&P500 – New York);
(2) 06.2007–02.2009 (WIG – Warsaw);
(3) 10.2007–02.2009 (PX – Prague);
(4) 07.2007–02.2009 (BUX – Budapest);
(5) 09.2007–03.2009 (SBITOP – Ljubljana);
(6) 03.2008–02.2013 (SAX – Bratislava);
(7) 09.2007–03.2009 (OMXV – Vilnius);
(8) 01.2007–03.2009 (OMXT – Tallinn);
(9) 09.2007–03.2009 (OMXR – Riga).

Fig. 1. Overall information about the U.S. and the CEE crises, in the whole sample period

Source: own elaboration based on Olbrys, Majewska (2014b).

crises is possible based on statistical procedures for dividing market states into up and down markets, see e.g. (Olbrys, Majewska, 2014a; 2014b) and references therein. Figure 1 presents overall information about all determined crisis periods for the S&P500 and the CEE stock market indexes obtained from the Pagan-Sossounov procedure. The evidence is that October 2007–February 2009 was the common period of the recent global financial crisis, except for the SAX index (Slovakia). In the case of Slovakia we observed a pronounced delay of crisis symptoms. Moreover, the evidence is that for Slovakia, which accessed the euro area in January 1, 2009, the crisis period is much longer and it includes the recent euro area crisis, which started in Spring 2010 (Merler, Pisani-Ferry, 2012).

2. Evidence of increasing cross-market correlations during crisis periods in the context of integration

The literature has shown that international stock market correlation is a crucial topic because of many practical implications, especially in the context of market integration as well as international portfolio choice and diversification. According to the portfolio theory, the motivations and gains of international diversification rely on low correlations across stock markets in the world. In their broadly cited paper, Longin and Solnik (2001) studied the conditional correlation structure of international equity returns and derived a formal statistical method, based on the extreme value theory. They found that conditional correlation increases in bear markets, but not in bull markets. Goetzmann et al. (2005) examined the correlation structure of the major world markets over 150 years. They found that international equity correlations change dramatically through time, thus the diversification benefits to global investing are not constant.

As a matter of fact, there is no agreement in research regarding the causes of increasing cross-market correlations in turmoil periods. Two analytical frameworks exist in the literature side by side. On one hand, the cross-correlation movements are attributed to international equity markets contagion during crises. However, the main problem is that no one definition of contagion exists (Edwards, 2000; Forbes, Rigobon, 2002; Rigobon, 2002; Pericoli, Sbracia, 2003; Bekaert et al., 2005). Moreover, a range of different methodologies of testing for the existence of contagion make it difficult to assess the evidence for and against contagion (Dungey et al., 2005). On the other hand, the increasing cross-market correlations are coupled with the growing integration and globalization of financial markets, especially during crisis periods (Bekaert et al., 2005; Brière et al., 2012; Bekaert et al., 2014). To address this issue, we employed tests interpreted as integration tests in the group of the CEE and the U.S. stock markets using formal procedures for testing the equality of correlation matrices computed over non-overlapping subsamples (Jennrich, 1970; Larntz, Perlman, 1985; Longin, Solnik, 1995; Chesnay, Jondeau, 2001; Goetzmann et al., 2005; Brière et al., 2012). Integration was evaluated by testing the hypotheses:

$$\begin{aligned} H_0 &: P_C = P_{PC} \\ H_1 &: P_C \neq P_{PC} \end{aligned} \tag{1}$$

where P_C, P_{PC} are true (population) correlation matrices in the crisis and pre-crisis periods, respectively, and the null hypothesis states that there is no integration effect during crises. Different test statistics have been proposed in the literature to test the problem (1). One of the most popular is the test introduced by Jennrich (1970).

Let $\hat{P}_C = (\hat{\rho}_{ij}^{C})$ and $\hat{P}_{PC} = (\hat{\rho}_{ij}^{PC})$ be sample correlation matrices in the crisis and pre-crisis periods of sample size n_C and n_{PC}, respectively. The average correlation matrix is equal to $\hat{P} = \dfrac{n_C \hat{P}_C + n_{PC} \hat{P}_{PC}}{n_C + n_{PC}}$, $\hat{P} = (\hat{\rho}_{ij})$ and $\hat{P}^{-1} = (\hat{\rho}^{ij})$. As we investigated dependencies in two subsamples of equal size $n_C = n_{PC} = n$, we employed the following version of the Jennrich test statistic T_J:

$$T_J = \frac{1}{2} tr(Z^2) - diag(Z)' \times S^{-1} \times diag(Z) \tag{2}$$

where Z is a square matrix given by the following equation:

$$Z = \sqrt{\frac{n}{2}} \cdot \hat{P}^{-1} \cdot (\hat{P}_C - \hat{P}_{PC}) \tag{3}$$

nd matrix $S = (\delta_{ij} + \hat{\rho}_{ij} \cdot \hat{\rho}^{ij})$, where δ_{ij} is the Kronecker delta. In Eq. (2), *diag*(Z) denotes the diagonal of the matrix Z (3) in a column form. The Jennrich test statistic T_J has an asymptotic $\chi^2(p(p-1)/2)$ distribution if the correlation matrix is computed for p variables. If the value of the T_J statistic (2) is greater than the critical value, the null hypothesis of identical correlation matrices can be rejected.

Although the Jennrich test statistic (2) is quite popular in the literature, Larntz and Perlman (1985) pointed out that this test is basically a large sample test and can perform poorly for small samples. They proposed a test statistic T_{LP} which determined a test with reasonable small sample properties and with power comparable to that of the Jennrich test (2) for large samples (Larntz, Perlman, 1985). The basic idea is to apply the Fisher (1921) z-transformation to each sample correlation coefficient in the correlation matrices $\hat{P}_C = (\hat{\rho}_{ij}^C)$ and $\hat{P}_{PC} = (\hat{\rho}_{ij}^{PC})$, and to consider the $\dfrac{p(p-1)}{2}$-dimensional random column vectors consisting of the off-diagonal z-transformations $(1 \le i < j \le p)$ arranged in lexicographic order. In the case of two subsamples of equal size $n_C = n_{PC} = n$, we used the following version of the Larntz-Perlman test statistic T_{LP}:

$$T_{LP} = \sqrt{\frac{(n-3)^2}{2n-6}} \cdot \max_{1 \le i < j \le p} \left| z_{ij}^C - z_{ij}^{PC} \right| \tag{4}$$

where z_{ij}^C and z_{ij}^{PC} are the Fisher z-transformations of the sample correlation coefficients $\hat{\rho}_{ij}^C$ and $\hat{\rho}_{ij}^{PC}$, respectively. Larntz and Perlman propose the significance level α test under which the null (3) is rejected if $T_{LP} > b_\alpha$, where $b_\alpha > 0$ is chosen such that $\left[\Phi(b_\alpha) - \Phi(-b_\alpha)\right]^{p(p-1)/2} = 1 - \alpha$, and Φ is the cumulative distribution function of the standard normal distribution.

Based on the cases studied, Larntz and Perlman propose the following rule-of-thumb: when the ratio of the sample size to dimension does not exceed 4, i.e. when $n / p \le 4$, then the

T_{LP} test statistic (4) is recommended (Larntz, Perlman, 1985). As the sample size $n \to \infty$, both the Jennrich and the Larntz–Perlman tests are asymptotically consistent.

3. Data description and empirical results of integration tests for the CEE and the U.S. stock markets

In this research, we used our own database, not a commercial one. The raw data consisted of daily closing prices of the stock market indexes. We calculated daily, weekly, and monthly logarithmic returns of the major CEE stock market indexes (i.e. WIG, PX, BUX, SBITOP, SAX, OMXV, OMXT and OMXR), and the New York market index – S&P500. There are 2190 daily, 522 weekly, and 120 monthly observations for each series for the period beginning May 2004 and ending April 2014 (ten years).

We used weekly Wednesday-to-Wednesday logarithmic returns, which are thought to iron out any possible impact of the day-of-the-week effects of daily data. It is known in the literature that there are day-of-the-week effects reflected in the significantly positive Friday and negative Monday returns. As for daily returns, one potentially serious problem, which may substantially disrupt various analyses employing multivariate time series, is the nonsynchronous trading effect II between international stock markets. This problem occurs when we investigated relations in a group of stock markets in various countries. International stock markets operate in different time zones with different opening and closing times, thereby making return observations nonsynchronous. The differences in returns arose from the fact that the trading days in various countries are subject to different national and religious holidays, unexpected events, and so forth. Previous studies have attempted various methods to deal with this effect. Especially, the data-matching procedure called a ‘common trading window’ is very popular. In this method, the data are collected for the same dates across the stock markets, removing the data for those dates when any series has a missing value due to no trading. This approach is widely applied in the case of synchronized financial databases with multivariate time series, see e.g. (Olbryś, Majewska, 2013; 2014c; 2014d) and references therein. In our research, we used a common trading window procedure as a daily data-matching method. We performed the robustness analysis with respect to various data frequencies. Therefore, we employed integration tests (2) and (4) using daily, weekly, and monthly logarithmic returns of the stock market indexes. All analyses were conducted using the open-source computer software Gretl 1.9.14 (Adkins, 2014).

3.1. Preliminary statistics

Table 1 reports summarized statistics for the monthly logarithmic returns for nine stock market indexes (in the order of decreasing value of market capitalization at the end of 2013), as well as statistics testing for normality.

Table 1. Summarized statistics for the monthly logarithmic returns of nine stock indexes

	Market	Index	Market Cap. billion € Dec 2013	Mean	Standard deviation	Skewness	Excess kurtosis	Doornik-Hansen test
1	New York	S&P500	13,026.2	0.004	0.043	–1.086 [0.000]	2.754 [0.000]	18.680 [0.000]
2	Warsaw	WIG	148.7	0.006	0.064	–0.735 [0.001]	2.599 [0.000]	17.871 [0.000]
3	Prague	PX	22.0	0.002	0.068	–1.269 [0.000]	4.483 [0.000]	24.882 [0.000]
4	Budapest	BUX	14.4	0.004	0.072	–0.941 [0.000]	3.211 [0.000]	19.983 [0.000]
5	Ljubljana	SBITOP	5.2	–0.002	0.059	–0.388 [0.084]	1.342 [0.003]	9.521 [0.009]
6	Bratislava	SAX	4.1	0.001	0.056	0.851 [0.000]	6.787 [0.000]	69.936 [0.000]
7	Vilnius	OMXV	2.9	0.006	0.081	–0.449 [0.046]	5.882 [0.000]	76.461 [0.000]
8	Tallinn	OMXT	1.9	0.007	0.084	–0.004 [0.985]	5.394 [0.000]	76.595 [0.000]
9	Riga	OMXR	0.9	0.002	0.064	–0.868 [0.000]	2.769 [0.000]	17.563 [0.000]

Notes: The table is based on all sample observations during the period May 2004–April 2014.
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. The numbers in brackets are *p*-values.

Source: authors' calculations (using the *Gretl 1.9.14* software).

Several results in Table 1 are worth a comment. The sample means are near to zero. The measure for skewness shows that the return series are skewed, except for the SBITOP and OMXT series. The measure for excess kurtosis shows that all series are leptokurtic with respect to the normal distribution. The Doornik-Hansen (2008) test rejects normality for each of the return series at the 5 per cent level of significance.

3.2. Robustness analysis of the integration tests

The research hypothesis states that during the 2007–2009 global financial crisis there was no integration effect between the U.S. and the CEE stock markets. As pointed out in Section 2, the evidence shows that October 2007–February 2009 was the common period of the recent global financial crisis, except for the SAX index (Slovakia). In the case of Slovakia a pronounced delay of crisis symptoms was observed (see Figure 1). Therefore, we excluded the SAX index from the integration tests. To check the robustness of the empirical results, we utilized various data frequencies.

Tables 2–4 present the empirical results of integration tests (2) and (4) performed on the whole group containing the S&P500 and seven indexes of the CEE markets (excluding SAX). The statistics test the null hypothesis (1) which states that the correlation matrix is constant over two adjacent sub-periods of an equal number of observations: (1) the pre-crisis period, and (2) the crisis period. As we tested the null with respect to different data frequencies, the corresponding sub-periods of equal size are: (1) May 2006–September 2007 & October 2007–February 2009 in Table 2 (both of 17 months), (2) May 2006–September 2007 & October 2007–February 2009 in Table 3 (both of 74 weekly returns), and (3) April 19, 2006–September 27, 2007 & October 1, 2007–February 27, 2009 in Table 4 (both of 309 daily returns).

Table 2. Results of the Jennrich (1970) and Larntz-Perlman (1985) integration tests (monthly logarithmic returns)

Test periods	Jennrich test					Larntz-Perlman test				
	Test statistic T_J	χ^2 critical value (5%)		χ^2 critical value (10%)		Test statistic T_{LP}	b_α critical value (5%)		b_α critical value (10%)	
May 2006–Sept 2007 & Oct 2007–Feb 2009	34.04	41.54	H_0	37.92	H_0	2.08	3.12	H_0	2.90	H_0

Notes: The table is based on: (1) the pre-crisis period May 2006–September 2007 (17 months); (2) the crisis period October 2007–February 2009 (17 months). The table contains the Jennrich test statistic, given by Eq. (2), as well as the Larntz–Perlman test statistic, given by Eq. (4). The statistics test the null of no integration. The amount of variables $p = 8$.

Source: authors' calculations (using the *Gretl 1.9.14* software).

Table 3. Results of the Jennrich (1970) and Larntz–Perlman (1985) integration tests (weekly logarithmic returns)

Test periods	Jennrich test					Larntz-Perlman test				
	Test statistic T_J	χ^2 critical value (5%)		χ^2 critical value (10%)		Test statistic T_{LP}	b_α critical value (5%)		b_α critical value (10%)	
May 2006–Sept 2007 & Oct 2007–Feb 2009	54.12	41.54	H_1	37.92	H_1	2.58	3.12	H_0	2.90	H_0

Notes: The table is based on: (1) the pre-crisis period May 2006–September 2007 (74 weekly returns); (2) the crisis period October 2007–February 2009 (74 weekly returns). The table contains the Jennrich test statistic, given by Eq. (2), as well as the Larntz-Perlman test statistic, given by Eq. (4). The statistics test the null of no integration. The amount of variables $p = 8$.

Source: authors' calculations (using the *Gretl 1.9.14* software).

Table 4. Results of the Jennrich (1970) and Larntz–Perlman (1985) integration tests (daily logarithmic returns)

Test periods	Jennrich test					Larntz-Perlman test				
	Test statistic T_J	χ^2 critical value (5%)		χ^2 critical value (10%)		Test statistic T_{LP}	b_α critical value (5%)		b_α critical value (10%)	
April 19, 2006–Sept 27, 2007 & Oct 1, 2007-Feb 27, 2009	107.84	41.54	H_1	37.92	H_1	6.08	3.12	H_1	2.90	H_1

Notes: The table is based on: (1) the pre-crisis period April 19, 2006–September 27, 2007 (309 daily returns); (2) the crisis period October 1, 2007–February 27, 2009 (309 daily returns). The table contains the Jennrich test statistic, given by Eq. (2), as well as the Larntz-Perlman test statistic, given by Eq. (4). The statistics test the null of no integration. The amount of variables $p = 8$.

Source: authors' calculations (using the *Gretl 1.9.14* software).

It is important to note that the results reported in Tables 2–4 are diverse. Changes in the data frequency had a pronounced impact on the results obtained. Firstly, when monthly logarithmic returns are used, not a single rejection of the null hypothesis (1) is found (see Table 2). Secondly, in the case of weekly returns the results reported in Table 3 show that the differences in the correlation between the two sub-periods are significant based on the Jennrich test (2). On the other hand, we have no reason to reject the null hypothesis of no integration effect based on the Larntz-Perlman test. Another important piece of evidence from Table 3 is that the Larntz-Perlman test (4) was found to be more sensitive than the Jennrich procedure (2), as Lartnz and Perlman (1985) stated. Thirdly, the results for daily returns in Table 4 allow rejecting the null of no integration effect during the recent global financial crisis in the group of investigated stock markets. Finally, the results reveal that both the Jennrich procedure (2) and the Lartnz-Perlman test (4) are sensitive with respect to the choice of data frequency.

Conclusions

The purpose of this paper was to test the research hypothesis that there was no integration effect among the U.S. and the CEE stock markets during the 2007–2009 Global Financial Crisis. To explore this issue we employed the equality tests of correlation matrices computed over non-overlapping subsamples: the pre-crisis and crisis periods, in the group of investigated markets. It has been reported in the literature that both the Jennrich (1970) and the Larntz-Perlman (1985) tests can be interpreted as integration tests. The robustness analysis presented in Section 4 reveals that the empirical results are not qualitatively the same and they are linked both to the integration test and data frequency. This evidence does not allow any conclusions to be drawn concerning the research hypothesis mentioned above. In other words, our results neither explicitly confirm nor reject the impact of integration on international market interdependence during crises. As the problem is crucial, a possible direction for further investigation would be to test the integration effect applying other methods, e.g. tests based on international asset pricing models (Bekaert et al., 2005; Hardouvelis et al., 2006; Bekaert et al., 2014).

References

Adkins, L.C. (2014). *Using Gretl for Principles of Econometrics*. 4th Ed., Version 1.041.

Bartram, S.M. & Bodnar, G.M. (2009). No Place to Hide: The Global Crisis in Equity Markets in 2008/2009. *Journal of International Money and Finance*, 28 (8): 1246–1292. DOI: 10.1016/j.jimonfin.2009.08.005.

Bekaert, G., Harvey, C.R. & Ng, A. (2005). Market Integration and Contagion. *Journal of Business*, 78 (1): 39–69.

Bekaert, G., Ehrmann, M., Fratzscher, M. & Mehl, A. (2014). *The Global Crisis and Equity Market Contagion.* Working Paper No. 1352, DIW Berlin.

Brière, M., Chapelle, A. & Szafarz, A. (2012). No Contagion, Only Globalization and Flight to Quality. *Journal of International Money and Finance*, 31 (6): 1729–1744. DOI: 10.1016/j.jimonfin.2012.03.010.

Brunnermeier, M.K. (2009). Deciphering the Liquidity and Credit Crunch 2007–2008. *Journal of Economic Perspectives*, 23 (1): 77–100. DOI: 10.1257/jep.23.1.77.

Calomiris, C.W. (2009). The Subprime Turmoil: What's Old, what's New, and what's Next. *Journal of Structured Finance*, 15 (1): 6–52. DOI: 10.3905/JSF.2009.15.1.006.

Calomiris, C.W., Love, I. & Martínez Pería, M.S. (2012). Stock Returns' Sensitivities to Crisis Shocks: Evidence from Developed and Emerging Markets. *Journal of International Money and Finance*, 31 (4): 743–765. DOI: 10.1016/j.jimonfin.2012.01.002.

Chesnay, F. & Jondeau, E. (2001). Does Correlation Between Stock Returns Really Increase During Turbulent Periods? *Economic Notes*, 30 (1): 53–80. DOI: 10.1111/1468-0300.00047.

Claessens, S., Dell'Ariccia, G., Igan, D. & Laeven, L. (2010). Cross-country Experience and Policy Implications from the Global Financial Crisis. *Economic Policy*, 25 (62): 267–293. DOI: 10.1111/j.1468-0327.2010.00244.x.

Dooley, M. & Hutchison, M. (2009). Transmission of the U.S. Subprime Crisis to Emerging Markets: Evidence on the Decoupling-Recoupling Hypothesis. *Journal of International Money and Finance*, 28 (8): 1331–1349. DOI: 10.1016/j.jimonfin.2009.08.004.

Doornik, J.A. & Hansen, H. (2008). An Omnibus Test for Univariate and Multivariate Normality. *Oxford Bulletin of Economics and Statistics*, 70, Supp. 1: 927–939. DOI: 10.1111/j.1468-0084.2008.00537.x.

Dungey, M., Fry, R., Gonzales-Hermosillo, B. & Martin, V.L. (2005). Empirical Modeling of Contagion: A Review of Methodologies. *Quantitative Finance*, 5 (1): 9–24**.** DOI: 10.1080/14697680500142045.

Edwards, S. (2000). Contagion. *World Economy*, 23 (7), 873–900. DOI: 10.1111/1467-9701.00307.

Fisher, R.A. (1921). On the "Probable Error" of a Coefficient of Correlation Deduced From a Small Sample. *Metron*, 1: 3–32.

Forbes, K.J. & Rigobon, R. (2002). No Contagion, Only Interdependence: Measuring Stock Market Comovements. *Journal of Finance*, 57 (5): 2223–2261. DOI: 10.1111/0022-1082.00494.

Goetzmann, W.N., Li, L. & Rouwenhorst, K.G. (2005). Long-term Global Market Correlations. *Journal of Business*, 78 (1): 1–38.

Hardouvelis, G.A., Malliaropulos, D. & Priestley, R. (2006). EMU and European stock market integration*. Journal of Business*, 79 (1): 365–392.

Jennrich, R.I. (1970). An Asymptotic Chi-square Test for the Equality of Two Correlation Matrices. *Journal of the American Statistical Association*, 65 (330): 904–912. DOI: 10.1080/01621459.1970.10481133.

Lane, P.R. & Milesi-Ferretti, G.M. (2011). The Cross-Country Incidence of the Global Crisis. *IMF Economic Review*, 59 (1): 77–110. DOI: 10.1057/imfer.2010.12.

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.

Longin, F. & Solnik, B. (1995). Is the Correlation in International Equity Returns Constant: 1960-1990? *Journal of International Money and Finance*, 14 (1): 3–26. DOI: 10.1016/0261-5606(94)00001-H.

Longin, F. & Solnik, B. (2001). Extreme Correlation of International Equity Markets. *Journal of Finance*, 56 (2): 649–676. DOI: 10.1111/0022-1082.00340.

Marer, P. (2010). The Global Economic Crises: Impact on Eastern Europe. *Acta Oeconomica*, 60 (1): 3–33. DOI: 10.1556/AOecon.60.2010.1.2.

Merler, S. & Pisani-Ferry, J. (2012). Sudden Stops in the Euro Area. *Breugel Policy Contribution*, 6, March: 1–16.

Mishkin, F.S. (2011). Over the Cliff: From the Subprime to the Global Financial Crisis. *Journal of Economic Perspectives*, 25 (1): 49–70. DOI: 10.1257/jep.25.1.49.

Olbryś J. & Majewska, E. (2013). Granger Causality Analysis of the CEE Stock Markets Including Nonsynchronous Trading Effects. *Argumenta Oeconomica*, 31: 151–172.

Olbryś, J. & Majewska, E. (2014a). The 2007–2009 Financial Crisis on Emerging Markets: Quantitative Identification of Crisis in Continent-Based Regions. *Chinese Business Review*, 13 (7): 411–426. DOI:10.17265/1537-1506/2014.07.001.

Olbryś, J. & Majewska, E. (2014b). Direct Identification of Crisis Periods on the CEE Stock Markets: The Influence of the 2007 U.S. Subprime Crisis. *Procedia Economics and Finance,* 14: 461–470. DOI: 10.1016/S2212-5671(14)00735-7.

Olbryś, J. & Majewska, E. (2014c). Implications of Market Frictions: Serial Correlations in Indexes on the Emerging Stock Markets in Central and Eastern Europe. *Operations Research and Decisions*, 24 (1): 51–70. DOI: 10.5277/ord140104.

Olbryś, J. & Majewska, E. (2014d). On Some Empirical Problems in Financial Databases. *La Pensee*, 76 (9): 2–9.

Pagan, A.R. & Sossounov, K.A. (2003). A Simple Framework for Analysing Bull and Bear Markets. *Journal of Applied Econometrics*, 18 (1): 23–46. DOI: 10.1002/jae.664.

Pericoli, M. & Sbracia, M. (2003). A Primer on Financial Contagion. *Journal of Economic Surveys*, 17 (4): 571–608. DOI: 10.1111/1467-6419.00205.

Pisani-Ferry, J. & Sapir, A. (2010). Banking Crisis Management in the EU: An Early Assessment. *Economic Policy*, 25 (62): 341–373. DOI: 10.1111/j.1468-0327.2010.00243.x.

Rigobon, R. (2002). Contagion: How to Measure it? In: *Preventing Currency Crises in Emerging Markets*. Eds. S. Edwards, J.A. Frankel. Chicago: University of Chicago Press.