9. The Spillover Effect on the CEE Equity Markets and the Financial Contagion in the context of Financial Integration

Claudia BOGHICEVICI[1]
Simona STAMULE[2]
Iulian Cornel LOLEA[3]

Abstract

The purpose of this paper is to analyze the contagion effect between the equity markets in some of the CEE countries, namely Hungary, Poland, the Czech Republic, Romania, and Bulgaria, as compared to the Euro Zone. In this paper, we focus on the volatility transmission during the crisis period using the spillover index introduced by Diebold and Yilmaz (2009, 2012), which measures both total and directional volatility spillovers in a generalized VAR framework that eliminates the possible dependence of results on ordering. Also, we have used a DCC-GARCH approach to follow conditional correlations between markets. Because all our initial expectations were confirmed, the results should be taken into consideration by investors, who should take caution when investing in the CEE equity markets as well as when diversifying their portfolios to minimize risk.

Keywords: volatility, risk, contagion, financial markets, European Union, correlation, time series

JEL Classification: G15, C22, G11

1. Introduction

Financial crises and their impacts on economic activity help us find out how a specific shock initiated in a country is rapidly transmitted towards the global markets. A financial crisis may start in a developed economy and, through the contagion effect, it may actually expand internationally.

Thus, in this paper we show that market dynamics affect financial integration among some of the countries that joined the European Union in the past 15 years. The level of financial

1 *Aurel Vlaicu University of Arad, contact_cb@yahoo.com.*

2 *Technical University of Civil Engineering of Bucharest, simona.mascu@rcc.ro.*

3 *Bucharest University of Economic Studies. Corresponding author: loleaiulian@gmail.com*

integration as well as how the business cycles in these countries correlate is very important for the accession of these countries to the Euro Zone. Several authors claim that the behavior of financial markets during crisis is different from the one during good economic times (*e.g.*, Longin and Solnik, 2001; Sandoval Jr., and De Paula Franca, 2012; Mynhardt, Plastun and Makarenko, 2014, Öztek and Öcal, 2017). Accession to the EU implies an integration of financial markets to a greater extent, and this can lead to a higher exposure to the contagion effect. So, this paper highlights how the financial integration amplified the contagion effect in five CEE equity markets at different periods of time, and focuses on the transmission of shocks from the Euro Zone equity markets towards these countries. Quantifying these relationships, we try to highlight that the increase in the level of integration leads to an increased contagion effect in certain periods of market turbulences (Diebold and Yilmaz, 2012).

To further emphasize the way in which the analyzed markets are correlated in times of crisis, we also analyze the conditional correlation in the DCC-GARCH model as according to Engle (2002). We aim to emphasize whether the correlations were lower in the pre-EU accession period, but also if in the crisis period these correlations increased. We expect, at least for the case of Romania and Bulgaria, to have lower correlations in the pre-EU accession period. Moreover, we expect these correlations to significantly increase and indicate a contagion effect during the crisis period.

A powerful correlation has disadvantages, such as the transmission of negative shocks, which can be transmitted across national borders more quickly. Although, reductions in volatility are observed only after countries have attained a level of financial integration, researchers such as Dungey and Martin (2007) have argued that if the impact of a shock is observed with only a lag of one period and after the shock no more lags have occurred, then it is the case of a spillover, while contagion is a residual transmission after accounting for all other transmissions, including spillover.

Shocks originating from one market are transmitted more quickly to other markets increasing the risk of contagion, especially when taking into consideration unified markets. One such example is the 2008 financial crisis, which began in the US real estate sector and then spread rapidly around the world, becoming a global financial and economic crisis.

The financial integration among countries that have recently joined the EU is extremely difficult to quantify; therefore, financial integration should be measured in different market situations, at different times. Furthermore, a very strong correlation brings disadvantages, such as the faster transmission of negative shocks and, implicitly, of economic crises to all member countries. Moreover, trade and financial ties are known to be important determinants of integration into international financial markets, as long as these markets have become more interconnected over time. The term "financial market integration" refers to a field of research that covers many aspects of the interdependencies between financial markets.

Further, in this paper we bring more novelty by analyzing the concept of financial contagion that has always been a very important element of concern in financial analysis and risk management. To this end, we depart from the concept of financial integration and move on to financial contagion, measuring the impact on the equity markets in the countries we have selected for the current analysis. In the context of financial integration, especially for the EU member states from Central and Eastern Europe, such as Hungary, Poland, the Czech Republic – that have become members of the EU since 2004, and Romania and Bulgaria -

since 2007, the expectations are that there is a contagion effect and it will intensify as the integration proceeds. The ranges for which the data is processed are the following:

- Pre-crisis period: January 2000 – August 2007;
- Crisis-period: September 2007 – December 2012;
- Post-crisis period: January 2013 – April 2019, with daily observations for 6 equity indices**:** Euro Stoxx 50 Index – Euro Zone, BET Index – Romania, BUX Index – Hungary, WIG Index – Poland, PX Index – Czech Republic, SOFIX Index - Bulgaria.

The data was divided into subperiods based on a Markov regime switching methodology (Marcucci, 2005). We chose as the period of crisis the longest period for which the model indicated that we have a high volatility regime.

This article presents how the financial integration amplified the contagion effect on the CEE equity markets, but also how this effect is transmitted to different markets at different times in countries which have recently acceded to the EU. We focus on the transmission of shocks from the Euro Zone equity markets to countries from CEE and on the quantification of these relationships.

2. Literature Review

The phenomenon of contagion has always been a very important topic that was studied in the context of financial analysis and risk management, being an element that could be quantified and predicted with certain difficulty. Contagion is influenced by the increased trade flow capital movements, financial reforms across economies, international diversification by large financial institutions, movement of global industries to emerging economies, advances in computer technology and information processing, among many other (R Shahani, F. Umar, 2020).

Eichengreen *et al.* (1996) state that the contagion effect represents a significant increase in the probability of a crisis, conditioned by the existence of another crisis in a different country. Later, Forbes and Rigobon (1999) stated a distinct definition according to which the contagion represents a significant increase in the connections between the markets as a result of a shock appeared in one of the countries. Increasing connections involve either the emergence of new transmission channels or the intensification of the existing ones. Hence, we can conclude that contagion refers to the spread of financial market disruptions at the regional and global level.

Bekaert *et al*. (2014) analyze the phenomenon during the crisis of 2008 highlighting the impact on the equity market. There are also research papers in the field of contagion effect during the sovereign debt crisis in Europe, based on correlation analysis. Some of them, Claeys and Vasicek (2014) and Altınbaş *et al.* (2021) establish an increase in correlations during turbulent periods and suggest a spillover effect. Moreover, the research published by Baur (2020) addressed in detail the issue of financial contagion during the sovereign debt crisis in the Euro Zone.

Corsetti *et al.* (2001) adopted the broad definition of contagion according to which the effect of contagion occurs when a country shock spreads regionally or globally. Starting from this definition, Horta (2013) analyzes the impact of a shock on the Greek equity market in correlation with the equity markets in the developed countries. The methodology used for measuring the contagion effect was based on copula functions, as other authors did in the past. Equally broadly, the contagion effect on the equity and forex markets was analyzed by

Tsiaras (2020), where he focused on the developed markets and the effects of the economic and financial crisis from 2008-2010, also addressing the issue of sovereign debt.

There is a plethora of papers analyzing and measuring the contagion in the Asian financial markets. A relevant one has been published by Cho and Parhizgari (2009) for East Asia, where they analyze the contagion effect using DCC-GARCH. Moreover, the problem of contagion in the Asian financial markets is very well measured by Lee *et al.* (2018) using several methodologies based on copula functions and combinations of this approach. The authors pointed out that in periods of turmoil, there is an exponential increase in the correlation between markets, no matter how it is measured, and that there is a strong contagion effect, even when the variation over time is considered. Furthermore, among many other authors that highlight the usefulness of applying a dynamic correlation model (DCC), Chiang *et al.* (2010) analyze the whole contagion effect on the equity markets for the Asian market and globally.

In addition, Syllignakis and Kouretas (2010) focus on the analysis of the contagion for the countries of Central and Eastern Europe (CEE), those countries that have recently become part of the European Union. In turn, this analysis was performed using a multivariate DCC-GARCH model. The same type of methodology was applied by Joyo and Lefen (2019) in a paper which analyzes the movement in the same direction of capital portfolios in Pakistan and in countries that are its main trading partners: Indonesia, Malaysia, US and UK.

Thus, we have highlighted several ways in which the contagion effect may be analyzed, and which was the main basis of extensive scientific literature. Further, we should consider the research of Diebold and Yilmaz (2009, 2012), where they developed a complex methodology that can analyze the effect of contagion, taking into account the possibility of measuring it and determining the meaning in which it is performed. At the same time, the methodology proposed by them is the basis for building a total volatility index that shows the risk of contagion in different periods of time.

We noticed that the same methodology was later used in several other articles such as Alola and Bekun (2021), Mesi *et al*. (2018)), Caloia *et al*. (2018), which added value to the literature and highlighted the usefulness of the approach. At the same time, this methodology has been extended to other asset classes, such as the commodity market (Liu and Gong, 2020) or cryptocurrencies (Matkovsky *et al*., 2020). All these articles, together with the initial one by Diebold and Yilmaz (2012), represent the basis for the methodology of the current research.

The most recent economic and financial crisis has shown that financial markets can be atypical in times of turbulence, and the correlations can be different from one period to another. Thus, the level of correlation and stability can be strongly dependent on the economic situation. The economic situation is dependent on the stability of the financial markets. Mendoza *et al*. (2009) addressed this issue, but the literature is not very rich in this direction. Therefore, we aim to capture in this research the dependence of financial market stability on the economic situation or on certain important events that may affect the economic and market stability.

3. Data and Methodology

The methodology of this paper goes in directions that highlight the contagion effect, and if it is transmitted on the CEE equity markets. Also, we want to confirm the assumption that the correlation of capital markets increases during periods of crisis, considering that during this period the negative effects are transmitted significantly faster. Most of the methodology is structured according to DY spillover extended index developed by Diebold and Yilmaz (2012), using a generalized vector autoregressive framework. According to it, forecast-error variance decompositions are invariant to variable ordering, measuring both total and directional volatility spillovers in a generalized VAR framework that eliminates the possible dependence of results on ordering. This method is adapted for the aim of this paper and uses of our methods to characterize daily volatility spillovers across the indexes of the analyzed countries. Moreover, we implement a DCC-GARCH model in order to obtain conditional correlations allowing for time-varying processes and Markov switching (Marcucci, 2005) to detect high volatility regimes.

The first direction is the one that addresses the problem of correlation between the equity markets in Romania, Hungary, Poland, the Czech Republic, Bulgaria and the Euro Zone. There is evidence that the level of correlation is statistically significantly different in the period of crisis as compared to a normal period. For this purpose, we use the Pearson correlation coefficient, calculated for different time periods.

In order to conclude if the two correlations differ statistically, a decision rule is constructed based on the t-Student test, considering the values of the Student distribution, one-tailed (upper-tailed). The alternative hypothesis of the Student test is: the value of the correlation coefficient in the crisis period is greater than the value of the correlation coefficient in the pre-crisis period.

As mentioned, DCC-GARCH models are used to analyze contagion and correlation over time, out of which we extract the dynamic conditional correlations. The methodology used for estimating such a model is that proposed by Engle (2002). The general equation of the DCC GARCH model is as follows:

$$H_t = D_t R_t D_t$$

Where H_t is the conditional variance matrix

D_t is a diagonal matrix which has on the first diagonal the conditional variance $\sqrt{h_{it}}$

R_t is the time-varying correlation matrix of the elements on the first diagonal.

As Engle (2002) did, the conditional variance (h_{it}) is estimated based on the univariate GARCH model:

$$h_{it} = \omega_i + \sum_{x=1}^{X_i} \alpha_{ix} r_{it-x}^2 + \sum_{y=1}^{Y_i} \beta_{iy} h_{it-y}$$

Based on the above equation we can obtain the errors (ε_t) and the standard deviation ($\sqrt{h_{it}}$). On the other hand, the conditional standard deviation is expressed by the diagonal matrix:

$$D_t = \begin{bmatrix} \sqrt{h_{11.t}} & 0 & \cdots & 0 \\ 0 & \sqrt{h_{22.t}} & \cdots & 0 \\ \vdots & \vdots & \vdots & 0 \\ 0 & 0 & \cdots & \sqrt{h_{33.t}} \end{bmatrix}$$

The standardized errors are used to estimate the matrix which contains the dynamic correlations:

$$R_t = Q_t^{*-1} Q_t Q_t^{*-1}$$

$$Q_t^* = \begin{bmatrix} \sqrt{q_{11}} & 0 & \dots & 0 \\ 0 & \sqrt{q_{22}} & \dots & 0 \\ \vdots & \vdots & \vdots & 0 \\ 0 & 0 & \dots & \sqrt{q} \end{bmatrix}$$

Where Q_t^* is the diagonal matrix and Q_t is the conditional covariance matrix.

The conditional correlation may be expressed in it's clasical form defining as follows:

$$\rho_{ij,t} = \frac{(1-a-b)\bar{Q} + a\varepsilon_{t-1} - 1\varepsilon_{t-1}^{'} + bQ_{t-1}}{\sqrt{(1-a-b)\bar{Q} + a\varepsilon_{t-1} - 1\varepsilon_{t-1}^{'} + bQ_{t-1}} \cdot \sqrt{(1-a-b)\bar{Q} + a\varepsilon_{t-1} - 1\varepsilon_{t-1}^{'} + bQ_{t-1}}}$$

The volatility transmission is analyzed using the spillover index introduced by Diebold and Yilmaz (2012), which uses a VAR model to measure the directional transmission:

$$x_t = \sum_{i=1}^{p} \Pi_i x_{t-1} + \varepsilon_t,$$

ε_t ~ i.i.d. (0, Σ)

$$x_t = \sum_{i=0}^{\infty} A_i \varepsilon_{t-i},$$

where A_i is the coefficient matrix, fulfilling the recurrent process: $A_i = \sum_{k=1}^{p} \Pi_k A_{i-k}$, with A_0 the identity matrix.

The variance decomposition allows the analysis forecasted error variances of each variable, in parts that are attributed to different system shocks.

The VAR approach introduced by Koop et al. (1996) and Pesaran and Shin (1998) can useful in solving this problem.

The decomposition of the variance of predicted error H steps ahead is as follows:

$$\theta_{ij}^{g}(H) = \frac{\sigma_{jj}^{-1} \sum_{h=0}^{H-1} (e_i A_h \Sigma e_j)^2}{\sum_{h=0}^{H-1} (e_i A_h \Sigma e_j)},$$

Each element of the variance decomposition matrix is normalized, in order to obtain the sum 1 for each row of the matrix.

$$\tilde{\theta}_{ij}^{g}(H) = \frac{\theta_{ij}^{g}(H)}{\sum_{j=1}^{N} \theta_{ij}^{g}(H)}$$

The total spillover index reveals the contribution to spillover across countries, taking into consideration an incremental approach. This contribution is calculated as follows:

$$S^g(H) = \frac{\sum_{\substack{i,j=1 \\ i \neq j}}^{N} \tilde{\theta}_{ij}^{g}(H)}{\sum_{i,j=1}^{N} \tilde{\theta}_{ij}^{g}(H)} x100 = \frac{\sum_{\substack{i,j=1 \\ i \neq j}}^{N} \tilde{\theta}_{ij}^{g}(H)}{N} x100$$

The VAR model has a big advantage in calculating this index represented by the fact that it allows for directional calculation of the spillover index. Directional volatility impulses received to market "i" from all other markets j are measured as follows:

$$S_{i \to j}^{g}(H) = \frac{\sum_{\substack{j=1 \\ i \neq j}}^{N} \tilde{\theta}_{ij}^{g}(H)}{\sum_{i,j=1}^{N} \tilde{\theta}_{ij}^{g}(H)} x100 = \frac{\sum_{\substack{j=1 \\ i \neq j}}^{N} \tilde{\theta}_{ij}^{g}(H)}{N} x100$$

This type of approach is used on the data series divided into 3 subperiods, in order to highlight the fact that in certain periods the spillover effect is stronger and that the correlation between markets increases during the crisis periods. Thus, the aim is to study the contagion on the equity markets in Central and Eastern Europe in correlation with the Euro Zone.

The purpose of this study is to investigate the correlation of equity markets in Central and Eastern Europe compared to those in the Euro Zone. For a more complex analysis, the integration of the financial markets with the Euro Zone was also pursued, rendering important implications for analyzing the contagion effect between the developing and Euro Zone markets.

An important step is the description of the data series. Daily frequency data is used for five countries in Central and Eastern Europe and for the Euro Zone:

6 equity indices with daily data

Euro Stoxx 50 Index – Euro Zone

BET Index – Romania

BUX Index – Hungary

WIG Index – Poland

PX Index – Czech Republic

SOFIX Index – Bulgaria

The EURO STOXX 50 Index, Europe's leading blue-chip index for the Euro Zone, provides a blue-chip representation of leaders in the region. Hence, it reveals the evolution of the major companies in Euro Zone. This index has a capitalization of EUR 3.7 trillion, which represents almost 35% of Euro Area's GDP. We find this level to be representative in order to be able to analyze the financial contagion.

On the other hand, indices from the CEE countries have a lower weight in GDP due to lower development of equity markets in those countries. These levels are the followings: BET (6% of GDP), BUX (21% of GDP), WIG (15% of GDP), SOFIX (4% of GDP), Czech Republic (10% of GDP).

Daily data was processed to obtain series of returns using the logarithmic approach:

$$R_t = 100(\ln(p_t) - \ln(p_{t-1})),$$

The range for which the data was processed is the following, with daily observations:

03/01/2000– 30/04/2019

This period is divided into 3 subintervals:

Pre-crisis period: Jan 2000 – Aug 2007

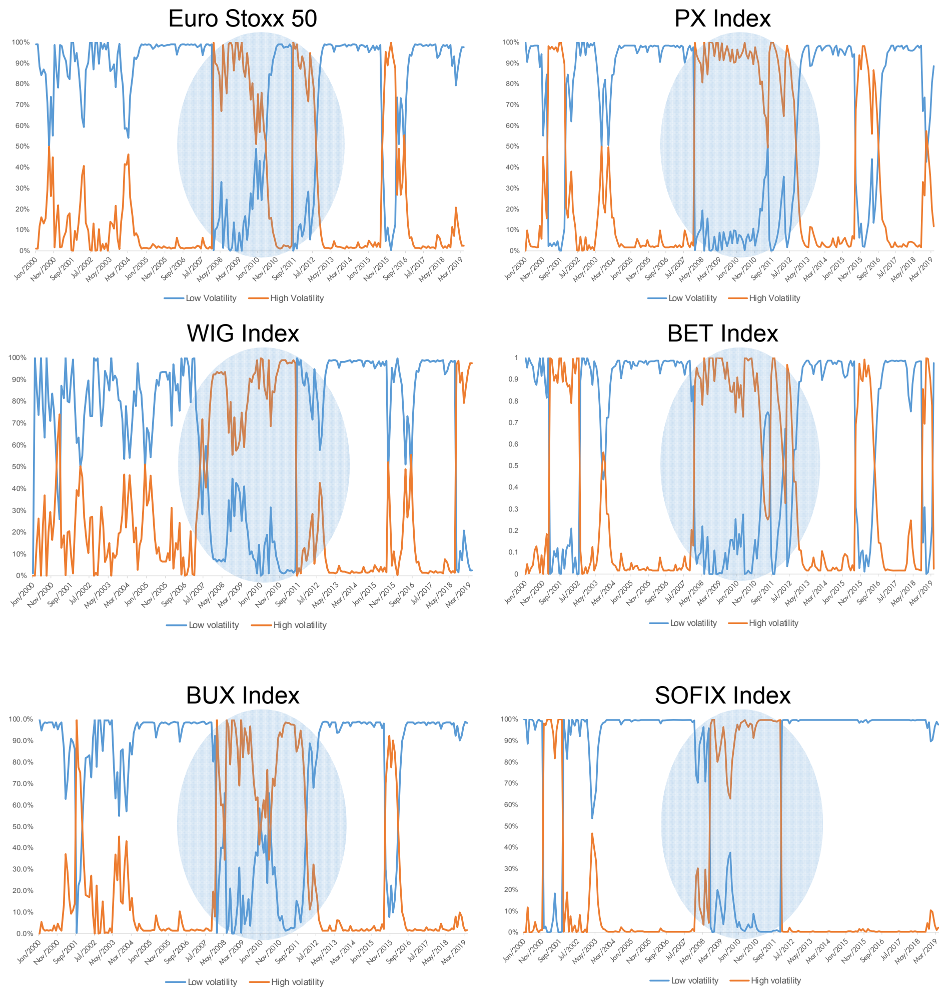
Crisis-period: Sep 2007 – Dec 2012

Post-crisis period: Jan 2013 – Apr 2019

We divided the data series into sub-intervals using the Markov Switching methodology according to Marucci (2002), which helps us identify regime changes in terms of volatility. Thus, two regimes were considered: low volatility and high volatility. In order to choose the crisis period, i.e., the period for which there is a possibility that the contagion effect is manifested on most of the analyzed markets, we chose the longest period for which the Markov Switching methodology suggested a high volatility regime. This period was marked on the following graphs and led us to obtain the previously mentioned sub-intervals.

Figure 1

Regime switching - unconditional posterior probabilities



Source: Authors' own computation.

For better organization of this paper, we also present below a table that summarizes the descriptive statistics for our data series using the main statistical indicators that can provide relevant information. These descriptive statistics represent a helpful step in the process to analyze the contagion effect and the level of integration of the capital markets in Central and Eastern Europe as compared to the capital market in the Euro Zone. These statistics refer to the first five moments in the series, their normality, heteroscedasticity and stationarity. According to the standard deviation of time series Bulgaria (SOFIX index) and Romania

(BET index) embed the higher risk. Most of the series illustrate a positive kurtosis and negative skewness.

Table 1

Descriptive statistics

Indicators	EUROSTOXX 50	BET	WIG	BUX	PX	SOFIX
Mean	-0.003	0.034	0.001	0.022	0.013	0.011
Median	0.018	0.018	0.003	0.011	0.01	0.005
Maximum	10.7	18.3	9.4	13.5	13.4	12.4
Minimum	-9.7	-21.5	-8.1	-11.2	-18.3	-8.7
Std. Dev.	1.387	1.632	1.391	1.318	1.391	1.452
Skewness	-0.09	-0.41	-0.15	-0.05	-0.33	-0.12
Kurtosis	8.33	23.22	7.32	6.83	13.87	15.41
Observations	4950	4950	4950	4950	4950	4950

Source: Authors' own computation based on Bloomberg data.

4. Empirical results

Contagion, as presented in the introductory part of the paper, is a complex phenomenon, which cannot be characterized by a single coefficient or indicator. Hence, we have considered a series of methodologies to analyze this phenomenon and we have applied them in order to be able to reach a conclusion and to be able to highlight a potential increase of contagion in turbulent periods on the financial markets.

In the first place, we have used the following hypotheses to test the significance of the increase of correlation coefficients through t-Student test:

$$\begin{cases} H_0 : \rho_s = \rho_c \\ H_1 : \rho_c > \rho_s \end{cases}$$

The rejection of the alternative hypothesis shows a significant increase in the correlation between two markets in the two sub-periods. In this scenario, there is a simple correlation between two markets and not a contagion effect. On the other hand, a rejection of null hypothesis means a significant increase in the correlation between two markets. This second scenario reveals the existence of the contagion phenomenon. The decision will be based on the comparison between the two values of t-Statsitics.

Table 2

Contagion test results

Indices	Pre - crisis	Crisis	t - Student	Contagion
	ρs	ρc		
BET	0.0412	0.4291	144.2*	Present
BUX	0.4561	0.5721	51.3*	Present
PX	0.4277	0.5981	63.1*	Present
WIG 20	0.4211	0.6321	213.2*	Present
SOFIX	0.355	0.586	55.1*	Present

*Note:*** reveals that the parameter is significant for a level of confidence of 1%.*
Source: Authors' own computation based on Bloomberg data.

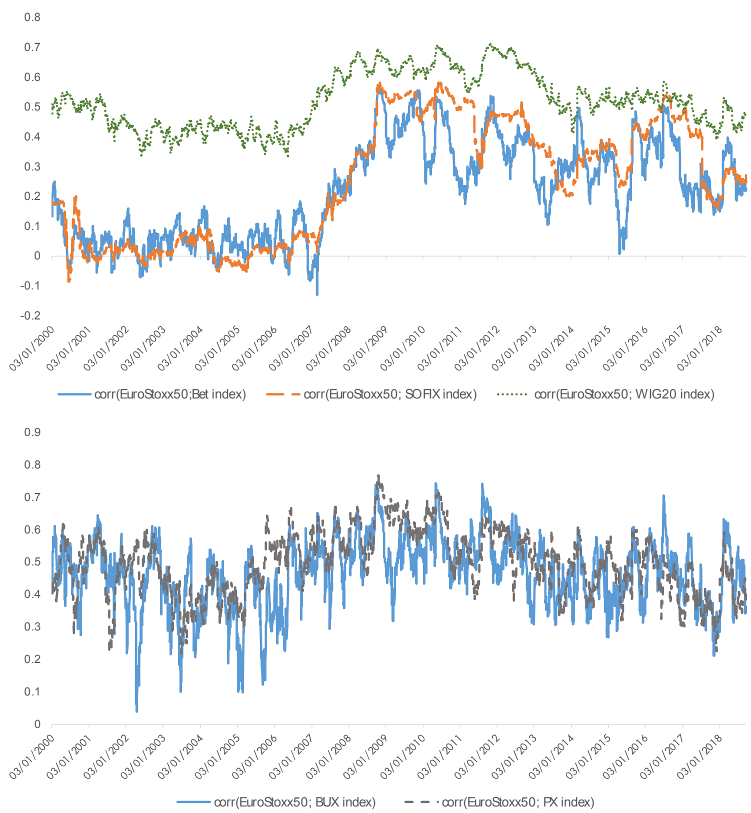
As we can see in Table 2, the calculated t - Statistic is significant for all the pairs analyzed at a level of 1%. Hence, the null hypothesis - the correlation coefficients of the two periods are not significantly different - is rejected. Thus, one can conclude that there is contagion generated by the crisis period.

It is also important to analyze the correlation in returns in order to see how it has varied over time. The aim is to capture the moments when the correlation increased and whether it was achieved against the background of a notable event.

We applied the DCC-GARCH model for the indices's returns and it led to the conditional dynamic correlations. These results are presented for the BUX, SOFIX, BET, PX and WIG indices in relation to Euro Stoxx 50. Their evolution over time shows the level of correlation of the equity markets in CEE with those in the Euro Zone.

Figure 2

Conditional dynamic correlations for the 5 CEE equity markets in relation with Euro Stoxx 50



Source: Authors' own computation based on Bloomberg data.

In the following part of this paper, we present an analysis of the spread of volatility. This analysis was done based on a VAR model following the methodology proposed by Diebold and Yilmaz (2012). Unlike Diebold and Yilmaz, we did not use inflation-adjusted returns, considering that it is more relevant for our approach to use nominal returns, given that all the variables used are nominal.

The results are presented in tables 3, 4 and 5 and were divided into three sub-periods to capture the pre-crisis period, the crisis period and the post-crisis period.

Table 3

Volatility Spillover pre-crisis

Jan.2000 – Jul 2007		From						
		EUROSTOXX50	WIG	BET	BUX	PX	SOFIX	Contribution from others
To	EUROSTOXX50	97.1	0.3	0	0.4	1.1	1.1	2.9
	WIG	4.9	94.1	0	0.1	0.3	0.6	5.9
	BET	0	0.2	98.5	0.7	0.4	0.2	1.5
	BUX	5.7	6.5	0.3	84.3	2.7	0.5	15.7
	PX	4.1	7.5	0.4	6.3	80.5	1.2	19.5
	SOFIX	0.2	0.1	0.4	0.5	0.3	98.5	1.5
Contribution to others		14.9	14.6	1.1	8	4.8	3.6	47
Contribution including own		112	108.7	99.6	92.3	85.3	102.1	Spillover index = 8.4%

Source: Authors' own computation based on Bloomberg data.

Table 4

Volatility Spillover during the crisis

Sep.2007 – Dec 2012		From						
		EUROSTOXX50	WIG	BET	BUX	PX	SOFIX	Contribution from others
To	EUROSTOXX50	95.5	0.3	1.4	0	1.3	1.5	4.5
	WIG20	30.5	65.1	1.7	0.3	1.1	1.3	34.9
	BET	9.8	8.4	80.1	0.2	0.9	0.6	19.9
	BUX	29.5	6.1	9.1	50.7	4.2	0.4	49.3
	PX	25.1	9.1	15.1	0.9	49.1	0.7	50.9
	SOFIX	30.5	0.2	0.3	0.7	0.8	67.5	32.5
Contribution to others		125.4	24.1	27.6	2.1	8.3	4.5	192
Contribution including own		220.9	89.2	107.7	52.8	57.4	72	Spillover index = 32.1%

Source: Authors' own computation based on Bloomberg data.

Table 5

Volatility Spillover post-crisis

Jan.2013 – Apr 2019		From						
		EUROSTOXX50	WIG	BET	BUX	PX	SOFIX	Contribution from others
To	EUROSTOXX50	96.1	0	0.4	0.1	2.3	1.1	3.9
	WIG	19.1	80.4	0	0.2	0.2	0.1	19.6
	BET	5.1	3.6	90.5	0.4	0	0.4	9.5
	BUX	14.5	8.1	1	75.1	0.9	0.4	24.9
	PX	23.1	3.5	2.1	2.5	67.5	1.3	32.5
	SOFIX	10.1	0.7	1.5	2.5	1.1	84.1	15.9

Jan.2013 – Apr 2019	From						
	EUROSTOXX50	WIG	BET	BUX	PX	SOFIX	Contribution from others
Contribution to others	71.9	15.9	5	5.7	4.5	3.3	106.3
Contribution including own	168	96.3	95.5	80.8	72	87.4	Spillover index =17.9%

Source: Authors' own computation based on Bloomberg data.

Tables 3, 4 and 5 show the volatility fluctuations on different equity markets. The variance of the forecast errors and the spillover index of volatility are calculated based on the VAR model and the generalized variance decomposition, as presented in the methodology.

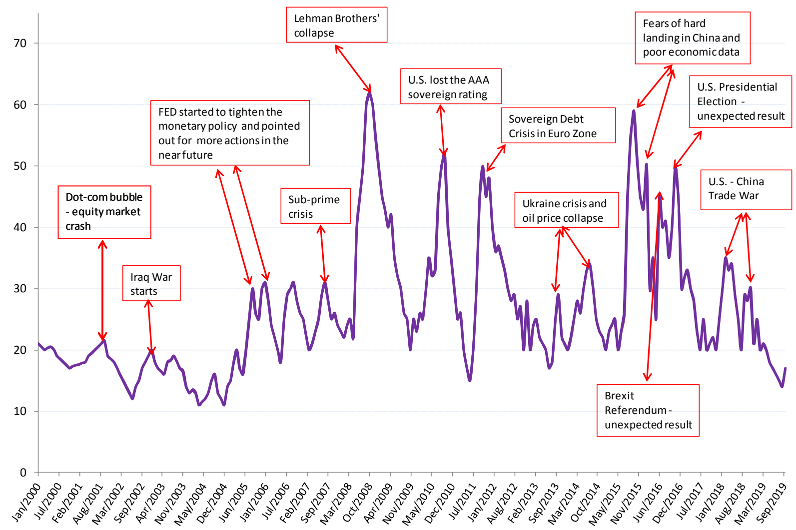
The above results reveal that during turbulent periods, the spread of volatility is higher than in normal times. Hence, in the crisis period the total spillover index was 32.1% compared to 8.4% before crisis and 17.9% in the post-crisis period. As it can be observed, the values outside the first diagonal are lower and they reveal the impact of other markets.

The equity markets in Hungary and Czech Republic were the ones with the highest level of contagion, followed by Poland, Romania and Bulgaria. This can be accounted for by better integration for countries that have joined the U.E. before Romania and Bulgaria, observing that subsequently the level of contagion measured by spillover index increased for the case of Romania and Bulgaria, as well. Hence, the equity markets in these two countries were more dependent on the Euro Zone in the post-crisis period than in the pre-crisis period. A similar conclusion was reached by Hung (2019), based a more a complex methodology which included GARCH-BEKK, CCC and DCC models, however this could represent a way to expand our research in the future.

This analysis is complemented by another approach according to the methodology promoted by Diebold and Yilmaz (2012) which considers a 200-day rolling sample for calculating an aggregate contagion index for all 6 markets considered in the analysis. This index evaluates the magnitude and the nature of contagion through time for the series presented in table 1. The results complement the ones presented through tables 3, 4 and 5 which analyze the values for the index in a static manner, without observing the evolutions in time. Thus, we move from a static approach, focused on each country, to a dynamic and global approach, which acknowledges the common contagion between the 6 markets. All this analysis is summarized by Figure 3.

Figure 3

Total volatility spillover effect



Source: Authors' own elaboration based on Bloomberg data.

As shown in Figure the spread of volatility has a wide variation and is positively associated with extreme economic events, such as the collapse of equity markets, the sovereign debt crisis or important political events. Thus, the spillover index calculated according to the methodology of Diebold and Yilmaz (2012) captures very well the stress periods on the capital markets, registering increases when the recorded events occur. Therefore, volatility increases at the same time on each of the five markets, highlighting the presence of the contagion and a higher risk perceived by investors. It is also noted that the spillover index calculated for the equity markets in Poland, Hungary, Czech Republic, Romania, Bulgaria and the Euro Zone was higher in the post-crisis period than in the pre-crisis period, pointing out that the higher level of financial integration could lead to an increased risk of contagion. These results were in line with what other researchers found (Hung, 2019 and Demiralay and Bayraci, 2015).

5. Conclusions

First of all, we considered that an increase in the level of correlation between the equity market in each country and the equity market in the Euro Zone during the crisis period compared to the period before the crisis is a sign that there is contagion on the markets during the crisis. Hence, these markets become significantly more correlated during the crisis period. The usage of t-Student test highlighted this idea, since the differences between the values for the correlation coefficients with the Euro Zone were statistically significant for all four countries. Furthermore, the conditional dynamic correlations from DCC-GARCH emphasize the same result of the increase in correlations during the crisis period, while in the pre-accession to EU, the BET (Romania) and SOFIX (Bulgaria) were slightly correlated with Euro Stoxx 50, unlike PX, WIG and BUX.

Moreover, we should point out that the data set was divided into subperiods using the Markov switching methodology introduced by Marcucci (2005) to identify the volatility regimes on the equity markets. The time period for which the model indicated the most days with high volatility regime was chosen as the crisis period.

Another analysis method applied in this paper was the one based on the approach of Diebold and Yilmaz (2012), which uses a spillover index and the contribution of each market to this spillover index. This type of approach emphasized that the level of contagion measured by this index was significantly higher during the crisis period. Furthermore, in the post-crisis period, it was higher than in the pre-crisis period, pointing out that once the market integration increased, the level of shock transmission increased. This conclusion is also reinforced by the last graph of this paper, where one may observe that the spillover index increases significantly in times of stress, when important events occur on financial markets such as: Brexit referendum, sovereign debt crisis, US presidential election, Lehman Brothers fall. Our results show that during turbulent times, the spread of volatility is on average higher than in the periods before and after the crisis. Respectively, 32.1% of the volatility of forecast error in all 6 markets comes from the spread of volatility during the crisis periods compared to 8.4% before the crisis to 17.9% after the crisis.

Following the analysis based on the spillover index, we observed that the stock markets in the Czech Republic and Hungary were the most influenced by the developments in the Euro Zone, being ones of the most prone to the contagion effect. On the other hand, the Romanian and Bulgarian equity markets were the least influenced during the pre-financial crisis period. We have noticed that the Romanian equity market became more sensitive to the developments in the Euro Zone subsequent to joining the EU. This was most likely since Romania achieved a better level of financial integration and, as previously stated, as the level of integration increases the country becomes more prone to experience the financial contagion phenomenon.

The results are relevant and offer valuable information to the equity market participants. They can be used to improve portfolio management and could be integrated into early-warning mechanisms of stock market contagion. Thus, equity market participants can take decisions about reducing their exposure to this asset class when signs of contagion appear, or they can trade on several markets, speculating that the shock from one market is transmitted to another market as it happened in the past, and in the manner measured by the methodology proposed by Diebold and Yilmaz (2012).

All in all, i) in the crisis period, the contagion from the Euro Zone was more pronounced in the countries with a higher level of financial integration (both, conditional dynamic correlations from DCC-GARCH and the spillover methodology from Diebold and Yilmaz revealed the same conclusions); ii) in the post-crisis period the contagion from the Euro Zone was stronger than during the pre-crisis period, given the higher level of financial integration in the countries that recently joined the EU; iii) the spillover index increased during the periods associated with important events, suggesting that the risk of contagion increases during periods of high uncertainty. Same results were obtained through estimating the conditional dynamic correlations from DCC-GARCH.

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