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Financial Contagion in Central and Eastern European Capital Markets: The Case of Russia's Invasion of Ukraine

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Abstract: *Russia invaded Ukraine on February 24th, 2022, marking a steep escalation of the Russo-Ukrainian War, which began in 2014 after the Ukrainian Dignity Revolution. The invasion caused Europe's largest refugee crisis since World War II, with more than 5.5 million Ukrainians leaving the country and a quarter of the population displaced. At the outbreak of war in 2014, Russia annexed Crimea and Russian-backed separatists who participated in the south-eastern Donbas region of Ukraine, starting a regional war there. Considering these events, it is relevant for policymakers and regulators to understand how contagious crises are to take appropriate measures to prevent or contain the side effects. To verify the levels of contagion or interdependencies we use Pindyck and Rotemberg's t-statistic, as well as Forbes and Rigobon's t-test, which suggests that we are facing extreme volatility in the capital markets analysed, and financial contagion is very significant. In conclusion, the capital markets analysed mostly show that correlations have increased in this period of uncertainty in the global economy (Russian invasion in Ukraine), evidencing that investors will find it difficult to diversify risk in these markets. The authors believe that the results achieved represent interest for investors seeking opportunities in these stock markets, and for policymakers to undertake institutional reforms to increase stock market efficiency and promote sustainable growth in financial markets. These findings also open room for market regulators to take steps to ensure better information in these regional markets.*

1. INTRODUCTION

In recent years, globalization has shown that the correlation between international financial markets has increased. The linkages between international stock markets can be strong during quiet periods as well as in times of crisis, which may make it difficult to implement portfolio diversification efficiently. The integration of capital markets globally has been a hot topic in recent decades, especially after the stock market crash during the 2008 global financial crisis. Investors who buy stocks in domestic and foreign markets seek to reduce risk through international diversification. Risk reduction occurs if the various markets are not perfectly correlated. The increasing correlation between markets during and after crises has restricted the possibilities for international diversification. From the investor's point of view, knowledge of the form and intensity of interdependence between different financial markets is vital for making efficient hedging decisions to minimize the adverse effect of uncertainty on expected investment returns.

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Similarly, understanding the interdependent relationships between international stock markets facilitates the identification of diversification opportunities. The demise of barriers to investment in recent years has meant that many countries have undergone the process of integration on both a financial and economic level. This leads to the benefits of international diversification being called into question mainly due to the various financial crises that have plagued financial markets around the world (Dias et al., 2020; Dias et al., 2021; Dias and Carvalho, 2021; Dias et al., 2022; Dias, Alexandre, et al., 2021; Dias, Heliodoro, and Alexandre, 2020; Dias, Heliodoro, Alexandre, et al., 2020; Dias, Heliodoro, Alexandre, Santos, and Farinha, 2021; Dias, Heliodoro, Alexandre, Santos, and Vasco, 2021; Dias, Pardal, et al., 2020; Dias, Santos, et al., 2021; Dias et al., 2019; Dias and Carvalho, 2020; Dias and Pereira, 2021; Dias and Santos, 2020; Heliodoro et al., 2020; Pardal, P., Dias, R., Šuleř, P., Teixeira, N., and Krulický, 2020; Pardal et al., 2021; Silva et al., 2020; Vasco et al., 2021; Zebende et al., 2022).

This paper aims to analyse the financial contagion in the stock market indices of Austria (Austrian Traded), Budapest (BUX), Bulgaria (SE SOFIX), Croatia (CROBEX), Russia (MOEX), Czech Republic (PragueSE PX), Romania (BET), Slovakia (SAX 16) and Slovenia (SBI TOP) in the period from January 2nd, 2017, to May 6th, 2022. The results of Pindyck and Rotemberg's t-statistic as well as Forbes and Rigobon's t-test show that the analysed capital markets exhibit extreme volatility and contagion is very significant. These findings show that the hypothesis of implementing risk diversification strategies could be called into question.

This research adds relevant contributions to the literature, namely in what concerns understanding whether the uncertainty experienced in the global economy arising from the global pandemic of 2020 and the Russian invasion of Ukraine in 2022 cause contagion between the capital markets of Austria (ATX), Slovenia (SBITOP), Hungary (BUDAPEST), Croatia (CROBEX), Bulgaria (SOFIX), Poland (WIG), Czech Republic (PX PRAGUE), Russia (IMOEX), Romania (BET); to the best of our knowledge, this is the first study that examines these markets in a period that contemplates the War of 2022.

In terms of structure, this paper is organized into 5 sections. In addition to the current introduction, section 2 presents a state-of-the-art analysis of articles on financial contagion in international financial markets, section 3 describes the methodology and section 4 contains the data and results. Section 5 presents the general conclusions of the paper.

2. LITERATURE REVIEW

Since the mid-2000s, international financial markets have been subject to a significant number of financial crises, namely the subprime crisis in the US in 2008, and the sovereign debt crisis in Europe in 2010, which originated in developed economies. These events significantly infected developed economies, however, this significance was not dense in emerging economies (Wong and Li, 2010).

Assessing the current state of financial integration and shocks between markets is also relevant from the standpoint of cost versus benefit analysis. The literature commonly agrees that financial integration brings benefits, in good times. However, in times of crisis, high financial integration increases the probability of contagion, due to the close interrelationship between financial markets through the proximity of markets. Overall, in the long run, the benefits of financial integration are expected to outweigh the costs (Babecký, Komarek, and Komárková, 2017)

Jin and Na (2016) studied the contagion effects between the BRIC capital markets and the U.S. market; the authors show that during the 2008 financial crisis there was contagion between the stock markets analysed. Tsai (2017) analysed the financial markets of China, Japan, Europe and the United States and evidence partial contagion between markets. Alexakis and Pappas (2018) analysed the existence of financial contagion in the European Union during the 2008 and 2010 financial crises, showing significant contagion in all sectors of activity.

De Morais et al. (2019) investigated the existence of contagion in 11 emerging country stock markets, namely from Latin America and Central Europe. For this purpose, they used deterministic GARCH and stochastic volatility models, both univariate and multivariate. The authors show the presence of financial integration among the countries and further suggest that the crisis has intensified these relationships. In addition, several characteristics common to the financial series were identified, such as leverage effect, grouping volatility, and persistence.

Meanwhile, the authors Heliodoro et al. (2020) analysed financial contagion in the six major markets in Latin America (Argentina, Brazil, Chile, Colombia, Mexico, and Peru) and the U.S. over the period 2015-2020. The results of the autocorrelation tests are fully coincident with those obtained by the BDS test. The rejection of the null hypothesis, i.i.d., can be explained, among other factors, by the existence of autocorrelation or by the existence of heteroscedasticity in the stock market indices series, in which case the rejection of the null hypothesis is explained by the non-linear dependence of the data, except for the Argentinean market. However, significant levels of contagion between these regional markets and the U.S. were expected to occur as a result of the global pandemic (COVID-19), which did not happen. Gunay (2020) examined the influence of the 2020 global pandemic on six stock markets, evidencing contagion and structure breakdowns between February 19th and 21st, 2020, in most markets, while in the Chinese market the breakdown is on January 30th, 2020. Fang et al. (2021) analysed contagion in developed and emerging markets over the period 2000-2016; for this purpose, they used the impulse response function method and the dynamic conditional correlation model (MGARCH). The authors show that the level of volatility in emerging equity markets was higher than in developed markets, namely the European Union and US markets. Additionally, they suggest that emerging equity markets are significantly subject to residual contagion during the subprime mortgage crisis in the US and the prolonged debt crisis in Europe. Moreover, the residual contagion effects of these two crises are noticeably heterogeneous across emerging markets. Malik et al. (2021) investigated the presence of pairwise contagion or volatility transmissions in the stock market returns of India, Brazil, Russia, China, and the US before and during the COVID-19 pandemic period; for the purpose, they estimated generalized autoregressive conditional heteroscedasticity (GARCH) models under diagonal parameterization to estimate the multivariate GARCH framework also known as the BEKK model. The authors highlight that Russia is less vulnerable to external shocks. Finally, after examining the results in pairs, it is suggested that the stock indices of BRIC countries exhibited significant contagion due to the COVID-19 pandemic.

In more recent studies, authors Saijai et al. (2022) examined contagion effects in developed and emerging equity markets, debt markets, gold, and cryptocurrencies over the period January 2018 to July 2020 using multivariate GARCH models based on dynamic conditional correlations. The authors show that the returns exhibit high levels of persistence (greater than 0.80), except for the US stock market (DJI) and the gold market. When comparing the degree of contagion effects before and during COVID-19, the conditional correlation increases significantly after the pandemic announcement in many financial market pairs, indicating the contagion effects between these markets during the last months of the 2020 pandemic. However, it is observed that the dynamic correlations between gold-DJI, Gold-Stock Exchange of Thailand (SET) and US Treasury Bill (TNX) are negative during the COVID-19 pandemic, indicating that gold may act as a safe haven in these financial markets.

In summary, this paper aims to contribute to providing information to investors and regulators in the Central and Eastern European capital markets where individual and institutional investors seek diversification benefits. Thus, the context of this paper is to examine the contagion between the stock indices under analysis, in order to understand whether the increase/decrease of financial integration causes or may cause shocks between these regional markets.

3. METHODOLOGY AND DATA

3.1. Data

The data used are the prices index of 9 capital markets under analysis, namely, the stock indices of Austria (Austrian Traded), Budapest (BUX), Bulgaria (SE SOFIX), Croatia (CROBEX), Russia (MOEX), Czech Republic (PragueSE PX), Romania (BET), Slovakia (SAX 16) and Slovenia (SBI TOP), for the period from January 2nd, 2017, to May 6th, 2022. The sample was partitioned into two sub-periods: the first sub-period comprises the days from January 2nd, 2017, to December 31st, 2019, which corresponds to the Tranquil period; while the second comprises the period from January 1st, 2020, to May 6th, 2022, which comprises the periods marked by high turbulence triggered by the 2020 pandemic occurrence and the Russian invasion of Ukraine in 2022, in which we refer to as Crisis. Quotes are daily and were obtained through the DataStream platform and are in local currency to avoid exchange rate distortions.

Table 1. The name of countries and their indices used in this paper

Country	Index
Austria	AUSTRIAN TRADED
Hungary	BUDAPEST BUX
Bulgaria	BULGARIA SE SOFIX
Croatia	CROBEX
Russia	MOEX
Czech Republic	PRAGUE SE PX
Romania	BET
Slovakia	SAX 16
Slovenia	BLUE CHIP SBI TOP

Source: Own elaboration

To analyse the behaviour of financial markets, Tsay (2005) proposes the use of return series instead of price series, because investors are mainly interested in knowing the return on an asset or a portfolio of assets. In addition, profitability series show statistical features that simplify the analytical treatment, namely the characteristic of stationarity, not usually present in price series. For the reasons explained above, the price indices series have been modified into growth rates or series in the differences of the Napierian logarithms of the current and previous returns, of logarithmic, instantaneous, or continuously compounded returns, through the following expression:

$$r_t = \ln P_t - \ln P_{t-1} \quad (1)$$

Where r_t is the rate of the return, at day t, and P_t and P_{t-1} are the closing prices of the series, at the moments t and $t-1$, respectively.

3.2. Methodology

The methodology used to answer the research questions is structured as follows: in the first stage we perform the descriptive statistics (mean, standard deviation, asymmetry and kurtosis), and to validate the time series distributions we use the Jarque and Bera (1980) test. To validate the assumptions of stationarity of the time series we used the unit root tests in panel by Breitung (2000), Levin, Lin, and Chu (2002), which postulate that the null hypothesis has unit roots, while the Hadri (2000) test presents the stationarity in the null hypothesis. The intersection of the tests will give robustness to the estimated models. In order to analyse the occurrence of financial contagion between the capital markets under analysis, the unconditional correlations were estimated, and the statistical significance of the estimated correlation coefficient was examined. For this purpose, the statistic t was used, which follows the distribution of t, with $n-2$ degrees of freedom, where r is the correlation coefficient between two series and n is the number of observations. In turn, to test whether the matrix of correlation coefficients is globally different from the identity matrix, we resort to the likelihood ratio test of Pindyck and Rotemberg (1990), whose null hypothesis postulates the non-existence of correlation between the various markets in the sample. The test statistic is given by t = - N * Log [R], which is proved to follow a chi-square distribution, with 0.5p (p-1) degrees of freedom, where [R] is the determinant of the correlation matrix, N is the number of observations in the common sample and p is the number of series analysed in the test. To assess whether we are facing contagion or interdependence we estimate the Forbes and Rigobon (2002) t-test.

4. RESULTS

Figure 1 shows the evolution, in first differences, of the 9 capital markets under analysis, namely, the stock indices of Austria (Austrian Traded), Budapest (BUX), Bulgaria (SE SOFIX), Croatia (CROBEX), Russia (MOEX), Czech Republic (Prague SE PX), Romania (BET), Slovakia (SAX 16) and Slovenia (SBI TOP), for the period from January 2^{nd}, 2017 to May 6^{th}, 2022, which comprises periods marked by high turbulence triggered by the occurrence of the COVID-19 pandemic and the Russian invasion of Ukraine. The time series returns reveal the instability experienced by the markets, with significant breaks in the time series being observed essentially during the year 2020, a period marked by the occurrence of the pandemic crisis. It should be noted that the Slovakian and Russian capital markets during this period were the markets that showed the least volatility, with comparatively less significant falls. Having said this, there was a tendency to rebalance during the year 2021. In 2022, there were structural breaks in the capital markets under analysis at the beginning 2022, with special emphasis on the Russian stock market index.

Figure 2 represents the evolution of the capital markets under analysis, in the first differences. The sample under study comprises a period from January 2^{nd}, 2017, to May 6^{th}, 2022, a rather complex period due to the outbreak triggered by the 2020 global pandemic (Covid-19) and more recently, due to the invasion of Ukraine by Russia. The returns reveal the instability experienced by these markets in February, March, and April 2020. During the first quarter of 2022, it can be observed that particularly the Russian stock market index, shows a rather sharp drop, less significantly, than the Budapest stock market index.

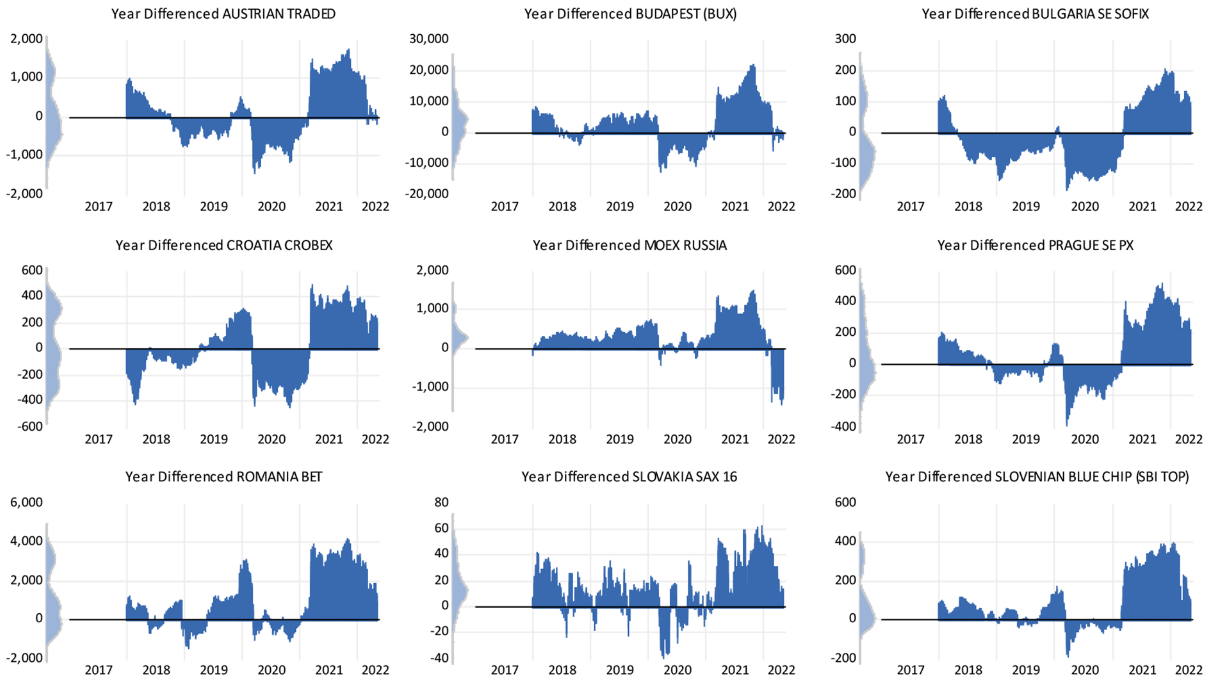
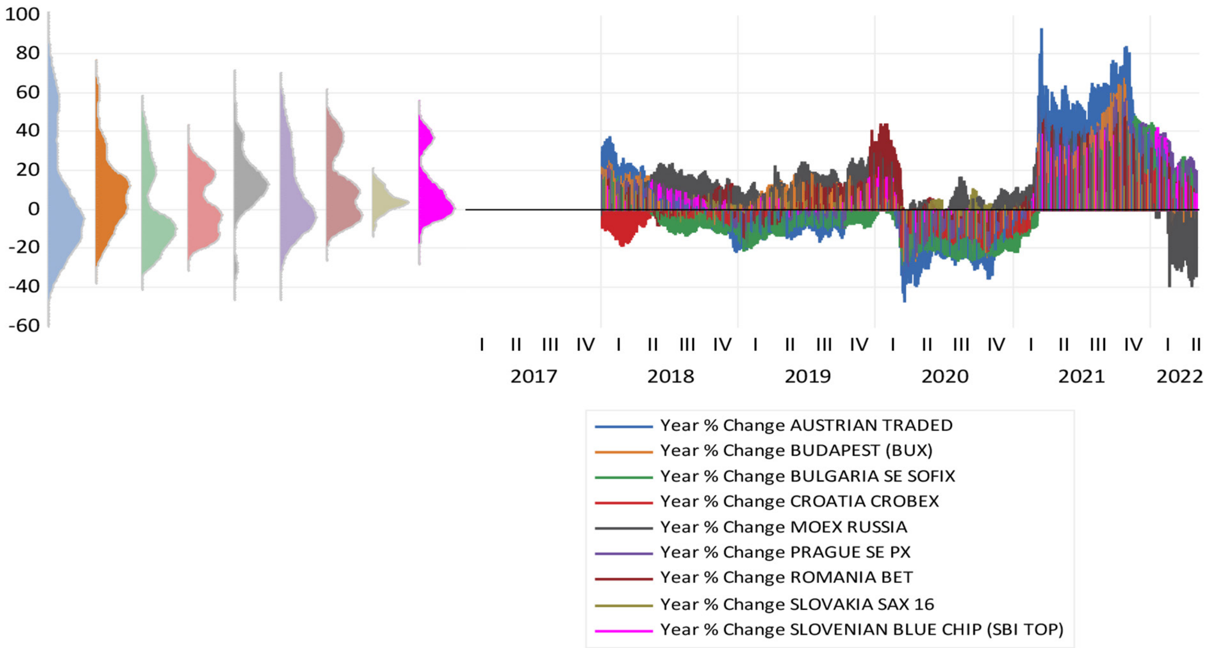


Figure 1. Evolution, in levels, of the 9 financial markets, in the period January 2nd, 2017, to May 6th, 2022

Source: Own elaboration



Note: DataStream

Figure 2. Evolution, Year % Change, of the 9 financial markets, in the period January 2nd, 2017, to May 6th, 2022

Source: Own elaboration

In tables 2, 3, and 4 the stationary nature of the data series can be examined, referring to the 9 capital markets under analysis, namely, the stock market indices of Austria (Austrian Traded), Budapest (BUX), Bulgaria (SE SOFIX), Croatia (CROBEX), Russia (MOEX), Czech Republic (PragueSE PX), Romania (BET), Slovakia (SAX 16), and Slovenia (SBI TOP). The Breitung

(2000), Levin, Lin, and Chu (2002) tests postulate that the null hypothesis has unit roots, showing the stationarity of time series in first differences. The Hadri (2000) test, on the other hand, postulates stationarity in the null hypothesis and we can see that for a significance level of 1% the H_0 is validated in the first differences, showing that the data series are stationary, suggesting that we are facing a white noise (mean = 0; constant variance)

Table 2. Levin et al. (2002) test performed on the 9 capital markets under analysis over period January 2nd, 2017, to May 6th, 2022

Null Hypothesis: Unit root (common unit root process)							
Method				Statistic		Prob.**	
Levin, Lin & Chu t*				-111.196		0.0000	
Intermediate results on D(UNTITLED)							
Series	2nd Stage Coeff.	Variance of Reg	HAC of Dep.	Lag	Max Lag	Band-width	Obs
D(AUSTRIAN TRADED)	-0.94904	1456.0	41.953	0	23	70.0	1393
D(BUDAPEST BUX)	-0.92290	266119	16207.	2	23	34.0	1391
D(BULGARIA SE_SOFIX)	-0.87082	19.330	0.0588	2	23	670.0	1391
D(CROATIA CROBEX)	-0.68352	202.48	3.3914	4	23	169.0	1389
D(MOEX RUSSIA)	-1.12448	2095.7	42.693	0	23	103.0	1393
D(PRAGUE SE PX)	-0.98091	91.557	6.9707	0	23	26.0	1393
D(ROMANIA BET)	-0.85841	9469.3	42.194	1	23	530.0	1392
D(SLOVAKIA SAX 16)	-1.10561	10.518	0.1741	0	23	119.0	1393
D(SLOVENIAN BLUE CHIP SBI TOP)	-0.86932	63.625	1.3172	1	23	112.0	1392
	Coeff.	t-Stat	SE Reg	mu*	sig*		Obs
Pooled	-0.97920	-88.943	1.004	-0.500	0.707		12527

Note: * Automatic lag length selection based on SIC: 0 to 4. Newey-West automatic bandwidth selection and Bartlett kernel. ** Probabilities are computed assuming asymptotic normality.

Source: Own elaboration

Table 3. Breitung (2000) test performed on the 9 capital markets under analysis for the period January 2nd, 2017, to May 6th, 2022

Null Hypothesis: Unit root (common unit root process)				
Method			Statistic	Prob.**
Breitung t-stat			-55.2754	0.0000
Intermediate regression results on D(UNTITLED)				
Series	S.E. of Regression	Lag	Max Lag	Obs
D(AUSTRIAN TRADED)	52.6619	0	23	1393
D(BUDAPEST BUX)	583.006	2	23	1391
D(CROATIA CROBEX)	15.0320	4	23	1389
D(MOEX RUSSIA)	69.2338	0	23	1393
D(PRAGUE SE PX)	13.4113	0	23	1393
D(ROMANIA BET)	114.666	1	23	1392
D(SLOVAKIA SAX 16)	4.85148	0	23	1393
D(SLOVENIAN BLUE CHIP SBI TOP)	9.40043	1	23	1392
	Coefficient	t-Stat	SE Reg	Obs
Pooled	-0.54904	-55.275	0.010	12518

Note: * Automatic lag length selection based on SIC: 0 to 4. ** Probabilities are computed assuming asymptotic normality.

Source: Own elaboration

Table 4. Hadri (2000) test performed on the 9 capital markets under analysis for the period January 2nd, 2017, to May 6th, 2022

Null Hypothesis: Stationarity				
Method			Statistic	Prob.**
Hadri Z-stat			-1.07307	0.8584
Heteroscedastic Consistent Z-stat			0.51081	0.3047
Series	LM	Variance HAC	Bandwidth	Obs
D(AUSTRIAN TRADED)	0.0844	2134.105	14.0	1394
D(BUDAPEST BUX)	0.0513	304245.8	11.0	1394
D(BULGARIA SE SOFIX)	0.1695	27.32660	14.0	1394
D(CROATIA CROBEX)	0.0310	366.8914	19.0	1394
D(MOEX RUSSIA)	0.1339	1961.207	6.0	1394
D(PRAGUE SE PX)	0.0851	127.4769	14.0	1394
D(ROMANIA BET)	0.0441	11496.70	5.0	1394
D(SLOVAKIA SAX 16)	0.0156	6.475281	16.0	1394
D(SLOVENIAN BLUE CHIP SBI TOP)	0.0492	98.34921	14.0	1394

Note: * High autocorrelation leads to severe size distortion in Hadri test, leading to over-rejection of the null. ** Probabilities are computed assuming asymptotic normality.

Source: Own elaboration

To analyse the occurrence of financial contagion between the stock market indices of Austria (Austrian Traded), Budapest (BUX), Bulgaria (SE SOFIX), Croatia (CROBEX), Russia (MOEX), Czech Republic (Prague SE PX), Romania (BET), Slovakia (SAX 16), and Slovenia (SBI TOP) over the period from January 2nd, 2017, to May 6th, 2022, we estimated the unconditional correlations and examined the statistical significance of the estimated correlation coefficient. For this purpose, we used the t statistic, which follows the distribution t, with $n-2$ degrees of freedom, where r is the correlation coefficient between two series and n is the number of observations. In turn, to test whether the correlation coefficients matrix is globally different from the identity matrix, we resort to the likelihood ratio test of Pindyck and Rotemberg (1990), whose null hypothesis postulates the non-existence of correlation among the various markets in the sample. The test statistic is given by t = - N * Log [R], which is proved to follow a chi-square distribution, with 0.5p (p-1) degrees of freedom, where [R] is the determinant of the correlation matrix, N is the number of observations in the common sample and p is the number of series analysed in the test.

Table 5. Correlation in the Tranquil period, concerning the 9 capital markets, in the period from January 2nd, 2017, to December 31st, 2019

	AUSTRIAN	BUX	SOFIX	CROBEX	MOEX	PRAGUE	BET	SAX 16	SBI TOP
AUSTRIAN	-								
BUX	0.352840***	-							
SOFIX	0.106755***	0.086957***	-						
CROBEX	0.101463***	**0.036294**	0.120128***	-					
MOEX	0.333990***	0.225511***	0.060352*	**0.025779**	-				
PRAGUE	0.580227***	0.370233***	0.097964***	0.073565**	0.257412***	-			
BET	0.236308***	0.139268***	**0.051579**	0.092200***	0.084818**	0.263403***	-		
SAX16	**0.026347**	**0.033119**	**0.048260**	**0.031010**	**0.034153**	**0.009317**	**0.019745**	-	
SBI TOP	0.100261***	0.102279***	0.085161**	0.165258***	**0.007164**	0.115481***	0.096438***	**0.012068**	-

Note: ***, **, * indicate significant results at 1%, 5% and 10%, respectively.

Source: Own elaboration

In Table 5 we can observe the unconditional correlation coefficients of statistic t referring to the Tranquil period, in the period from January 2nd, 2017, to December 31st, 2019. As can be seen, in general, during the so-called quiet period in the financial markets, the markets show 60 significant correlation coefficients (out of 72 possible). On the other hand, market pairs AUSTRIAN-SAX 16, BUX- CROBEX, BUX-SAX 16, SOFIX-BET, SOFIX-SAX 16, COBEX-MOEX, CROBEX-SAX 16, MOEX-SAX 16, MOEX-SBI TOP, PRAGUE-SAX 16, BET-SAX 16, SAX 16-SBI TOP do not show significant correlation coefficients, which could mean the existence of risk diversification possibilities.

In table 6 we can see the unconditional correlation coefficients of the statistic t referring to the Crisis period, for the period from January 1st, 2020, to May 6th, 2022, and we can observe the existence of 65 markets with significant unconditional correlations, except for market pairs AUSTRIAN-SAX 16, BUX-SAX 16, SOFIX-SAX 16, CROBEX-SAX 16, MOEX-SAX 16, PRAGUE-SAX 16, BET-SAX 16, SAX 16-SBI TOP. Note that these non-correlations have already been seen in the Tranquil period; overall, the non-conditional correlations increased significantly which suggests that the 2020 global pandemic and the war in 2022 caused these regional markets to become more integrated.

Table 6. Correlation in the Crisis period, concerning the 9 capital markets, in the period from January 1st, 2020, to May 6th, 2022

	AUSTRIAN	BUX	SOFIX	CROBEX	MOEX	PRAGUE	BET	SAX 16	SBI TOP
AUSTRIAN	-								
BUX	0.713444***	-							
SOFIX	0.497778***	0.406416***	-						
CROBEX	0.636475***	0.589457***	0.509287***	-					
MOEX	0.457959***	0.479809***	0.155186***	0.396839***	-				
PRAGUE	0.777624***	0.635514***	0.457198***	0.590677***	0.435281***	-			
BET	0.618764***	0.531258***	0.488525***	0.610539***	0.328432***	0.624445***	-		
SAX 16	**-0.055256**	**-0.028632**	**0.025896**	**-0.007599**	**-0.028176**	**-0.043315**	**-0.010969**	**-**	
SBI TOP	0.539947***	0.505972***	0.523948***	0.679207***	0.354066***	0.530053***	0.540994***	0.021582	-

Note: ***, **, * indicate significant results at 1%, 5% and 10%, respectively.

Source: Own elaboration

Table 7 presents the results of Forbes and Rigobon's (2002) t-test to the contagion effect between the Tranquil and Crisis subperiods, the latter marked by the global pandemic of 2020 and the Russian invasion of Ukraine in 2022 and tested 72 pairs of markets to gauge whether increased correlations between markets resulted in contagion or interdependencies. The t-test results suggest that there are 62 pairs of markets showing significant contagion, except for SAX 16 - AUSTRIAN, SAX 16 - BUX, SAX 16 - SOFIX, SAX 16 - CROBEX, SAX 16 - MOEX, SAX 16 - PRAGUE, SAX 16 - BET, SAX 16 - SBI TOP, MOEX - AUSTRIAN, MOEX-PRAGUE. These results highlight that the global pandemic of 2020 and the Russian invasion of Ukraine in 2022 caused uncertainty in the global economy and consequences in the financial markets analysed; these findings validate that investors should exercise caution in risk diversification in these regional markets. These results are validated by authors Dias et al. (2021), Pardal et al. (2021), Dias, Heliodoro, Alexandre, Santos, and Vasco (2021), Dias and Carvalho (2021), Dias et al., (2022), Zebende et al. (2022) who evidence that the 2020 global pandemic caused shocks, commotions, persistence, and (in) efficiency, in its weak form, in global financial markets.

Table 7. Results of the contagion effect between the Tranquil / Crisis subperiods

Markets	t-Statistic	Results	Markets	t-Statistic	Results
AUSTRIAN - BUX	2.89***	**Contagion**	CROBEX - AUSTRIAN	2,21**	**Contagion**
AUSTRIAN - SOFIX	3.93***	**Contagion**	CROBEX - BUX	2.95***	**Contagion**
AUSTRIAN - CROBEX	3.91***	**Contagion**	CROBEX - SOFIX	4.14***	**Contagion**
AUSTRIAN - MOEX	3.27***	**Contagion**	CROBEX - MOEX	3.37***	**Contagion**
AUSTRIAN - PRAGUE	2.28**	**Contagion**	CROBEX - PRAGUE	2.27**	**Contagion**
AUSTRIAN - BET	3.44***	**Contagion**	CROBEX - BET	3.57**	**Contagion**
AUSTRIAN - SAX 16	2.89***	**Contagion**	CROBEX - SAX 16	4.75***	**Contagion**
AUSTRIAN - SBI TOP	3.92***	**Contagion**	CROBEX - SBI TOP	4.89***	**Contagion**
BUX - AUSTRIAN	2.04**	**Contagion**	MOEX - AUSTRIAN	0,91	No Contagion
BUX - SOFIX	3.95***	**Contagion**	MOEX - BUX	1.72*	**Contagion**
BUX - CROBEX	3.93***	**Contagion**	MOEX - SOFIX	3.22***	**Contagion**
BUX - MOEX	3.19***	**Contagion**	MOEX - CROBEX	3.18***	**Contagion**
BUX - PRAGUE	2,11**	**Contagion**	MOEX-PRAGUE	0.99	No Contagion
BUX - BET	3,39***	**Contagion**	MOEX - BET	2.47**	**Contagion**
BUX - SAX 16	4.57***	**Contagion**	MOEX - SAX 16	4.05***	**Contagion**
BUX - SBI TOP	4.11***	**Contagion**	MOEX - SBI TOP	3.42***	**Contagion**
SOFIX - AUSTRIAN	1.42*	**Contagion**	BET - AUSTRIAN	1.99**	**Contagion**
SOFIX - BUX	2.23**	**Contagion**	BET - BUX	2.75**	**Contagion**
SOFIX - CROBEX	3.61***	**Contagion**	BET - SOFIX	3.98***	**Contagion**
SOFIX - MOEX	2.71**	**Contagion**	BET - CROBEX	3.95***	**Contagion**
SOFIX - PRAGUE	1.49*	**Contagion**	BET - MOEX	3.17***	**Contagion**
SOFIX - BET	2.95***	**Contagion**	BET - PRAGUE	2.05**	**Contagion**
SOFIX - SAX 16	4.40***	**Contagion**	BET - SAX 16	4.62**	**Contagion**
SOFIX - SBI TOP	3.83***	**Contagion**	BET - SBI TOP	4.14***	**Contagion**
SAX 16 - AUSTRIAN	-3.43	No Contagion	SBI TOP - AUSTRIAN	2.02***	**Contagion**
SAX 16 - BUX	-3.51	No Contagion	SBI TOP - BUX	2.82***	**Contagion**
SAX 16 - SOFIX	-5.67	No Contagion	SBI TOP - SOFIX	4.15***	**Contagion**
SAX 16 - CROBEX	-4.30	No Contagion	SBI TOP - CROBEX	4.12***	**Contagion**
SAX 16 - MOEX	-3.02	No Contagion	SBI TOP - MOEX	3.28***	**Contagion**
SAX 16 - PRAGUE	-3.28	No Contagion	SBI TOP - PRAGUE	2.09*	**Contagion**
SAX 16 - BET	-3.92	No Contagion	SBI TOP - BET	3.51**	**Contagion**
SAX 16 - SBI TOP	-3.49	No Contagion	SBI TOP - SAX 16	4.83***	**Contagion**

Notes: Critical values correspond to a one-tailed significance on the right, 2.7638 (1%), 1.8125 (5%) and 1.3722 (10%). ***, **, * indicate significant results at 1%, 5% and 10%, respectively.

Source: Own elaboration

5. CONCLUSION

The general conclusion to be retained and supported by the results obtained through the econometric model tests is that the global pandemic of 2020 and the Russian invasion of Ukraine in 2022 had a significant impact on the memory properties of the Central and Eastern European financial markets. We found that the level of contagion is very significant, that is, in 72 contagion tests we verified the existence of 62 pairs of markets showing significant contagion, except for the pairs SAX 16 - AUSTRIAN, SAX 16 - BUX, SAX 16 - SOFIX, SAX 16 - CROBEX, SAX 16 - MOEX, SAX 16 - PRAGUE, SAX 16 - BET, SAX 16 - SBI TOP, MOEX - AUSTRIAN, MOEX-PRAGUE. This evidence may call into question the assumption of efficient portfolio diversification, meaning that investors in these regional markets should exercise caution when deciding to invest solely in these markets.

We believe that our empirical findings contribute considerably to the advancement of practices from the perspective of portfolio diversification. For academics, the results provide sufficient information for them to make reasonable comparisons with other situations and contexts, and they can also gather ideas for further research in related areas. Investors can learn about the effect of global uncertainty on the stock market prices index in general and thus be able to make their investment decisions accordingly. Finally, the results of our study are useful for policymakers to identify which additional components and parameters should be analysed for the efficient functioning of stock markets and growth of the economy and thus be able to devise appropriate strategies. For future investigations, they may go through a larger sample of markets to estimate the synchronizations between oil price declines and volatility in stock markets.

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