

COVID-19 and stock markets comovement in emerging Europe

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Abstract. *This study analyzes the stock market's comovement between eleven Eastern European countries in the pre-COVID-19 and COVID-19 period with the USA and China. The methodology used is the wavelet analysis and subsequently the Toda Yamamoto causality test for robustness. This study improves literature by analyzing the ante and COVID-19 crisis period for Eastern European stock markets in relation to the USA and China. The results show that the COVID-19 crisis has generated an increase in the degree of interdependence with USA stock from medium and long to short term; in relation to China stock, if COVID-19 ante there were no links, during the crisis they began to manifest in the medium and long term.*

Keywords. Covid19, stock markets, comovement, Eastern Europe

1. Introduction

In March 2020, the World Health Organization declared COVID-19 a pandemic. Governments gradually began to impose restrictions that developed to a total lockdown in some countries and the partial closure of the economies. The world's stock markets have reacted to social and economic events that increased volatility and large and sudden drops in stock market prices, in some cases the highest in history (Cepoi, 2020; Sharif et al., 2020; Hashmi et al. 2021).

The impact of the COVID-19 crisis on stock markets was studied by academics with newly emerging papers (Akhtaruzzaman et al., 2021; Nguyen et al., 2021; Tripathi et al., 2021). However, these authors link the evolution of stock markets during COVID-19 to Western European countries (Choi, 2020; Karamti & Belhassine, 2021; Yu et al., 2021).

The linkage between Eastern European and USA stock markets was studied (Boubaker & Raza, 2016; Reboredo et al., 2015). Nevertheless, the study of the relationship between Eastern European and China stock and China are inexistent (Özer et al., 2020; Tilfani et al., 2020).

To the best of our knowledge, there are no studies that try to investigate stock market comovement in COVID-19 crisis of all Eastern Europe countries. For some of these stock markets, the response has led to steep and significant decreases (Salisu et al., 2020; Topcu & Gulal, 2020; Bannigidadmath et al., 2021).

Our study aims to complement precisely this lack in the literature on the behavior of Eastern European stock markets in the COVID-19 period. The methodology used in this study is wavelet coherence, the analysis focusing on the stock markets of Eastern European, USA and China. Subsequently, a wavelet decomposition is performed over periods (short, medium and long). Finally, for robustness testing we use Toda Yamamoto causality test. The novelty of the study is given by three levels: a) the analysis of the behavior of Eastern European stock markets in time of COVID-19; b) the use of the wavelet methodology that can detect sudden and significant changes in comovement; c) comovement analysis with USA or China stocks. After this introductory part,

section 2 explains the data and methodology used for the analysis; Section 3 represents empirical results, followed by the conclusions of the article.

2. Literature review

The COVID-19 pandemic took over the entire world and generated unknown economic results. Uncertainty and increased volatility reached high values decisively influencing stock markets, which far exceeded the other previous crises: 1929, 1987 or 2008. Based on these features, numerous studies have tested the impact of COVID-19 on stock markets. The analyses carried out, either globally or sectorally, showed the negative impact of the pandemic on stock markets. Emerging stock markets, characterized by reduced capital inflows and economic weak revenues, have faced the hardest impact of COVID-19.

Al-Awadhi et al. (2020) analyzes whether the Chinese market by different sectors of activity and shows that both the number of cases of illness and death COVID-19 negatively influence the stock market. Ali et al. (2020) investigates the reaction of stock markets as decreases and volatility and shows that they were affected at the same time as the spread of the pandemic; at first it was China, which subsequently recovered, then the European markets, and finally the American market, which influenced all markets including safe commodities. He and al. (2020) investigates the effects and spillovers COVID-19 for major stock markets and discovers that they manifest themselves in the short term with two-way relations between Asian and European/American countries. Topcu & Gulal (2020) analyzes the impact of COVID-19 on emerging stock markets by region and concludes that the effect depends on the time it was exposed to the pandemic; Asian markets were the worst affected and European markets the least. Zhang et al. (2020) analyzes the risk and uncertainty caused by the COVID-19 pandemic and how they spread on stock markets; the authors conclude that fiscal and monetary policies have helped the recovery of the markets. Bannigidadmth et al. (2021) analyzes the impact of government policies on COVID-19 (lockdown, travel ban and stimulus package) on stock markets in 25 countries and shows that the effects were mainly negative. Liu et al. (2021) analyzes the transmission of volatility during the COVID-19 pandemic for the top 16 stock markets and concludes that during this period there has been an increase in global volatility (for European and U.S. markets there is an increase and for Asian markets a decrease).

The Chinese stock market is one of the world's largest markets and the economic ties between China and Eastern Europe are strong. However, few studies examine the relationship of mutual interdependence between the China and Eastern European stock markets. Özer et al. (2020) examines volatility between South-East European (SEE) stock markets and global stock markets (Europe, Japan, China, and the US) and shows that these countries have stronger ties to the USA and Europe, and are non-existent with Asian stock markets. Tilfani et al. (2020) investigates the integration of Eastern European stock markets with major markets (China and the USA) and concludes that for a number of these stock markets there is cross-correlation with China and for others not.

3. Data and methodology

Data used in this study are daily stock markets data for eleven Eastern European countries: Bulgaria - *Sofix*; Croatia - *Crobex*; Czech Republic - *PX*; Estonia - *OmxTallin*; Hungary - *Bux*; Latvia - *OmxRiga*; Lithuania - *OmxVilnius*; Poland - *WIG*; Romania - *BET*; Slovakia - *SAX* and Slovenia - *SbiTop*. The important markets for which the comovement analysis is carried out are USA –

S&P500 (as the most developed market) and China - *SSEComposite* (as the market where the phenomenon started). The data is daily, collected from Datastream, and the time period is 1 January 2019 - 31 May 2021. The sample is divided into two sub-period: 1 January 2019-31.12.2019 (pre crisis) and 1 January 2020-1 June 2021 (Covid19 Crisis). Estimates were made in view of daily stock returns, calculated as natural logarithm. The wavelet analysis was carried in Matlab.

The wavelet analysis methodology performs a decomposition of the time series by using two basic filter functions (mother and father wavelet) in two functions to simultaneously plot time and frequency. Grinsted et al. (2004) and Aguiar-Conraria and Soares (2011) have developed the methodology and argue for the advantages in stock market analysis due to its ability to detect rapid variations of indicators. Starting from a single equation, called mother wavelet $\psi_{(\rho,s)}(t)$, and working with integrable square functions, ie $x(t) \in L^2(R)$, the wavelet equation is the following:

$$\psi_{\tau,s}(t) = \frac{1}{\sqrt{|s|}} \psi\left(\frac{t-\tau}{s}\right) \quad (1)$$

In equation 1, the important values to analyze are the parameters s (represents the wavelet space) and τ (represent the wavelet location).

Wavelet power spectrum (WPS) for an x_t and y_t and series are given by the following formulas (Rua and Nunes, 2009):

$$(WPS)_{xy} = W_x(\tau, s) \times W_y(\tau, s) \text{ for the series } x_t, y_t \quad (2)$$

Starting from equation 2 we calculate the wavelet coherence as the ratio of the cross-spectrum of and the product of the cross-spectrum of x and y , according to the formula (Grinsted et al., 2004):

$$R_{xy} = \frac{|S(W_{xy})|}{[S(|W_x|^2)S(|W_y|^2)]^{\frac{1}{2}}} \quad (3)$$

where S is a smoothing operator for both time and frequency, and $0 \leq R_{xy} \leq 1$. The parameter R_{xy} is the correlation coefficient localized in time and frequency. The values of the parameter vary from 0 (no coherence) and 1 (perfect coherence), and thus vary from low values (weak comovement) to high values (strong comovement). The significance of the colors used implies blue (low correlation in volatility) to red (high correlation in volatility).

In order to highlight lead-lag relationship, in this article, we use the wavelet phase-differences ϕ_{XY} , by plotting arrows on color maps. The meaning of the arrows can be to the right (\rightarrow indicates that the two series X_t, Y_t are in phase), left (series are in anti-phase), down (\searrow then X_t is leading Y_t), up (\nearrow then Y_t is leading X_t).

Furthermore, we will investigate the relationship between stock markets using the discrete wavelet transformation (DWT) to decompose the series (d1 short term, d3 medium term, d6 long term) and after that we use the Toda Yamamoto causality test. The wavelet-based Granger causality is used as a robustness test, as it allows the testing of the causal relationship between the stock markets at different time and frequencies.

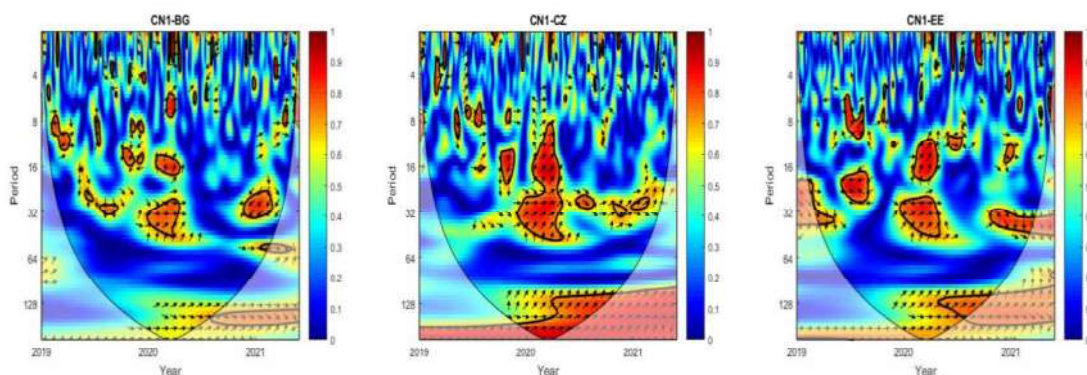
4. Empirical analysis

Table 1 presents the descriptive statistics for the eleven Eastern European stocks analyzed. We notice that USA, PL, HU are the countries with the highest deviations during the COVID-19 period, and BG, LV and SK the lowest. The variations in the COVID-19 period on stock markets are much greater than those pre COVID-19.

Table 1 descriptive statistics

PreCovid-19	BG	CH	CZ	EE	HR	HU	LT	LV	PL	RO	SI	SK	US
Mean	-0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000
Median	-0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Maximum	0.026	0.054	0.016	0.014	0.020	0.023	0.012	0.054	0.026	0.036	0.014	0.027	0.033
Minimum	-0.0193	-0.057	-0.020	-0.011	-0.015	-0.017	-0.011	-0.040	-0.024	-0.043	-0.016	-0.042	-0.030
Std. Dev.	0.005	0.011	0.005	0.003	0.004	0.007	0.003	0.008	0.007	0.008	0.004	0.007	0.007
Skewness	0.966	-0.166	-0.556	0.444	0.232	0.105	0.501	0.734	0.088	-0.118	0.100	-0.961	-0.636
Kurtosis	6.399	8.491	4.258	5.790	5.501	2.823	5.197	13.027	4.194	7.584	4.531	9.946	6.463
N	261	261	261	261	261	261	261	261	261	261	261	261	261
Mean	-0.000	0.000	0.000	0.000	-0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Median	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001
Maximum	0.0395	0.055	0.073	0.041	0.056	0.056	0.045	0.120	0.056	0.059	0.059	0.058	0.089
Minimum	-0.1081	-0.080	-0.081	-0.106	-0.107	-0.122	-0.098	-0.163	-0.135	-0.100	-0.093	-0.072	-0.127
Std. Dev.	0.0106	0.011	0.013	0.011	0.012	0.016	0.009	0.013	0.016	0.013	0.011	0.011	0.018
Skewness	-4.133	-0.909	-1.154	-3.823	-3.661	-1.520	-4.427	-2.656	-1.708	-1.736	-2.219	-0.091	-0.971
Kurtosis	41.505	10.485	12.685	37.321	35.307	13.276	49.609	68.163	16.216	17.277	21.791	11.976	14.756
N	370	370	370	370	370	370	370	370	370	370	370	370	370

The first part of the analysis presents the results of wavelet coherence for the eleven Eastern European and China or USA stock markets. On the horizontal axis we represent the time, and on the vertical axis frequency (short, medium and long). Figure 1 represents the results of wavelet coherence between the Eastern European and China stocks and shows that the behavior of these stock markets in regard to China changes in time and intensity. If in 2019, there is no comovement link between Eastern European and China stocks, then for the COVID- 19 period, the ties are strengthened, with most analyzed stock markets exhibiting at least medium and long relations. Previously COVID-19, EE and PL had a good relationship with China, as the latter leads. The relationship between China stock and the Eastern Europe exists only with two exceptions (EE and PL, similar to Özer et al., 2020), for most Eastern European stocks, there are no links with China.



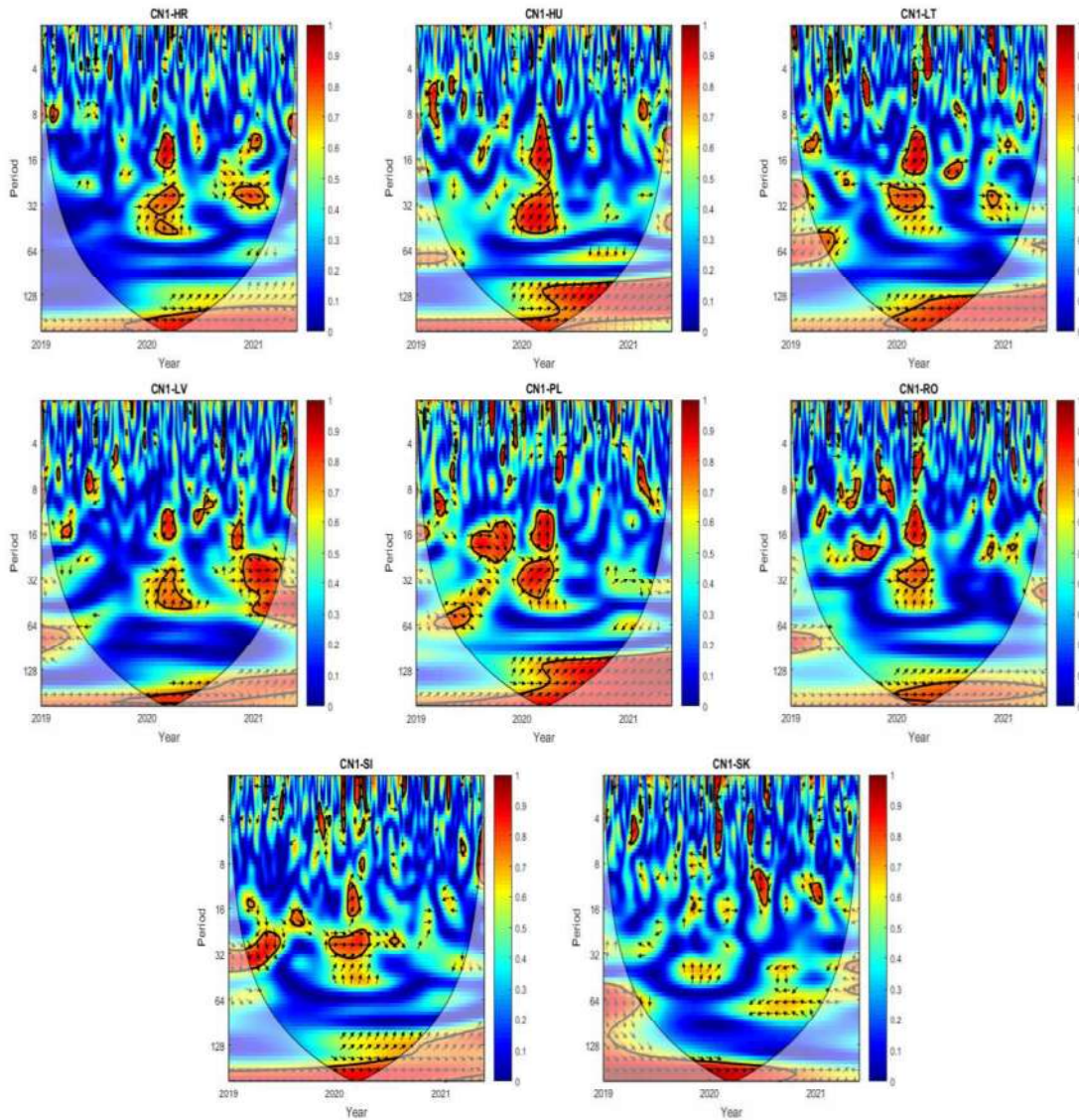
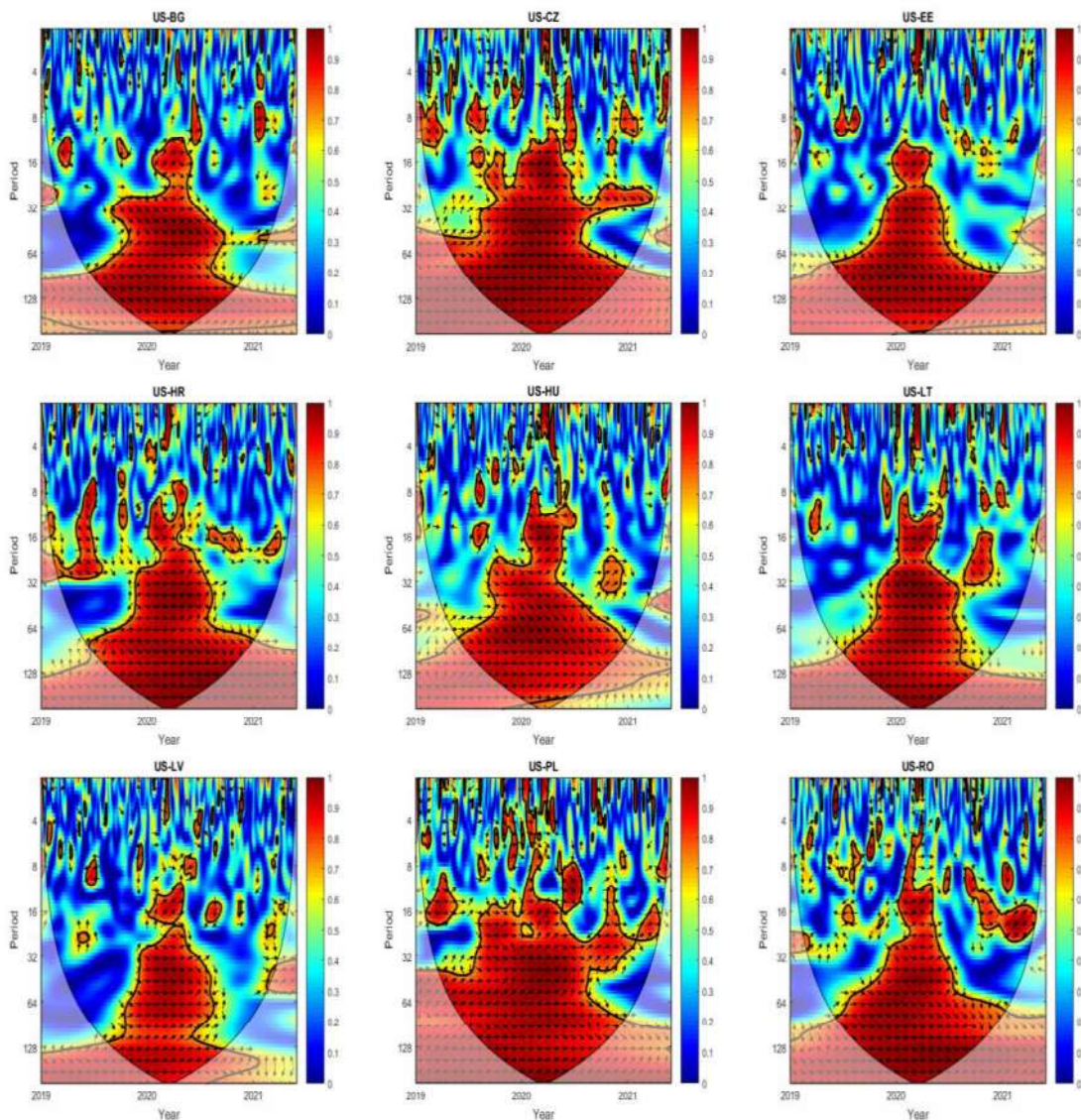


Figure 1. China vs Eastern Europe Stock Markets

During COVID-19, the comovement extends to more Eastern European stocks and more frequently. Thus, from eleven stocks, nine begin to show relations with China stock, especially in the medium and long term. The arrows pointing to the top right look like China leads in the interaction between markets. High coherence between the stocks is highlighted for this period (similar to Szczygielski et al., 2021; Seven & Yilmaz, 2021).

The comovement relationship between the USA and the eleven Eastern European stock markets experiences considerable variations during the two periods analyzed (figure 2). For the anteCovid19 period, USA presents strong comovement with BG, CZ, HR, HU, LT, PL, RO, SI, at low frequencies (medium and long period). In contrast with EE, HR, LV, SK, the influence of the American market manifests itself only in the long term. These results are based on the fact that, in the case of the last states, stock markets are poorly developed and international integration in turn is deficient (as Reboredo et al., 2015; Boubaker & Raza, 2016).

For the COVID-19 crisis period, the situation changed radically, with an increase in the wavelet coherence coefficients between stock markets. Contagion between the USA and the Eastern Europe is characterized by the increase of coherence and at high frequencies (short term), previously being in the medium and long term. For the period of crisis, Eastern European stock markets are lagging behind the USA market. For more developed stock markets (CZ, HU, PL, RO) and interaction is stronger and manifests itself in the short term, the USA acting as lead. For less developed markets (BG, EE, SK) medium and long-term ties are strengthened, and short-term ties are beginning to appear. The only exception is SK, but this is where medium-term bindings begin to appear. These results are not surprising; in the crisis market volatility is growing strongly, and interdependence relations are growing considerably (consistent with Ali et al., 2020; Salisu et al., 2020; Topcu & Gulal, 2020).



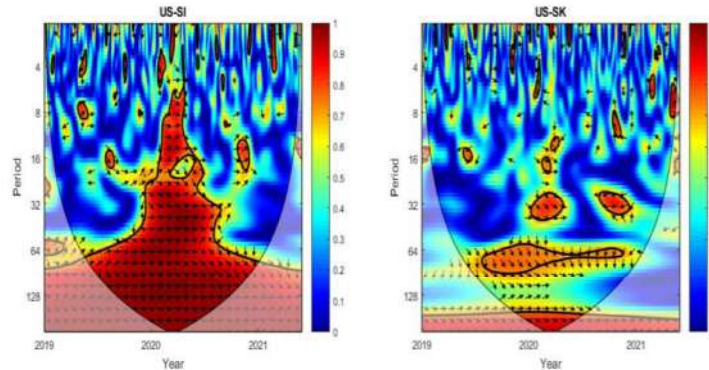


Figure 2. USA vs Eastern European stock markets

To show if the results obtained are adequate, we used the Toda Yamamoto causality test as a robustness test. The results obtained using this test are presented in Table 2, separately for the two periods.

Tabel 2. Robustness test Toda Yamamoto Causality test pre COVID-19 and COVID-19 (probability)

		pre COVID-19						COVID19						
		China			USA			China			USA			
		Short (d1)	Medium (d3)	Long (d6)	Short (d1)	Medium (d3)	Long (d6)	Short (d1)	Medium (d3)	Long (d6)	Short (d1)	Medium (d3)	Long (d6)	
BG	BG→CH	0.9218	0.1025	0.4205	0.7054	0.7909	0.0817	0.6286	0.0585	0.9387	0.1453	0.4988	0.1320	BG→US
	CH→BG	0.5980	0.7875	0.2153	0.6579	0.0001	0.0003	0.6615	0.0463	0.0685	0.1697	4.E-13	0.0004	US→BG
Cz	CZ→CH	0.6950	0.6369	0.5641	0.3359	0.7336	3.E-26	0.3724	0.0806	0.4979	0.1139	0.1318	0.4988	CZ→US
	CH→CZ	0.1655	0.0918	0.3025	0.3814	1.E-41	9.E-09	0.8344	0.0192	0.0331	0.0013	0.0009	0.0111	US→CE
EE	EE→CH	0.8685	0.3378	0.1412	0.2499	0.0793	0.6655	0.7441	0.0782	0.1502	0.6957	0.1211	0.1146	EE→US
	D→EE	0.2380	0.0208	0.2370	0.6027	0.0082	1.E-08	0.1023	0.0094	2.E-09	0.2108	3.E-09	2.E-06	US→EE
HR	HR→CH	0.6006	0.5463	0.1865	0.6856	0.4801	0.3203	0.7665	0.0758	0.5084	0.1453	0.3927	0.0652	HR→US
	CH→HR	0.8154	0.7745	0.31021	0.6441	0.0328	4.E-08	0.0544	0.0047	0.1370	0.2757	8.E-05	1.E-18	US→HR
HU	HU→CH	0.7336	0.3005	0.1617	0.7786	0.1543	0.2281	0.0918	0.1427	0.4551	0.0606	0.5473	0.6775	HU→US
	CH→HU	0.7514	0.4458	0.4962	0.6823	0.0104	4.E-44	0.1872	0.0003	7.E-11	0.0002	7.E-14	0.0234	US→HU
LV	LV→CH	0.1061	0.4358	0.3136	0.6536	0.1204	0.1294	0.1333	0.5606	0.3029	0.3106	0.1453	0.0575	LV→US
	CH→LV	0.0940	0.0317	0.1092	0.1504	0.0425	0.0097	0.1850	0.0037	0.0031	0.0652	0.0002	0.0017	US→LV
LT	LT→CH	0.1886	0.1065	0.7557	0.2425	0.4046	0.0669	0.0974	0.2623	0.1500	0.1997	0.3258	0.2244	LT→US
	CH→LT	0.8193	0.4423	0.4707	0.0703	0.0075	1.E-15	0.1152	0.0026	0.0960	0.2734	0.0022	7.E-10	US→LT
PL	PL→CH	0.8965	0.1626	0.6972	0.4027	0.3835	1.E-35	0.6818	0.1394	0.1344	0.1245	0.9173	0.0497	PL→US
	CH→PL	0.3985	0.0259	0.1874	0.1161	0.0013	3.E-29	0.2970	1.E-05	8.E-14	0.0002	0.0128	2.E-09	USA→POL
RO	RO→CH	0.8470	0.3616	0.4549	0.6538	0.1369	0.0540	0.1182	0.0819	0.2227	0.3126	0.1107	0.4340	RO→US
	CH→RO	0.8624	0.3713	0.0553	0.9743	0.0200	0.0002	0.3935	0.0075	1.E-14	0.0016	3.E-07	0.0024	US→RO
SK	SVK→CH	0.4228	0.7135	0.7106	0.1172	0.3628	0.1849	0.2036	0.2857	0.4430	0.1350	0.0865	0.1534	SK→US
	CH→SVK	0.1999	0.0888	0.1739	0.1712	0.0483	0.7660	0.6563	0.5938	0.2889	0.1567	0.0008	0.0176	US→SK
SI	SI→CH	0.1927	0.2727	0.2432	0.7048	0.0002	4.E-35	0.2292	0.9535	0.8761	0.2821	2.E-06	0.0122	SI→US
	CH→SI	0.8600	0.3651	0.0745	0.2003	2.E-09	9.E-40	0.5862	0.1465	0.9928	5.E-09	2.E-10	2.E-12	USA→SI

According to Toda Yamamoto causality test results, these are similar to those obtained from wavelet coherence analysis. The null hypothesis that China and the USA does not cause Eastern European stocks can be rejected in most cases, implying that the two markets influence the eastern markets. The results obtained are different for the two periods, ante-Covid19 and COVID-19. For the pre-Covid19 period, there are interdependencies between China and EE, LV and PL (medium term), the link being one-way from the Asian market to the respective stock markets. For the other stock markets, there are no relationships of causality between markets for any period. Instead, the relationship between the US and the Eastern European stocks is stronger; all Eastern countries have medium-term and long-term relationships with the US. The causal link manifests itself from the American market to them; developed markets (CZ and PL) present a bi-directional causality (similar to Özer et al., 2020; Tilfani et al., 2020).

For the COVID-19 period, interdependencies intensified; for nine of the Eastern markets, there is a causal link between them and China. The Asian market presents in the medium and long term a one-way link with these nine eastern markets; these markets do not influence China. In relation to the USA, causal links with the Eastern European markets are manifested in the short term, medium and long term. In the short term, the links are unidirectional of the American market (CZ, PL, RO), and birectional (HU), these markets being also the most integrated in the economic circuit; in the medium term, causality is one-way for all Eastern stock markets; in the long term, the causal link comes from the USA to Eastern European (as Salisu et al., 2020; Bannigidadmath et al., 2021).

Robustness testing through the Toda Yamamoto causality test confirms the results previously obtained using wavelet coherence and shows the different behavior of the Eastern markets during the pre-crisis and crisis period.

5. Conclusion

In this article, we analyzed the comovement of stock markets for eleven Eastern European countries with the USA and China to test the changes that occurred during the COVID-19 crisis, using the wavelet methodology.

The results show the contagion effect generated by the COVID-19 crisis on the stock for Eastern European countries. However, this effect changes over time.

After the COVID-19, we noticed significant changes in the markets. The behavior of nine Eastern European markets has led to the emergence of interdependencies on medium-term with the Chinese market. Compared to the American market, the COVID-19 crisis has led to the growth of existing ties and their amplification for all Eastern European countries. If before the crisis the markets had interdependence in the medium and long term, then the manifestation of comovement was manifested in the short term. For more developed countries, a two-way link with the American market was observed.

The obtained results are also important for capital investors, who can diversify their portfolio accordingly, taking into account the short, medium or long-term relations of manifestation between the markets. Our study shows a very important aspect about the comovement between markets, namely that this phenomenon is not a static one but a dynamic one. During the pre-crisis period, their integration at the global level was somehow lacking; however, during the COVID-19 crisis, the comovements between the markets increased at all levels and periods.

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