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COVID-19 Pandemic: Stock Markets Situation in European Ex-Communist Countries

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Abstract:

Purpose: *The aim of this article is to present the impact of the COVID-19 pandemic on the capital markets of post-communist economies and, whether these markets are reacting in the same way. The research concerns indices of stock exchanges in Poland, Hungary, Latvia, Lithuania, Bulgaria, Czech Republic, Romania, Estonia, Croatia, and Slovenia.*
Methodology: *The investigation covers the period from 30 SEP 2019 to 31 DEC 2020 divided into three sub-periods - pre-pandemic, pandemic shock, and pandemic stabilization. A trend analysis of the indices studied and a volatility analysis of the returns of the indices were conducted. Econometric trend models and GARCH-class models were applied.*
Findings: *As a main finding it can be concluded that the capital markets of the post-communist economies responded to the pandemic in an analogous way, as well as that the scale and level of development of stock markets does not affect their response to the pandemic and stock market prosperity during the pandemic period.*
Practical Implications: *The work focuses on the analysis of major stock market indices in countries with very different levels of capital market development. The course of the pandemic varies from country to country in terms of freezing the economy. As a consequence, it allows answering the fundamental question from the economic point of view: To what extent does a crisis of a non-economic nature affect the stock exchange situation in countries at the stage of capital market development?*
Originality/Value: *The analysis of the level of capital markets development in post-communist countries has been the subject of many works, including by authors. However, the emergence of a pandemic creates a unique (hopefully) opportunity for research under extreme conditions such as the pandemic. As a consequence, information is obtained about the economic resilience, or lack thereof, of post-communist countries to crisis situations of a non-economic nature.*

Keywords: *Stock index, market situation, regression, ARCH effect, GARCH model.*

JEL: *C13, C22, G15.*

Paper Type: *Research Paper*

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1. Introduction

Post-communist countries[2] are specific and unique because their economic system changed from a centrally planned economy to a market economy only 30 years ago, just after the communism collapse. For such young market economies and their capital markets, many of which remain in transition and still emerging, any change in their environment is crucial. It is enough to recall here the implications of dot-com bubbles boom 1995/2001 (Kizys and Pierdzioch, 2011), Russian default 1998 (Linne, 2000), Enron scandal 2001 (Zulauf, 2011), Lehman Brothers bankruptcy 2006/2008 (Mihaljek, 2010) or the Greek debt crisis 2010 (Bein and Tuna, 2015). Although these crises were not unexpected due to the warning calls from the markets, they were contagious to other economies having a strong impact on their financial and capital markets.

In this context, the COVID-19 pandemic crisis is fundamentally unique. It occurred as an exponential[3] self-infection at a time when the world economy was in relatively stable conditions and the markets did not show any particular or sudden signs of stress or imbalance (CFA, 2020). The lack of historical experience in the face of such a situation and the lack of appropriate regulatory routines must result in the reaction of the world' s capital markets. Here, the question arises whether this crisis is affecting the capital markets of post-communist economies (EExCCs), and, if so, whether these markets are reacting in the same way, and whether these reactions differ from the behavior of developed capital markets.

To address these research questions, the main indices of the post-communist countries' stock exchanges, selected European developed markets' indices (German DAX, French CAC40, British FTSE100) and a European index synthetically describing the behaviour of the whole regional market (MSCI Europe), were analysed. The properties of these indices were compared to each other in the pre-pandemic period, in the period directly after the pandemic outbreak and in the pandemic stabilization time span until December 2020. It can be assumed that the first period corresponds to the "normal" situation in the capital markets, when the stock exchanges perform all their basic functions. In the second period, investors react nervously and anxiously to the crisis. The quotations are driven by emotions arising from the inability to assess the situation and uncertainty about the future. Finally, the third period is getting used to the situation and slowly restoring the functions of stock exchanges.

The settlement of the above stated research questions may have important implications. This is because if the expectation of similar behaviour of capital markets

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[2]*The post-communist countries are understood here as the EU member states that were formerly part of the Eastern (Soviet) bloc (European ex-communist countries, EExCCs). We use the name EExCCs instead of CEECs to emphasize the specific, non-geographical character of these countries (OECD 2001).*

[3]*The term exponential is understood as by Ismail, Malone & Van Geest (2014).*

in post-communist countries holds true, and these reactions are like the reactions of developed market indices, then it can be argued that the stock market scale and level of development has no impact on their response to the pandemic and stock market prosperity during the pandemic period. This would be an important conclusion from the economic perspective, and, for young post-communist economies, a strong indication to try to re-position their capital markets among potential stakeholders.

The study presented in this paper covers the period from September 30, 2019, to December 20, 2020. The research has been conducted on daily close-end quotations of stock indices. It consists of several sections. First, the study time span, common to all exchanges, was divided into the three sub-periods described above. Cut-offs of these sub-period were determined for each index separately, according to the criteria assumed for splitting of the research sample. It results those sub-periods are different in length for most of the analysed indices. The second part of the study focuses on trends analysis. It covers all defined sub-periods of the research and all stock market indices selected for the examination. The quadratic trend functions were applied. This allowed to draw conclusions about the dynamics of indices in the analysed sub-periods, to compare them to each other, and to conclude about similarities. Next, the logarithmic returns of the stock market indices were analysed. Our study identified an ARCH effect for a residual autoregressive model of order 1. Accordingly, the research employed mainly a $GARCH(1,1)$ model, what allowed to formulate conclusions about the volatility of returns in the analysed sub-periods. The final section contains conclusions from the analyses and comparisons of the results.

2. COVID-19 Pandemic

The world is constantly shocked by crises of various character, scale, and scope. These crises, until recently local, territorially limited, and usually exogenous, more and more often become global crises due to the all-embracing globalization, infiltrating various areas of social, political and economic activity[4], paralyzing the world equilibrium. However, these crises are always preceded by symptoms that announce, sometimes even indirectly and ambiguously, their arrival (Allais, 1999).

The COVID-19 pandemic is a viral disease pandemic that emerged locally in China at the end of 2019 and has spread remarkably aggressively. At the end of February 2020, almost 90,000 cases were detected worldwide, at the end of April - over 3 million, at the end of June - over 10 million, and at the end of December - 82 million. The world has implemented unprecedented tools to break the spread of the disease - partial and complete lockdowns have been introduced, all types of air links have been

[4] *Crises caused by nature, such as earthquakes, tsunamis, floods, etc., are usually natural disasters and have limited interference with societies. However, there are also some natural shocks that have an impact far beyond their local universe. As an example, let us recall the eruption of the Icelandic volcano Eyjafjoell in 2010, whose volcanic ash closed the airspace over Europe, and caused enormous economic losses on a global scale.*

suspended, supply chains have been permanently disrupted or essentially limited, as well as the flows of people, capital, raw materials, food, and technology. In this situation, the economic downturn must have occurred on a global scale (Carlsson-Szlezak *et al.,* 2020; Estrada, 2020, Estrada *et al.,* 2020).

However, this crisis, unlike the turbulences already mentioned (Kizys and Pierdzioch 2011; Linne 2000; Zulauf 2011; Mihaljek 2010; Bein and Tuna 2015), is completely incomparable. It occurred without any anticipatory signs, in a relatively stable global economic environment and well-functioning supply corridors. The lack of historical experience in the face of such a situation and the absence of adequate remedial procedures must result in ad hoc responses by global markets, central banks, regulators, and public authorities. Thus, a demand was created for research into the nature of the crisis, its impact on markets, contagion, and the transmission of the effects of the pandemic between markets and economic sectors, etc.

The research covers commodity markets, among others, for which e.g., Ezeaku *et al.* (2021) investigated the volatility of international commodity prices in the times of COVID-19 by the effects of oil supply and global demand shocks. Dutta *et al.* (2020) studied crude oil prices volatility and the biodiesel feedstock market, and Güngör *et al.* (2021) used *ARIMA* models to investigate the effects of Covid-19 outbreak on Turkish gasoline consumption, while Kamdem *et al.* (2020) have studied the coronavirus impacts on the recent variability of commodity prices through the number of confirmed cases and the total number of deaths.

On the currency and cryptocurrency markets, Jiang *et al.* (2021) analysed the interrelationship between the COVID-19 pandemic and cryptocurrencies in a 5-year long time series applying a novel Quantile Cross-spectral (coherency) approach. Umar and Gubareva (2020) applied wavelet analyses to examine the impact of the Covid-19 fueled panic on the volatility of major fiat and cryptocurrency markets during January–May 2020. The spillover effect of RMB exchange rate among BRI countries before and during COVID-19 was evaluated by Zhixi *et al.* (2020).

Financial markets are studied in many ways. For example, (1) the behaviour of investment fund markets is analysed in terms of volatility, prices, and efficiency after the outbreak of the COWID-19 pandemic (which emphasizes the high efficiency of social funds) (Mirza *et al.,* 2020). (2) From a global crisis management perspective, research combining the impact of COVID with fundamental economic indicators are mainly interesting. Such research, using a multilateral comparative approach, were conducted by Uddin *et al.* (2021) among others, while Topcu and Gulal (2020) model and analyse stock market indices as a function of exchange rates, oil price shocks, and COVID-19. (3) The variability (risk) is studied in different periods of the pandemic.

Yousef (2020) assesses the impact of coronavirus on stock market volatility for indices by using *GARCH* and GJR-*GARCH* models and finds that the minimum value for analysed indices occurred in March 2020. Thanks to the analysis of the coefficients of the GARCH models, he confirmed the increase in volatility during the pandemic. Yilmaz and Furkan (2020) evaluate the effects of Covid-19 outbreak on financial markets using the Fourier-SHIN Cointegration Test as well as Fourier Granger Causality Test, confirmed the significant impact, and found that in the long term, the COVID-19 outbreak has a significant effect on stock markets, crude oil representing oil markets, and fear index. Laborda and Olmo (2021) evaluate volatility spillovers between sectors of economic activity. He *et al.* (2020) argue that COVID-19 has a negative but short-term impact on the stock markets of affected countries and that the impact of COVID-19 on stock markets has bidirectional spill-over effects between Asian countries and European and American countries. (4) A separate research topic is related to emerging markets, including capital markets in Eastern and Central Europe. Pappas *et al.* (2013) analyses CEE markets in terms of markets synchronization and contagion in a crisis, is using the *DDC-GARCH* and Markov-Switching approach, finding a significant strengthening of the correlation between markets (especially for young EU members).

Similar research, but already for the last crisis, were carried out by Pardal *et al.* (2020) aims to analyze financial integration in the stock indices of the capital markets of Austria, Russia, Serbia, and Slovenia, as well as some CEE countries, in the context of the global pandemic (COVID-19). Harjoto *et al.* (2020) argue that the unprecedented adverse shock of COVID-19 on the countries' economic growth translates into a negative shock to the stock markets, and that the impact of COVID-19 in emerging countries is different from developed ones. Thus, the market reaction during the stabilizing period of COVID-19 spread is different from the market reaction during the infection period.

The bibliography discussed above allows us to state clearly that the subject of the impact of the COVID-19 pandemic on capital markets is attracting a large attention of researchers from all over the world. It confirms our confidence that the research methodology we have chosen is valid. However, it remains to fill the gap that exists in the current state of research. First, an effort should be made to define the moment of a pandemic outbreak, which is stated arbitrarily in the literature. Moreover, it is necessary to assess whether the capital markets of the post-communist economies react in the same way to the spread of the pandemic. And finally, to resolve the hypothesis that the stock indices of post-communist and developed countries behave similarly during a pandemic. We consider each of these decisions as our contribution and novelty in the field of COVID-19 research.

3. Research Organization and Methodology

To verify the hypothesis that the capital markets of post-communist and developed European countries behave similarly, the research was conducted in a three-stage process. In the first, the basic statistical characteristics of each stock exchange indices were compared: the length of pandemic sub-periods and their cut-offs', as well as the growth rate and rate of return of each index over each sub-period. The information thereby obtained allows general, mainly qualitative, comparisons of the behaviours of evaluated stock markets. The next stage of the research is to analyse the trends of the indices using squared regression (Maddala, 2006):

$$y_{A,t} = \alpha_A + \beta_A t + \gamma_A t^2 + \varepsilon_{A,t}$$

where *A* is the symbol of the stock index, *t* is the time variable, $y_{A,t}$ is the index value at time *t*, α_A, β_A, γ_A are the structural parameters of the model for the index *A*, and $\varepsilon_{A,t}$ is the corresponding random component. The coefficients for the linear component provide information about the dynamics of the trend, while the coefficients for the square component are a measure of changes in the dynamics of the trend. The estimation of the parameters of the trend equation (1) is in our research performed by employing the classical OLS method, while correctness of model specifications is verified by White, Ljung-Box, Doornik-Hansen tests and Wald-Wolfowitz runs tests.

To address the question about "better" and "worse" stock markets from the point of view of their trends and dynamics, stock markets are classified according to the beta and gamma coefficients in model (1) and then Spearman rank correlation coefficients are calculated (Menardi and Lisi, 2010).

When dealing with financial data, there is often observed heteroscedasticity and autocorrelation of random components in regression models. While expecting such a situation, it was decided to carry out the third stage of the research, i.e., to analyse ARCH and GARCH effects in the time series of the indices being examined. It allows to describe the variance of random components, which is crucial in terms of risk analysis and, especially for the practical applications of indices as forecasting the underlying securities. This step will help to draw conclusions about the volatility of the markets studied.

At this stage of the research the daily quotations of the indices are transformed into logarithmic returns, which are expected to be stationary. Analysis of the autocorrelation of the residuals and the squares of the residuals of the autoregressive model provides information on the relationship between returns and the possible occurrence of the ARCH effect.

The ARCH and GARCH models were used to describe the changes of indices, and thus the dynamics of stock exchange indices. The autoregressive model of *AR(1)* is described by the equation (Maddala, 2006):

$$r_{A,t} = c_A + d_A r_{A,t-1} + \epsilon_{A,t} \quad (2)$$

where $r_{A,t} = \ln\frac{y_{A,t}}{y_{A,t-1}}$ is the log rate of return of index A at time *t*. Marking with the symbol $Z_{A,t-1}$the available set of information at the time *t* - 1, the following notation is adopted:

$$h_{A,t} = \varphi_{A,0} + \sum_{i=1}^{q} \varphi_{A,i}\epsilon_{A,t-i}^{2} + \sum_{j=1}^{p} \psi_{A,j}h_{A,t-j} \quad (3)$$

where, the random variable has a normal distribution with the expected value of zero and the variance depending on its realisation from *p* previous periods. Residual conditional variance $h_{A,t}$ has the form (Bollerslev, 1986):

$$h_{A,t} = \varphi_{A,0} + \sum_{i=1}^{q} \varphi_{A,i}\epsilon_{A,t-i}^{2} + \sum_{j=1}^{p} \psi_{A,j}h_{A,t-j} \quad (4)$$

where: $\varphi_{A,0} > 0, \varphi_{A,i} \geq 0, \psi_{A,j} \geq 0$ provide the positive conditional variance. For p and q equal to 1, $h_{A,t}$ is a linear function dependent on $\epsilon_{A,t-1}^{2}$and $h_{A,t-1}$ (Fiszeder, 2009). All statistical hypotheses were verified at the significance level of 0.05.

4. Data Characteristics and Descriptions

As described earlier, the study was conducted on the main stock market indices of the post-communist countries, on the indices of the three reference exchanges, and on a synthetic European index. The analyses were based on daily close-end quotations since September 30, 2019, until December 30, 2020, available from the open-accessed online services.

Table 1. *Scope of respondents*

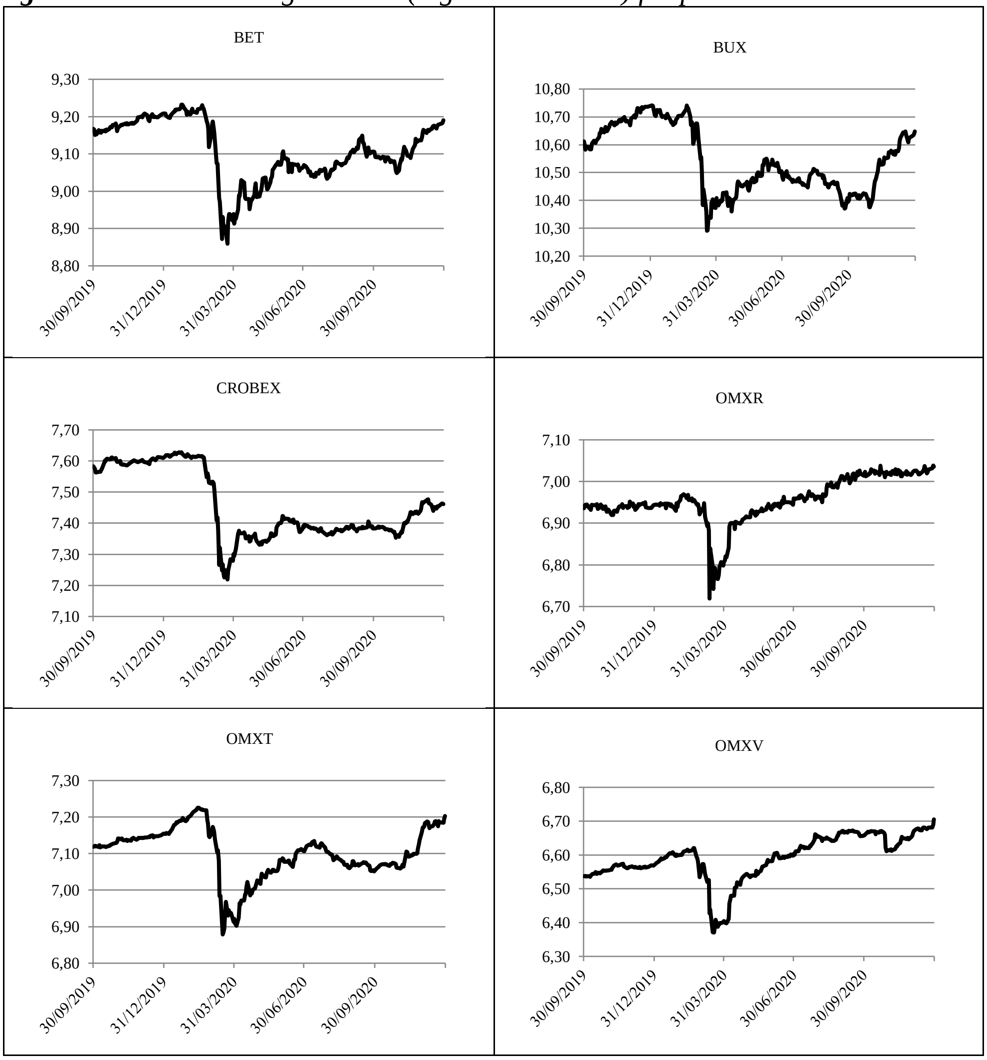
Country	Index	Number of companies
BET	Romania	17
BUX	Hungary	14
CROBEX	Croatia	19
OMX Riga (OMXR)	Latvia	15
OMX Tallinn (OMXT)	Estonia	17
OMX Vilnius (OMXV)	Lithuania	21
PX	Czech Republic	12
SBITOP (SBITOP)	Slovenia	11
SOFIX	Bulgaria	15
WIG 20	Poland	20

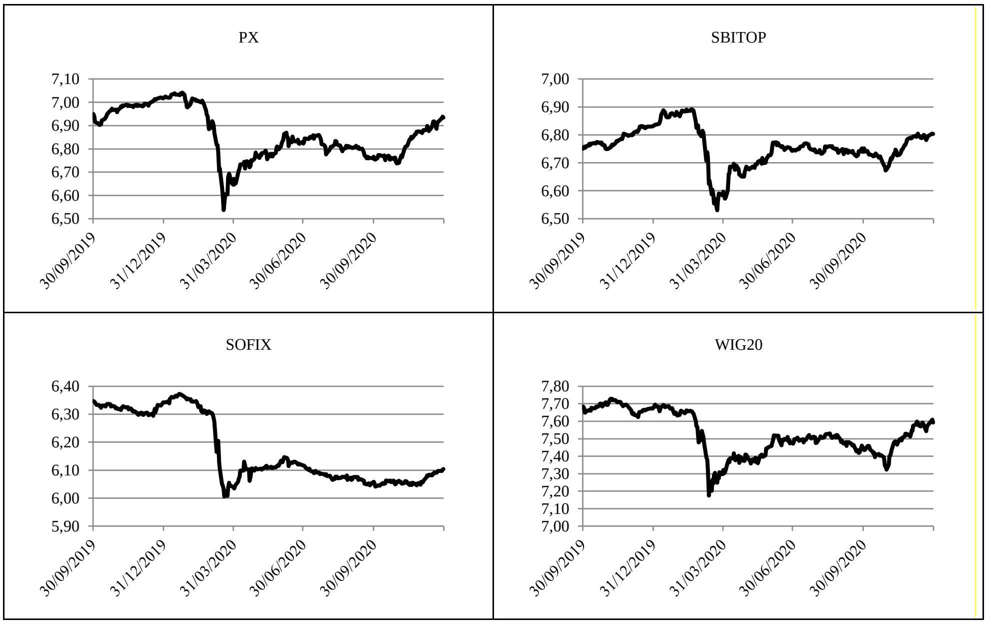
Source: *Own creation.*

Initially, eleven EExCCs countries, members of the European Union, were considered for the evaluation of pandemic behaviour, Bulgaria, Croatia, the Czechia, Estonia, Lithuania, Latvia, Poland, Romania, Slovakia, Slovenia, and Hungary. However, as the data for Slovakia was difficult to obtain and was not reliable, this market was excluded from further research. The final listing of ten stock exchange indices with the number of companies in their composition and abbreviated names of the indices is presented in Table 1.

The following indices were applied as representatives of developed economies and benchmarks in our study: DAX (Germany), CAC 40 (France), FTSE 100 (UK), as well as MSCI Europe as synthetic pattern. Figure 1a shows in log scale the plots of stock exchange indices quotations, for post-communist countries, while Figure 1b refers to developed countries.

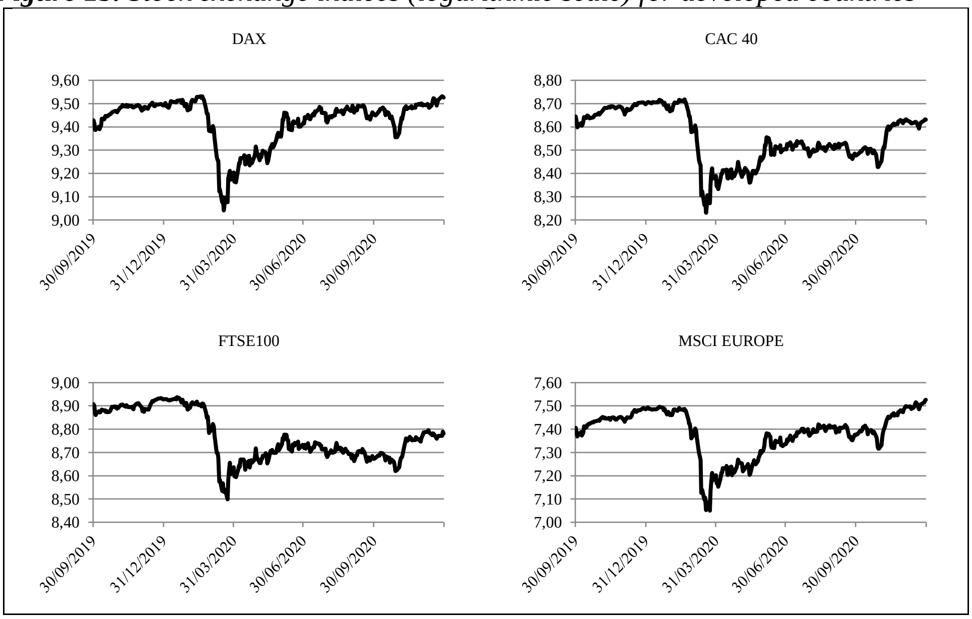
Figure 1a. *Stock exchange indices (logarithmic scale) for post-communist countries*





Source: *Own study.*

Figure 1b. *Stock exchange indices (logarithmic scale) for developed countries*



Source: *Own study.*

This whole-time span has been divided into three sub-periods: the first one, so-called pre-pandemic (I), covers data from 30 September 2019 until the absolute peak of the index's quotation in the first quarter of 2020. The second sub-period covers data from pre-pandemic sub-period cut-off to the point of the minimum of quotations and is identified as the pandemic response sub-period (II). The final sub-period, so called pandemic stabilization span (III), covers quotations from a pandemic outbreak sub-period end-cut until the end of research i.e., December 30, 2020. It should be noted that for different stock exchanges the sub-periods differ in terms of duration. The basic characteristics of the sub-periods are shown in Tables 2a, 2b.

Table 2a. *Statistical characteristics of indices in the research time span for EExCCs*

Description	BET	BUX	CROBEX	OMXR	OMXT
Index value on SEP 30, 2019	9 574	40 601	1 963	1 028	1 235
Index change in sub-period I	6.74	13.86	4.67	3.45	11.26
Number of trading sessions in period I	76	59	74	86	92
Average growth rate in period I (%)	0.09	0.22	0.06	0.04	0.12
Date of max quotation in Q1 2020 (max)	23.01.	02.01.	23.01.	07.02.	13.02.
Maximum quotation value on (max) date	10 220	46 230	2 055	1 064	1 374
Date of minimum quotation (min)	23.03.	18.03.	23.01.	12.03.	16.03.
Minimum quotation value on (min) date	7 039	29 464	1 365	828	971
Index change in period II	-31.12	-36.27	-33.59	-22.17	-29.33
Number of trading sessions in period II	41	54	42	24	21
Average growth rate in period II (%)	-0.91	-0.82	-0.97	-1.03	-1.63
Index value on DEC 30, 2020	9 806	42 108	1 739	1 136	1 344
Index change in the period III:	39.3	42.91	27.42	37.22	38.33
Number of trading sessions in period III	193	196	193	198	198
Average growth rate in period III (%)	0.14	0.15	0.11	0.08	0.11
	OMXV	PX	SBITOP	SOFIX	WIG20
Index value on SEP 30, 2019	691	1 042	855	571	2 173
Index change in sub-period I	8.65	9.71	15.10	2.66	1.23
Number of trading sessions in period I	96	77	93	74	60
Average growth rate in period I (%)	0.09	0.16	0.15	0.04	0.02
Date of max quotation in Q1 2020 (max)	20.02.	24.01.	19.02.	20.01.	02.01.
Maximum quotation value on (max) date	750	1143	983.78	586	2 200
Date of minimum quotation (min)	18.03.	18.03.	23.03	19.03.	12.03.
Minimum quotation value on (min) date	584	690	685	406	1 306
Index change in period II	-22.11	-39.60	-30.32	-30.72	-40.65
Number of trading sessions in period II	18	28	23	42	49
Average growth rate in period II (%)	-1.35	-1.76	-1.56	-0.85	-1.01
Index value on DEC 30, 2020	816.64	1027.14	900.37	447.53	1983.98
Index change in the period III:	39.73	48.78	31.34	10.28	51.94
Number of trading sessions in period III	196	195	195	192	202
Average growth rate in period III (%)	0.17	0.17	0.12	0.04	0.14

Note: *(sub)period I denotes time span from SEP 30, 2019 to the max (%), period II – time span from max to min (%), while period III time span from min to DEC 30, 2020.*
Source: *Own elaboration.*

Table 2b. *Statistical characteristics of indices in the research time span for developed countries*

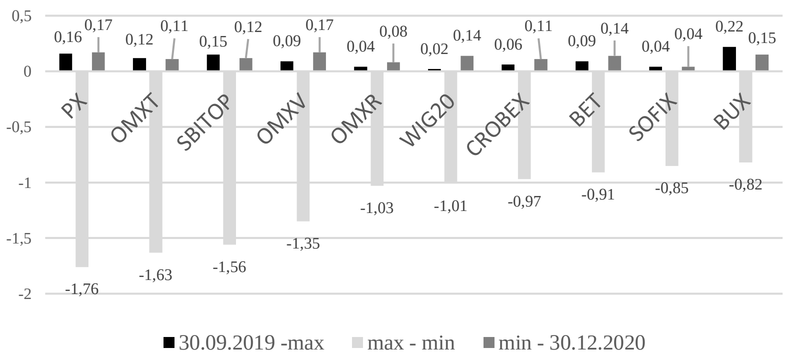
Description	DAX	CAC 40	FSSE 100	MSCI Europe
Index value on SEP 30, 2019	12 428	5 678	7 383	1 645
Index change in sub-period I	10.95	7.63	3.10	9.52
Number of trading sessions in period I	95	98	75	78
Average growth rate in period I (%)	0.11	0.08	0.04	0.12

Date of max quotation in Q1 2020 (max)	19.02.	19.02.	17.01.	17.01.
Maximum quotation value on (max) date	13 789	6 111	7 612	1 801
Date of minimum quotation (min)	18.03.	18.03.	23.03.	23.03.
Minimum quotation value on (min) date	8 442	3 755	4 907	1 153
Index change in period II	-38.78	-38,56	-35.54	-36.01
Number of trading sessions in period II	20	20	46	46
Average growth rate in period II (%)	-2.39	-2.36	-0.93	-0.95
Index value on DEC 30, 2020	13 719	5 599	6 506	1 856
Index change in the period III:	62.51	49.13	32.60	60.99
Number of trading sessions in period III	199	201	195	202
Average growth rate in period III (%)	0.22	0.17	0.13	0.22

Note: *Same as for Table 2a.*
Source: *Own elaboration.*

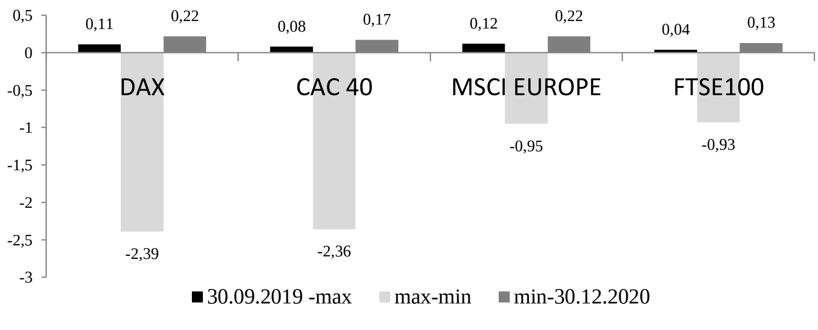
The growth rate of each index in each selected sub-period was also evaluated and the results are presented in Figure 2.

Figure 2a. *Comparison of the average daily changes (growth rate) of stock indices of post-communist countries*



Source: *Own study.*

Figure 2b. *Comparison of the average daily changes (growth rate) of stock indices of developed countries*



Source: *Own study.*

It is worth noting that the Hungarian BUX index showed the largest daily increase in pre-pandemic sup-period I, but also the smallest decrease in pandemic outbreak period (II). In the period II, the Czech stock exchange recorded the largest daily average drop. On the other hand, the highest average daily increase during sub-period III presented the Lithuanian and Czech stock exchanges. The growth rate of the indices is similar in sub-periods I and III, and stands at 0.1% and 0.12%, respectively, while in the pandemic outbreak period (II) is equal to -1.19%. Thus, one can see the enormous depth of decline that occurred in reaction to the pandemic in comparison to sub-periods I and III.

However, it should be noted that during the pandemic response period, the spread between declines was relatively large: the smallest daily drop was for the BUX index, at -0.82%, while the largest was for the PX index, at -1.76%. For developed countries and the MSCI index, the data for the pandemic period are different. In particular, the average daily change for periods I and III is 0.09% and 0.19%, respectively, while for period III it is -1.66%. The DAX index suffered the largest decrease at -2.39%, significantly exceeding that of the PX index. On the other hand, the FTSE100 index suffered less (-0.93%) and the MSCI EUROPE index slightly more (-0.95%). Accordingly, it is difficult to select a stock market that performed unambiguously well during the pandemic outbreak period (II) and during the pandemic period (III). Therefore, the remainder of this paper analyses the trends and returns of market indices.

5. Market Trends

This part of our study explores the trends of the stock market indices selected for the examination. The analysis of trends requires the estimation of the structural parameters of equation (1). The estimation results and determination coefficients are presented in Tables 3a, 3b, where the significance of the parameters at the 5% level is indicated in bold.

Table 3a. *Results of estimation of structural parameters for post-communist countries*

Index	Factor	Period			Index	Factor	Period		
		I	II	III			I	II	III
BET	$\hat{\alpha}$	**9455.1**	**9689.6**	**7833.0**	OMXV	$\hat{\alpha}$	**693**	**731.5**	**609.1**
	$\hat{\beta}$	**8.023**	**90.657**	**11.508**		$\hat{\beta}$	**0.259**	2.883	**2.469**
	$\hat{\gamma}$	-0.001	**-3.759**	**-0.020**		$\hat{\gamma}$	**0.003**	**-0.604**	**-0.008**
	R^2	0.908	0.923	0.734		R^2	0.909	0.883	0.907
BUX	$\hat{\alpha}$	**39183.9**	**43026.8**	**34166.8**	PX	$\hat{\alpha}$	**1006.6**	**1071.6**	**822.0**
	$\hat{\beta}$	**150.638**	**295.351**	-7.578		$\hat{\beta}$	**2.244**	**9.278**	**1.148**
	$\hat{\gamma}$	**-0.728**	**-8.155**	**0.161**		$\hat{\gamma}$	**-0.008**	**-0.449**	**-0.003**
	R^2	0.924	0.715	0.318		R^2	0.903	0.942	0.358
CROBEX	$\hat{\alpha}$	**1966.0**	**1968.8**	**1536.8**	SBITOP	$\hat{\alpha}$	**852.967**	**986.4**	**762.7**
	$\hat{\beta}$	0.485	**17.026**	**0.650**		$\hat{\beta}$	**0.775**	**-6.175**	**1.134**
	$\hat{\gamma}$	0.007	**-0.773**	0.001		$\hat{\gamma}$	**0.008**	**-0.302**	**-0.005**
	R^2	0.566	0.954	0.514		R^2	0.946	0.950	0.517

OMXR	$\hat{\alpha}$	**1033.2**	**1057.0**	**900.7**	SOFIX	$\hat{\alpha}$	**576.4**	**566.1**	**440.6**
	$\hat{\beta}$	**-0.275**	0.566	**2.647**		$\hat{\beta}$	**-1.465**	**3.167**	0.074
	$\hat{\gamma}$	**0.005**	**-0.145**	**-0.008**		$\hat{\gamma}$	**0.020**	**-0.150**	**-0.001**
	R^2	0.292	0.858	0.923		R^2	0.628	0.904	0.195
OMXT	$\hat{\alpha}$	**1242.5**	**1361.9**	**1055.3**	WIG20	$\hat{\alpha}$	**2110.3**	**2098.2**	**1497.4**
	$\hat{\beta}$	**-0.348**	3.883	**1.853**		$\hat{\beta}$	**6.807**	**11.833**	**3.807**
	$\hat{\gamma}$	**0.017**	**-0.760**	**-0.004**		$\hat{\gamma}$	**-0.123**	**-0.427**	**-0.011**
	R^2	0.954	0.897	0.571		R^2	0.437	0.863	0.480

Note: *Bold indicates the significance of the parameters.*
Source: *Own elaboration.*

Table 3b. *Structural parameters for developed countries*

Index	Factor	Sub-period			Index	Factor	Sub-period		
		I	II	III			I	II	III
DAX	$\hat{\alpha}$	**12243.2**	**13764.7**	**9451.1**	FTSE 100	$\hat{\alpha}$	**7187.9**	**7236.4**	**5768.2**
	$\hat{\beta}$	**29.888**	-112.017	**49.568**		$\hat{\beta}$	1.090	**54.013**	**3.069**
	$\hat{\gamma}$	**-0.183**	**-7.251**	**-0.164**		$\hat{\gamma}$	**0.054**	**-2.290**	-0.003
	R^2	0.783	0.958	0.841		R^2	0.648	0.946	0.262
CAC 40	$\hat{\alpha}$	**5499.4**	**6087.0**	**4320.2**	MSCI Europe	$\hat{\alpha}$	**1612.360**	**1699.640**	**1311.5**
	$\hat{\beta}$	**12.513**	-38.834	**6.670**		$\hat{\beta}$	**3.363**	**16.899**	**3.428**
	$\hat{\gamma}$	**-0.076**	**-3.741**	-0.006		$\hat{\gamma}$	**-0.014**	**-0.632**	**-0.006**
	R^2	0.812	0.953	0.671		R^2	0.876	0.937	0.835

Note: *Bold indicates the significance of the parameters.*
Source: *Own elaboration.*

Almost all γ_A coefficients are statistically significant, which can be considered a confirmation of the correctness of the choice of the quadratic trend function. The only exceptions are the BET and CROBEX indices in sub-period I and FTSE100 and CAC in subperiod III. In the large majority of cases, beta coefficients are also statistically significant, while alpha coefficients have this property for all sub-periods and all indices. It is also worth noting that in the vast majority of cases the determination coefficients are high, over 90%, except for the OMXR index where the coefficient of determination is 29.2% in the first sub-period. In few cases the coefficient of determination reaches values of 30%-50%, but in pre-pandemic and pandemic sub-periods. In short, during a pandemic these rates are high for both groups of indices. In the group of post-communist countries their lowest value is 71.5%, and in the group of developed countries they all exceed 90%.

The results of the trend model verification are presented in Tables 4a, 4b.

Table 4a. *Verification of econometric models with the quadratic trend for post-communist countries*

Index	Characteristic	Period			Index	Characteristic	Period		
		I	II	III			I	II	III
BET	heteroscedasticity	+	no	+	OMXV	heteroscedasticity	+	no	+
	autocorrelation	+	+	+		autocorrelation	+	no	+
	randomness	+	+	+		randomness	+	+	+
	normality	+	+	+		normality	+	+	no

BUX	heteroscedasticity	no	+	+	PX	heteroscedasticity	+	+	+
	autocorrelation	+	+	+		autocorrelation	+	+	+
	randomness	+	+	+		randomness	+	+	+
	normality	+	+	no		normality	+	+	no
CROBEX	heteroscedasticity	+	no	+	SBITOP	heteroscedasticity	no	no	+
	autocorrelation	+	+	+		autocorrelation	+	no	+
	randomness	+	+	+		randomness	+	+	+
	normality	+	no	no		normality	no	+	no
OMXR	heteroscedasticity	+	no	+	SOFIX	heteroscedasticity	+	+	+
	autocorrelation	+	no	+		autocorrelation	+	+	+
	randomness	+	+	+		randomness	+	+	+
	normality	+	no	no		normality	no	+	+
OMXT	heteroscedasticity	no	no	+	WIG20	heteroscedasticity	+	+	+
	autocorrelation	+	+	+		autocorrelation	+	+	+
	randomness	+	+	+		randomness	+	+	+
	normality	+	+	no		normality	+	+	no

Note: *Autocorrelation means the 1st order autocorrelation, + means occurrence of examined property.*
Source: *Own elaboration.*

Table 4b. *Verification of econometric models with the quadratic trend for developed countries*

Index	Characteristic	Period			Index	Characteristic	Period		
		I	II	III			I	II	III
DAX	heteroscedasticity	+	no	no	FTSE 100	heteroscedasticity	+	no	+
	autocorrelation	+	no	+		autocorrelation	+	+	+
	randomness	+	no	+		randomness	no	no	+
	normality	+	+	no		normality	+	+	no
CAC 40	heteroscedasticity	+	no	+	MSCI Europe	heteroscedasticity	+	+	no
	autocorrelation	+	no	+		autocorrelation	+	+	+
	randomness	+	+	+		randomness	no	no	+
	normality	no	+	no		normality	no	+	no

Note: *Same as for Table 4a.*
Source: *Own elaboration.*

Table 4b shows that in most cases we are dealing with the heteroscedasticity of residuals and first-order autocorrelation, which suggests the need to consider the ARCH effect. However, it is worth mentioning that the residuals in the trend models fulfil the randomness criterion and in most cases are also normally distributed. Based on the obtained results, the rankings of stock markets were developed taking into account the coefficients describing the trend, i.e., beta and gamma. Then Spearman rank correlation coefficients were calculated across sub-periods. The results are presented in Tables 5a, 5b.

Table 5a. *Spearman's rank correlation coefficients for post-communist countries*

Period	beta			gamma		
	I	II	III	I	II	III
I	1			1		
II	0.6055	1		0.6424	1	
III	0.2733	-0.1150	1	0.2278	0.1000	1

Note: *Bold indicates the significance of the parameters.*
Source: *Own elaboration.*

Table 5b. *Spearman's rank correlation coefficients for all indices*

Period	beta			gamma		
	I	II	III	I	II	III
I	1			1		
II	0.2530	1		0.5809	1	
III	0.4741	-0.0819	1	0.3013	0.0502	1

Source: *Own elaboration*

A non-significant value of the Spearman rank correlation coefficient means that the stock market's ranking position based on the value of a specific factor (beta or gamma) does not "transfer" from sub-period to sub-period. The ranking based on beta coefficients in sub-period I assigns a high position to the market when the beta coefficient is positive and with a high value compared to other markets. For sub-period II, all markets have declined. Accordingly, a high dynamic, i.e., a large negative beta coefficient, is interpreted negatively from the perspective of market behaviour.

On the other hand, the slow rate of change in this sub-period, i.e., a small negative beta coefficient, is considered as a positive effect. Table 5a contains the Spearman correlation coefficients between the subperiods in the group of post-communist countries, while Table 5b - in the group of all analysed stock exchange. All presented Spearman correlation coefficients are quite similar - are statistically significant and negative for sub-periods II and III. This can be interpreted as an indication that the behaviour of the post-communist's segment is like that of the European market. Stock exchanges that perform well in one of these subperiods, in terms of the dynamics of changes, fare slightly worse in the other (the coefficients are negative, but small in absolute terms). Of course, the coefficient does not determine which of these subperiods performed well and which did not perform well. On the other hand, Spearman's coefficients are positive between periods I and II, as well as sub-periods I and III.

However, they take on small values, the first pair of subperiods in the group of post-communist countries is a certain exception, the ratio is in the order of 60%. The remaining values indicate a weak correlation of ranking positions, but a positive one. This means that, within a very limited range, the stock market 'shifts' between the pre-pandemic, pandemic response, and pandemic sub-periods. The gamma coefficient is a measure of the change in the beta coefficient (as if "acceleration" of the index changes). A positive value means that the rate of change of the trend is accelerating, while a negative value means that it is slowing down. Additionally, in this case Spearman's rank correlation coefficients show similarities for the group of post-communist and European countries and for subperiods. All of them are positive, which means that in the case of the rate of changes of indices, we deal with similar positions of indices in the rankings, which, however, does not determine whether these positions indicate favorable or unfavorable behavior from the point of view of the stock market situation. The highest value of these coefficients is for subperiods I and II, namely, 0.6424 for the indices of post-communist countries and 0.5809 for all indices. These relationships can be roughly interpreted as similar in both groups of countries behavior of the dynamics of indices changes in the pre-pandemic and in the pandemic periods.

6. Rates of Return Statistical Properties

The third stage of our study began with verification of the stationarity of the indices' rates of return. For verification, the ADF test was applied, with the null hypothesis of the non-stationarity of the time series due to the existence of a unit root against the alternative hypothesis that the time series is stationary (Maddala, 2006). The research was carried out at the significance level of 0.05 using the *GRETL* software. In all cases, the series of log returns proved to be stationary. The distribution of the rates of return did not show that the distribution was consistent with the normal distribution. The residuals and squares of the residuals in the $AR(1)$ model, were then included in the autocorrelation analysis. Then, the autocorrelation analysis included the residuals and squares of the residuals in the $AR(1)$ model. Significant *ACF* values for the residuals indicate the existence of autocorrelation, while significant values for squared residuals indicate the presence of the *ARCH* effect. To verify the existence of an *ARCH* effect the *LM* test was used (Engle, 1982). The results of the verification are presented in Tables 6a, 6b. The null hypothesis of no *ARCH* effects was rejected in all cases.

Table 6a. *ARCH effect verification for post-communist countries*

Index	LM test statistic	p-value	Order of delay
BET	**128.052**	4.3130e-022	11
BUX	**84.723**	1.4144e-012	13
CROBEX	**92.726**	4.1983e-014	13
OMXR	**16.653**	8.3305e-004	3
OMXT	**80.699**	5.9938e-016	5
OMXV	**59.395**	2.5621e-006	18
PX	**121.473**	9.7969e-019	15
SBITOP	**91.819**	7,8202e-011	21
SOFIX	**54.405**	1.7303e-010	5
WIG 20	**71.563**	2.2111e-011	10

Note: *Bold indicates the significance of the parameters.*
Source: *Own elaboration.*

Table 6b. *ARCH effect verification for developed countries*

Index	LM test statistic	p-value	Order of delay
DAX	**85.5434**	3.9106e-011	17
CAC 40	**75.1807**	1.2514e-011	11
FTSE 100	**89.7838**	6.6827e-012	17
MSCI Europe	**63.4149**	8.1382e-010	10

Note: *Bold indicates the significance of the parameters.*
Source: *Own elaboration.*

The identification of an *ARCH* effect gave the basis for constructing a $GARCH(p,q)$ model. Various variants of model parameters were considered, considering the Akaike and Schwarz criteria. Tables 7a, 7b show the results of the parameter estimation for the best model.

Table 7a. *Parameters of $GARCH(p,q)$ model for post-communist countries*

Index	(p, q)	$\varphi_{A,0}$	$\varphi_{A,1}$	$\psi_{A,1}$	Akaike criterion	Bayes – Schwarz criterion
BET	1, 1	**4.51319e-06**	**0.294905**	**0.705095**	−1991.969	−1983.007
BUX	1, 1	**1.69846e-05**	**0.174890**	**0.752974**	−1751.569	−1742.613
CROBEX	1, 1	**7.24033e-06**	**0.167474**	**0.778782**	−2032.924	−2023.969
OMXR	1. 1	**9.15560e-06**	**0.436408**	**0.563592**	−2031.885	−2022.937
OMXT	1, 1	**7.74671e-06**	**0.473537**	**0.497092**	−2210.112	−2201.143
OMXV	1, 1	**6.63570e-06**	**0.555844**	**0.444156**	−2268.400	−2259.438
PX	1, 1	4.98091e-06	**0.262491**	**0.736329**	−1917.687	−1908.725
SBITOP	1, 1	**1.70474e-05**	**0.361882**	**0.505088**	−2036.268	−2027.299
SOFIX	1, 1	**7.88637e-06**	**0.688425**	**0.311575**	−2144.185	−2135.236
WIG 20	1, 1	**2.09084e-05**	**0.129140**	**0.800829**	−1674.943	−1665,974

Note: *Bold indicates the significance of the parameters.*
Source: *Own elaboration.*

Table 7b. *Parameters of $GARCH(p,q)$ model for developed countries*

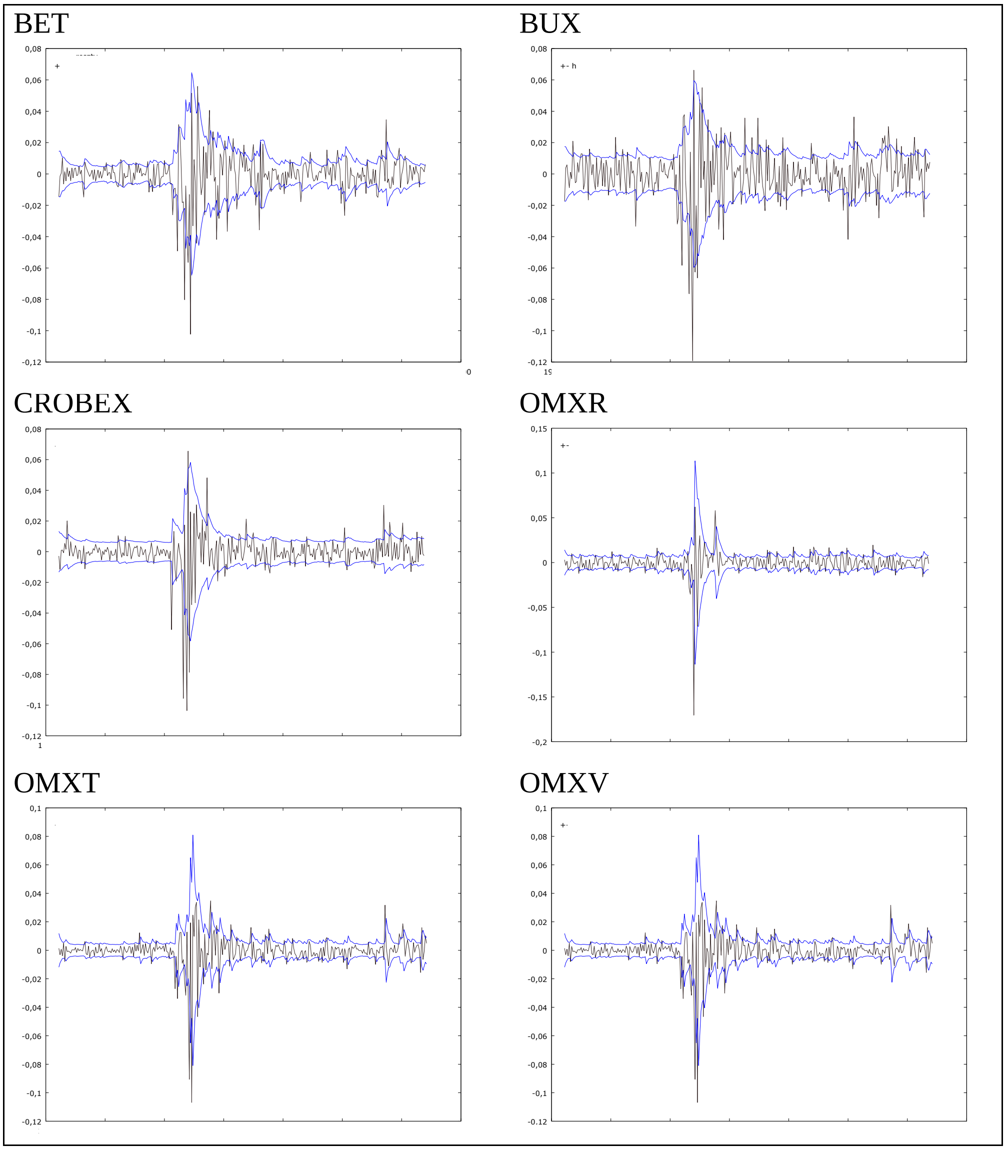
Index	(p, q)	$\varphi_{A,0}$	$\varphi_{A,1}$	$\psi_{A,1}$	Akaike criterion	Bayes – Schwarz criterion
DAX	1, 1	**9.18988e-06**	**0.174592**	**0.810110**	−1723.242	−1714.252
CAC 40	1, 1	**1.02143e-05**	**0.267190**	**0.730433**	−1796.341	−1787.319
FTSE 100	1, 1	4.71225e-06	**0.200816**	**0.799184**	−1815.635	−1806.633
MSCI	1, 1	**5.12851e-06**	**0.177413**	**0.819307**	1896.124	−1887.057

Note: *Bold indicates the significance of the parameters, MSCI is the abbreviation for MSCI EUROPE.*
Source: *Own elaboration.*

As a result, increasing the parameter values in the *GARCH* model results in less and less significant parameters. Therefore, in most cases, the *GARCH* model was considered the best $GARCH(1,1)$. Brzeszczyński and Kelm (2002), and Fiszeder (2009) indicate that if in the $GARCH(1,1)$ model the sum of the parameters φ_1 and ψ_1 is close to one, the model accurately describes the modeled phenomenon. Apart from the models for the *BET, OMXR, OMXV, SOFIX* and *FTSE 100* indices, all others had the sum of parameters lower than one, which proves the stationary covariance of the process generated by the model.

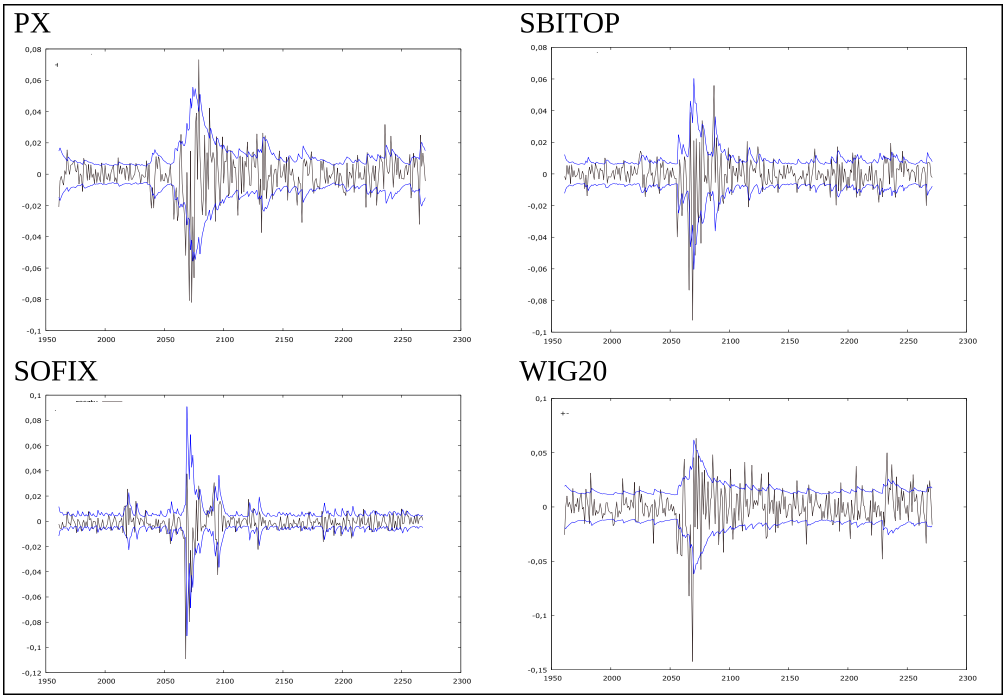
Adjusting the *GARCH* class models for the rates of return of the analysed indices allows for the assessment of its individual parameters. Parameters $\varphi_{A,i}$ greater than zero. confirm the occurrence of increasing variance, and positive values $\psi_{A,j}$ may indicate an asymmetric course of the rates of return of the analyzed indices. Since the onset of the pandemic, fitting the data with the *GARCH* model is much more difficult. It is confirmed, for instance, by the fact that the conditional standard deviation is unable to accommodate many more values of the residual component than before the pandemic (Figures 3a, 3b). The pandemic response in both post-communist and developed market indices is very strong and immediate. This response varies depending on the stage of the pandemic. However, it is much higher than in the pre-pandemic period. In the case of post-communist indices, the strength of the response at the onset of a pandemic is higher than in developed countries.

Figure 3a. *Conditional standard deviation for the stock index returns for post-communist countries*



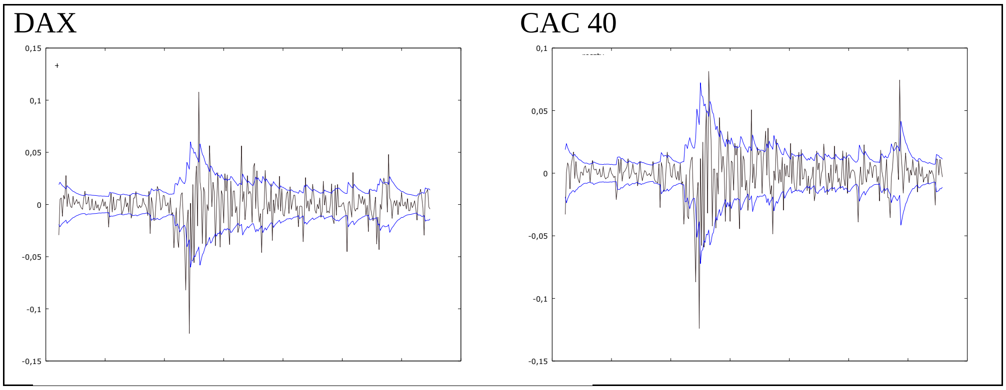
Note: *Blue line indicates +/- h(t)^0.5.*
Source: *Own study.*

Figure 3a. *(cont.) Conditional standard deviation for the stock index returns for post-communist countries*

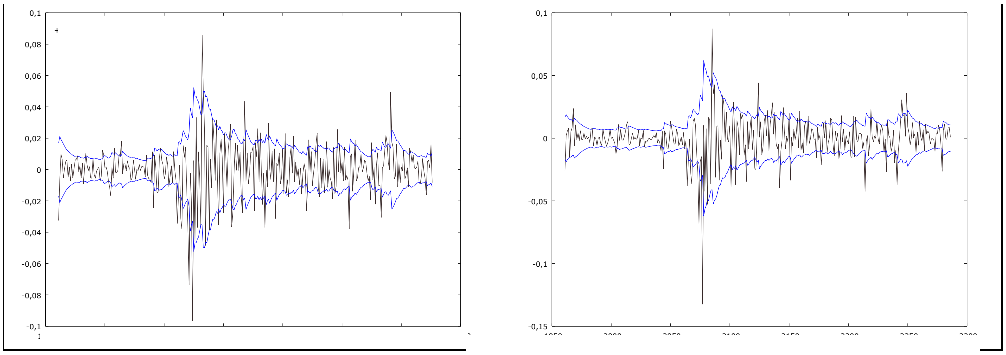


Note: *Blue line indicates +/- h(t)^0.5.*
Source: *Own study.*

Figure 3b. *Conditional standard deviation for the stock index returns for* developed *countries*



FTSE 100 MSCI EUROPE



Note: *Blue line indicates +/- h(t)^0.5.*
Source: *Own study.*

7. Conclusion

In conclusion, it can be stated that application of the quadratic trend function allows an acceptable description of the economic situation on the stock markets in the considered sub-periods. The first analysed sub-period covered a time span when nobody knew about the upcoming COVID-19 pandemic, while the other two sub-periods are clearly related to the pandemic and are well explained in terms of changes in stock indices.

The pre-pandemic period has a supporting role in our study, since it allows to determine the moments of indices reaction to the pandemic outbreak, i.e., the breakdown points of indices quotations in the first quarter of 2020. As a result, the determination coefficients, with few exceptions, are satisfying from an econometric point of view. Their values often exceed 90%, regardless of the group of analysed countries, either post-communist or developed, being represented by DAX, CAC40, FTSE100, and MSCI Europe indices. In this context, it can be assumed that the hypothesis formulated at the beginning is confirmed.

This conclusion is also supported by the analyses of the beta and gamma coefficients, which describe the trends and rates of change of the trends. The rankings created on the basis of both coefficients result in similar values of Spearman rank correlation coefficients. Accordingly, it is not possible to identify a better or worse dealing capital markets in the economic fluctuations environ caused by the pandemic. Based on the statistical analysis of the indices, it can be concluded that, in a very limited scope, the characteristics of the post-communist stock exchanges are slightly better. In this group, the largest average daily decline during the pandemic response period was in the PX index (Czechia), reaching -1.76%. On the other hand, the analogous change in the second group of analyzed stock exchanges was related to DAX index (Germany) and had the value of -2.39%, while a slightly lower value of -2.36% was related to CAC index (France) in the same sub-period. The lowest value of average daily changes reached -0.82% BUX index (Hungary) in the group of post-communist countries and -0.93% FTSE100 index (UK) for other countries. A very similar value was recorded for the MSCI Europe index (-0.95).

When adding to these conclusions the results from the third stage, it can be concluded that the response to the pandemic was stronger for the indices of the post-communist countries than for the developed countries. Over the time, the response to the pandemic was more significant in developed markets.

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