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COVID-19 pandemic impact on investment prospective in selected CEE stock markets: A stochastic dominance approach

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Abstract
The COVID-19 pandemic and its impact on the stock markets in the Central and East European (CEE) countries have been investigated in many papers, but mostly from the perspective of the market connectedness and the spillovers. None of the existing researches addressed the potential changes in the investors' utility in a certain market caused by the pandemics. Therefore, this paper compares investors' prospective in the periods before and during the pandemics in the selected CEE markets in terms of their utility and provides a new aspect to this research field. The analysis includes Bosnia and Herzegovina, Bulgaria, Croatia, Czech Republic, Hungary, Poland, Romania and Serbia. By using the first two degrees of the stochastic dominance (SD) criteria, market returns before and during the pandemics are compared in order to find dominant (efficient) investment alternative for all investors who prefer greater return and smaller variance (risk averters). This procedure is executed within a certain market and between different markets in these two periods. The results indicate that there is no dominance between pre-pandemic and pandemic returns for all CEE markets when the whole distribution is observed, indicating that the markets generally recuperated in the mid-run. The dominance relations can be found only in the trimmed series. Moreover, it is possible to find CEE markets which dominate over some other, in both pre-pandemic and pandemic period, representing a better investment opportunity for all risk averters.

Keywords: CEE, COVID-19, efficiency, k stochastic dominance, stock market.

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Introduction
The global pandemics caused by the COVID-19 and the accompanied lockdown created a significant shift in different aspects of social behaviour, following the consequent changes for businesses and the overall economies. Since stock markets

are under the influence of different economic and non-economic factors, it is reasonable to assume that stock markets reacted in a certain way on the outbreak of the COVID-19 pandemic even before the visible effects started to have overtaken the economy and businesses. The shock was not initially created in the financial sector, but due to the interconnections of all aspects of global life, all events sooner or later reflect in the financial sector and stock markets.

The line of pandemic impact on stock markets is at least twofold – firstly, many businesses were hit by the lockdowns and the shift in the consumption, first of all those which relied on travel and personal interactions (Anayi et al., 2022). On the other hand, some of the businesses exploded, for example Internet-based businesses and parcel services, healthcare and medication producers, just to name some (Donthu, Gusstafson, 2020). Secondly, it is familiar that investors react on all kind of news and also create market movements based on their sentiment and future expectations.

However, the recovery of economies was faster than expected in terms of real GDP growth and financial markets rebound strongly on the basis of quick recovery expectations (Žigman, 2021). The most of the CEE stock markets recuperated and regained lost values. Therefore, we question the position of the mid-term investor on selected CEE markets after the declaration of the pandemics with respect to the period before.

The aim of the paper is to examine how COVID-19 pandemic influenced investors in the selected CEE stock markets by comparing the market returns before and during the pandemics using the stochastic dominance (SD) criteria. The SD criteria are focused on pairwise comparisons of the selected distributions and examine if one distribution is dominated by the other in terms of the expected utility. Since expected utility is included, these decision criteria pose some assumptions on the characteristics of the utility function. However, the exact form of the investors' utility functions does not have to be known. Therefore, this approach is not limited to a certain type of utility functions. Also, it is applicable for all shapes of return distributions which makes it appropriate when normality assumption is violated.

Following the assumptions that all investors prefer more to less and risk averse, implying that they have a non-decreasing and concave utility function (Levy, 2016), the paper examines the first two degrees of the stochastic dominance between two chosen distributions. All distributions which are not dominated by any other are considered to be efficient. By means of SD methodology, the empirical analysis investigates the returns on the CEE stock market indices, as market proxies, over two periods – before and after the declaration of the pandemic caused by the coronavirus SARS-COV 2. The date which will be used to split data into two series is the date when the World Health Organization (WHO) declared COVID-19 a Pandemic - March 11 2019 (World Health Organization, 2019). Obviously, the markets should have reacted even before the official declaration of the pandemic. However, the main idea of this paper is to compare market returns from these two periods and to find a dominant investment period (if possible in term of the stochastic dominance up to a certain degree), which will indicate if the investors prospective have changed in the mid-term. Therefore, the returns of the same market before and during the pandemic will be compared to find if the markets changed their characteristics in terms of the stochastic dominance. Secondly, pair-wise comparison of market returns of all of the observed markets before and after the pandemic outbreak is obtained for all pairs to find if efficient investment alternatives exist and figure out if their relative position regarding other markets has changed. The SD results between markets will tell us if their characteristics and the

appeal for investors changed during the COVID-19 pandemics, and if some markets are more or less attractive for the average investor. The analysed countries are the following: Bosnia and Herzegovina, Bulgaria, Croatia, Czech Republic, Hungary, Poland, Romania and Serbia. The reason to investigate these markets is their connectedness, which was confirmed in the papers investigating the pre-pandemic period (for example, Šikić, Šagovac, 2017; Dedi, Škorjanec, 2017; Latinović et al., 2018; Škrinjarić, 2020; Maras, 2022; just to name some of the newest findings), while the overview of the papers concerned with connectedness during the pandemic is described in the literature overview of this paper. The overview of papers detecting inter-connectedness of CEE markets and its connectedness with other markets can be found in Rehman et al. (2022).

The paper is organized as follows. The second chapter provides the literature overview, while the third chapter presents the methodology of stochastic dominance criteria and the data. The fourth chapter gives results and the fifth is the conclusion.

Literature review

The literature overview is divided in two parts. The first part presents research concerned with the analysis of CEE stock markets. Since there are numerous researches investigating different elements of CEE stock markets, only the most recent papers focusing only on COVID-19 impact on different aspects of the stock markets of selected CEE countries will be presented in the following overview. The second part presents some of the recent papers using SD for finding efficient investment alternatives.

There are several scientific paper that deal with COVID-19 pandemics and CEE markets from different aspects. For example, Škrinjarić (2021) analysed Central Eastern and South Eastern European (CESEE) markets and their reaction to the COVID-19 pandemic, using the event study methodology approach. The author finds a strong negative effects of certain COVID-19 phenomena on the selected stock markets. Moreover, the obtained information has shown to be useful for constructing contrarian investment strategy to take advantage of large declines in the stock market indices. Papadamou et al. (2021) found that the Google search queries for COVID-19 have a direct effect on implied volatility and an indirect effect via stock returns on stock markets, which are stronger in Europe than in the rest of the world. Their results suggest that Google-based anxiety about COVID-19 leads to elevated risk-aversion in stock markets. Buszko et al. (2021) investigated sectoral indices on the Warsaw Stock Exchange and their stability during the COVID-19 pandemic. Using K-means and the Ward's technique for clustering, they conclude that the clusters composition is fairly stable over time and that the stability of the obtained clusters is similar, but that the origins of the stability are different.

However, a greater number of papers concerned with the CEE markets in times of COVID-19 pandemic investigate the level of their connectedness and spillovers. For example, Rehman et al. (2022) examined the returns inter-dependence of 42 stock markets applying several dependence measures. One of their conclusions is that the returns coherence of CEE and G-7 markets increased significantly during the COVID-19 period. Karkowska and Urjasz (2021) investigated the direction and scale of connectedness between selected post-communist countries from CEE, major global markets and European sovereign bond markets in the period of 2008–2020, including the COVID-19 pandemic. By using the directional method and dynamic conditional interconnectedness modelling, the authors found that CEE member countries are more interlinked with each other than with the global markets. Also, almost all CEE

bond markets are net receivers of risk from other markets excluding the COVID-19 sub-period. Fang et al. (2021) studied stock markets of Russia, Poland, the Czech Republic, Hungary, Croatia, and Slovenia from January 1, 2010 to March 10, 2021 and found that the COVID-19 pandemic has increased herding behaviour in all stock markets from their sample. They suggest that financial authorities should monitor investors in the stock market to avoid the increase in herding behaviour. Oner et al. (2022) investigated the correlation and the spillover effects between CEE stock markets (Bulgaria, Croatia, the Czech Republic, Hungary, Poland, Romania, the Slovak Republic, Slovenia, Estonia, Latvia, and Lithuania). Using the Pearson correlation coefficient, Multivariate VAR and Granger test, a high correlation and causality relationships were found during the period of COVID-19 pandemics, also supported by impulse-response and variance decomposition test results, which confirmed that there is a spillover effect between the CEE stock markets. Pardal et al. (2020) analysed the financial integration of Austrian, Slovenian Hungarian, Lithuanian, Polish, Czech, Russian and Serbian stock market in the COVID-19 pandemic using their market indexes. They used ADF, PP, KPSS tests, and Clemente et al. test to detect structural breaks, Gregory and Hansen integration test to analyse financial integration, which were validated using the impulse-response function (IRF) with Monte Carlo simulations. They have found very significant levels of integration and concluded that the most of the significant structural breaks occurred in March 2020. Boghicevici et al. (2021) also investigated the contagion effect of the stock markets in selected CEE countries (Hungary, Poland, the Czech Republic, Romania and Bulgaria) compared to the Eurozone during the COVID-19 crisis. They used the spillover index by Diebold and Yilmaz and a DCC-GARCH approach. Their results indicate an increase in correlations and higher level of contagion during the crisis period.

Regarding the SD methodology that is used in this paper, SD was used for finding efficient investment alternatives in many papers. Just to concentrate on the newest publication closely related to this paper, Zhu et al. (2019) analysed the impact of the 2007 global financial crisis (GFC) on the 7 Latin American stock markets, and among other indicators, used SD tests up to third degree to compare pre-GFC and post-GFC returns. They concluded that investors, in general, prefer investing in the post-GFC period. Mroua, Bouattour and Naifar (2022) analysed the performance of renewable energy investment in an international portfolio diversification strategy and used SD approach to compare diversified portfolios and find efficient portfolios. Anyfantaki et al. (2021) evaluated diversification benefits of cryptocurrencies and compared optimal portfolios with and without cryptocurrencies using a modified SSD test. Alkhazali et al. (2021) found that the gold-oil portfolio stochastically dominates the one without gold at the second and third degree stochastic dominance. Pho et al. (2021) investigated diversification possibilities of gold and Bitcoin and compared the returns of the diversified portfolios using SSD criteria which showed that portfolios diversified by gold dominate those diversified by Bitcoin.

Mroua, Bahloul and Nadifar (2022) also investigated diversification possibilities of Bitcoin in traditionally diversified financial portfolios and used a bootstrap- based SD test to find that portfolios with Bitcoin stochastically dominate traditional financial portfolios and that the optimal portfolio changes with the market regime.

Do (2020) used the concept of almost stochastic dominance and found that socially responsible investing (SRI) portfolio dominates market indexes. Chiu et al. (2020) combined the computational aspects of cumulative prospect theory with the stochastic dominance approach and found that investors under uncertainty on Chinese markets use Bitcoin for hedging, perhaps as an intermediary in times of

emergency. Liao et al. (2019) used bootstrap-based LMW (Linton, Maasoumi and Whang) test for testing SD between value and growth portfolios, defined in terms of 4 value premium indicators, in the period of pre and post the 2018 financial crisis. Guran et al. (2019) used SD criteria to pre-eliminate the SSD inefficient stocks before the Mean-Variance (MV) optimization and concluded that this procedure increases the performance of some MV- optimized portfolios which stand out with a better back-testing performance.

This literature overview indicates that, even though CEE markets are broadly explored, most of the research concentrate on connectedness and spillovers in this market, which is important for the diversification opportunities. However, there are no research about the attractiveness of certain markets for the investors pre and post the pandemic outbreak, which will indicate if the investors' prospective changed after the COVID-19 pandemics outbreak. This paper aims to fulfil this gap. On the other hand, the literature overview shows that SD is a popular method for comparing different investment alternatives, but was not used for this specific problem of finding SD-efficient investment alternatives in selected CEE stock markets before and during the pandemics.

Research methodology and data

An investment can be attributed as (relatively) efficient given a set of criteria if and only if there is no alternative investment that is better in at least one criterion and is no worse in all other criteria (Pareto-Koopmans efficiency). These criteria should ascend from the decision maker's (investors) preferences (Gardijan Kedžo, Šego, 2021). The stochastic dominance (SD) criteria can identify efficient choices, in terms of expected utility, for all decision makers who share the same preferences, i.e. whose utility functions belong to the same class of admissible utility functions, whereby the utility functions themselves do not have to be known (Hanoch, Levy, 1969). Also, this approach does not require the assumption of the theoretical shape of the return distributions. SD criteria are optimal selection criteria insofar as they are necessary and sufficient for determining dominance in terms of the expected utility. They can identify efficient investment alternatives compared to which there are no other alternatives that have a higher expected utility for a given class of utility functions. The relationship between efficiency, stochastic dominance and expected utility of investment alternatives is described by the following two statements (proofs can be found in Levy (2016)): (1) the expected utility of the decision maker (investor) is greater from one investment option than from another if and only if the return distribution that characterizes the first investment alternative stochastically dominates the return distribution of the second investment option, (2) the set of efficient investments consists of all investment opportunities that are not dominated by any other alternative.

The formulation of the criteria is as follows (following Levy, 2016). Let each risky alternative be described by their returns x. Let $f(x)$ and $g(x)$ be probability functions for some risky alternatives F and G. $F(x)$ and $G(x)$ are their cumulative probability functions. Let $F_k(x)$ be a k-th Integral of function $F(x)$, as a result of integrating function $F(x)$ k times with respect to variable x, and the same applies for $G_k(x)$. $U(x)$ is the decision makers' utility function, and $U^{(k)}$ its k-th derivative, $k \in \mathbb{N}$. $E_F(U)$ and $E_G(U)$ are the expected utilities under alternatives F and G, respectively.

We observe a closed interval $I = [a, b]$. In the empirical analysis I is the usually the union of returns of alternatives F and G, where a and b are the minimum and maximum values of their union. Let $\mathcal{U}_1$ be a set of all utility functions which are monotonically increasing, with continuous first derivate on $I = [a, b]$, therefore we

write $\mathcal{U}_1 = \{U|U^{'}(\cdot) \geq 0\}$. Now, let us observe when F has greater or equal expected utility than G:

$$E_F(U) - E_G(U) = \int_a^b (f(x) - g(x))U(x)dx \tag{1}$$

Since *F*(*b*)-*G*(*b*)=1-1=0 and *F*(*a*)-*G*(*a*)=0, then

$$E_F(U) - E_G(U) = \int_a^b (G(x) - F(x))U^{'}(x)dx \tag{2}$$

Since $U'(\cdot) \geq 0$ for all $U \in \mathcal{U}_1$, it follows that $E_F(U) \geq E_G(U) \Leftrightarrow F(x) \leq G(x), \forall x \in [a,b]$. Therefore, *F* has greater or equal expected utility than G if and only if its cumulative distribution *F*(x) is smaller than or equal to *G*(x) for each $x \in [a,b]$. Specifically, this means that *F* has is a smaller probability of realizing smaller values for each $x \in [a,b]$. F dominates G in first degree stochastic dominance (FD_1G) if and only if:

$$\begin{gathered} F(x) \leq G(x), \forall x \in [a,b], \ \wedge \ \exists x_0 \in [a,b] \text{ such that } F(x_0) < G(x_0) \\ \Leftrightarrow \\ E_F\big(U(x)\big) \geq E_G\big(U(x)\big), \forall U \in \mathcal{U}_1, \ \wedge \ \exists U_0 \in \mathcal{U}_1 \text{ such that } E_F\big(U_0(x)\big) > E_G\big(U_0(x)\big). \end{gathered} \tag{3}$$

If *F* does not stochastically dominate *G* in *FSD*, dominance of *G* over *F* can be concluded only by checking the reversed criteria over again. All alternatives which are not stochastically dominated by any other in FSD are found efficient according to the FSD. These two statements apply generally for the *n*-th degree SD. The existence of first degree stochastic dominance (FSD) can be established for any two non-intersecting distributions (proof in Levy (2006)). Therefore, using FSD criterion can still leave a large set of efficient possibilities. In order to further differentiate the set of efficient possibilities, it is possible to apply the criteria of higher degrees of stochastic dominance.

Second-order stochastic dominance (SSD) criteria are used to identify dominant alternatives which have greater expected utility for all utility functions that are non-decreasing and have a non-positive second derivative. So, let $\mathcal{U}_2 = \{U|U^{'}(x) \geq 0, U^{''}(x) \leq 0\}$. By further integration of equation (2), we have:

$$\begin{aligned} E_F\big(U(x)\big) - E_G\big(U(x)\big) &= \int_a^b \big(F(x) - G(x)\big)U^{'}dx = \\ &= U^{'}(b)(G_1(b) - F_1(b)) - \int_a^b U^{''}(x)[G_1(x) - F_1(x)]\,dx \end{aligned} \tag{4}$$

Since $\mathcal{U}_2 = \{U|U'(x) \geq 0, U''(x) \leq 0\}$, it follows that F does not have smaller expected utility than G for all $U \in \mathcal{U}_2$ if and only if $G_1(x) - F_1(x) \geq 0$. Therefore, F dominates over G in SSD (FD_2G) for all $U \in \mathcal{U}_2$ if and only if:

$$\begin{gathered} F_1(x) \leq G_1(x), \forall x \in [a,b], \ \wedge \ \exists x_0 \in [a,b] \text{ such that } F_1(x_0) < G_1(x_0) \\ \Leftrightarrow \\ E_F\big(U(x)\big) \geq E_G\big(U(x)\big), \forall U \in \mathcal{U}_2, \ \wedge \ \exists U_0 \in \mathcal{U}_2 \text{ such that } E_F\big(U_0(x)\big) > E_G\big(U_0(x)\big) \end{gathered} \tag{5}$$

For determining SSD, cumulative distribution *G*(x) does not have to be larger than *F*(x) for each $x \in [a,b]$ but the area enclosed between the graphs of their cumulative

distribution functions has to be positive for each $x \in [a, b]$, implying that *G*(x) has to have a fatter tail than *F*(x) for all x.

If we assume that our target investors prefer greater return, then their utility functions are non-decreasing and FSD criteria can be applied to find their efficient alternatives. By adding an assumption that they are also risk averse, their utility function should be non-decreasing and concave, therefore we use the SSD criteria to find their efficient investment alternatives. Most problems can be solved using these first two degrees. However, the SD is defined up to *n*-th degree. The *n*-th degree criteria can be applied for all investors for whom the signs of the first *n* derivatives of the utility functions are known.

In order to evaluate the impact of the COVID-19 pandemic on the CEE stock markets, this research observes them as investment alternatives and analyses their market return distributions in the pre-pandemic and in the pandemic period. Stochastic dominance criteria up to SSD are checked for pairs of the market return distribution to find (if possible) efficient investment alternative for all investors who prefer more to less and are risk averse. The data are the returns of the representative market indices of selected CEE countries, retrieved from the Wiener Borse (2022). All indices are observed in EUR. The data and their symbols, which will be used as abbreviations in this paper, are the following: Bosnian traded index in EUR (BXE), Bulgarian traded index in EUR (BTE), Croatian traded index in EUR (CRE), Czech traded index in EUR (CTE), Hungarian traded index in EUR (HTE), Polish traded index in EUR (PTE), Romanian traded index in EUR (ROE) and Serbian traded index in EUR (SRE). All of these indices are capitalization-weighted price indices made up of the most traded stocks of the particular country stock market. The returns are observed during the pre-pandemic period (March 11 2018 – March 11 2020) and during the pandemic period (March 12 2020 – March 12 2022).

Results and discussion

Tables 1 and 2 present basic descriptive statistics of the return series in the pre – pandemic period (March 10 2018 - March 10 2020) and during the pandemic period (March 11 2020 – March 11 2022). The tables include basic information on average return (mean), standard deviation (SD), skewness, kurtosis and historical Value at Risk at 5%.

Table 1 Descriptive statistics of market returns in the pre-pandemic period

	BXE	BTE	CTE	CRE	HTE	PTE	SRE	ROE
mean	0.03%	-0.09%	-0.05%	-0.01%	-0.04%	-0.08%	0.01%	0.01%
SD	0.96%	1.00%	0.80%	0.68%	1.08%	1.34%	1.16%	0.94%
skew	-0.47	-2.62	-1.12	-4.79	-0.77	-0.48	-2.45	-0.71
kurt	9.24	40.16	6.06	56.66	5.41	3.31	29.13	8.96
VaR	-2.00%	-1.66%	-1.83%	-1.16%	-2.17%	-2.68%	-1.80%	-2.02%

Source: Author's calculations.

Table 2 Descriptive statistics of market returns in the pandemic period

	BXE	BTE	CTE	CRE	HTE	PTE	ROE	SRE
mean	0.04%	0.08%	0.08%	0.04%	0.01%	0.03%	0.08%	0.04%
SD	0.98%	1.24%	1.67%	1.03%	1.68%	2.02%	1.28%	0.97%
skew	-0.44	-0.65	-1.30	-2.51	-1.37	-0.99	-0.86	-0.56
kurt	10.55	8.10	11.45	35.74	10.42	11.04	11.04	9.63
VaR	-2.01%	-2.14%	-3.09%	-1.51%	-3.13%	-3.65%	-3.15%	-1.69%

Source: Author's calculations.

What is interesting is that all of the markets increased their average return in the observed pandemic period. As expected, the all of the observed series increased their riskiness in terms of the standard deviations and historical Value at Risk at 5%. General observation cannot be concluded for the skewness and kurtosis. In the pre-pandemic period, highest average return was realised on BXE, and the smallest in BTE. PTE also had one of the smallest average returns and the highest risk in terms of SD and 5%-VaR. In the pandemic period, average returns for all markets were positive, with the highest daily return of 0.08% on BTE, CTE and ROE. All markets have an increase in the average return, on one side, and an increase in the SD and VaR (except for SRE with smaller VaR) on the other. Therefore, from this information, we cannot unambiguously say if the investors' prospective have changed on these markets.

To reach some conclusions about the mid-term changes in observed CEE markets, implied by the pandemic, market returns from the period before and during the pandemics are compared using the stochastic dominance criteria up to second degree. These criteria are able to detect dominant investment alternatives, in terms of their expected utility, for all investors who are risk-averters and prefer more to less. The investments which are not dominated by any other alternative are found efficient for all investors of the observed profile. In this research, market returns from a certain period (before and during the pandemics) in a certain CEE market are assumed to be returns of an investment alternative.

Firstly, pairwise comparisons are obtained between pre pandemic and the pandemic returns within a certain market. Figure 1 shows empirical cumulative distributions of returns before and during the pandemic for each of the observed markets. It is obvious that all graphs intersect at least once. Therefore, even without running the SD tests, it is obvious that there is no FSD in the observed sample. The legend of Figure 1 is omitted because the only important aspect is that the cumulative distributions graphs intersect at least once. It is less important which curve represents which distribution. Therefore, there are no dominance relations between pre and the pandemic returns for all investors who prefer more to less.

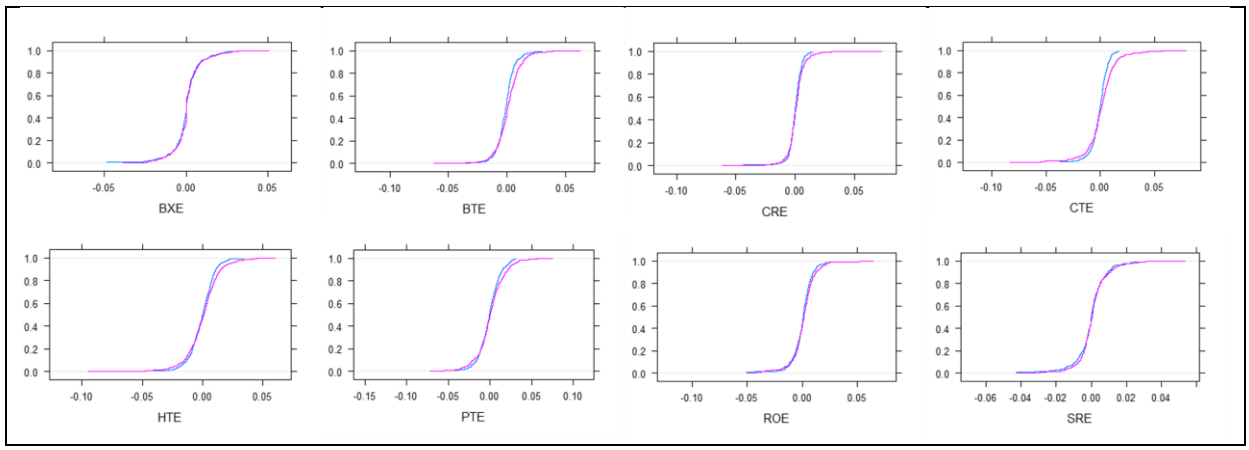

Figure 1 ECDFs of before and during the pandemic returns of CEE stock markets indices

Source: Author.

The following graphs show pairs of ecdfs for all possible pairs of different indices in the pre-pandemic period (Figure 2) and during the pandemic (Figure 3). We observe that all curves intersect at least once, which leads to the conclusion of impossible

FSD. Again, there are no dominance relations between observed CEE markets in the pre-pandemic and in the pandemic period for all investors who prefer more to less.

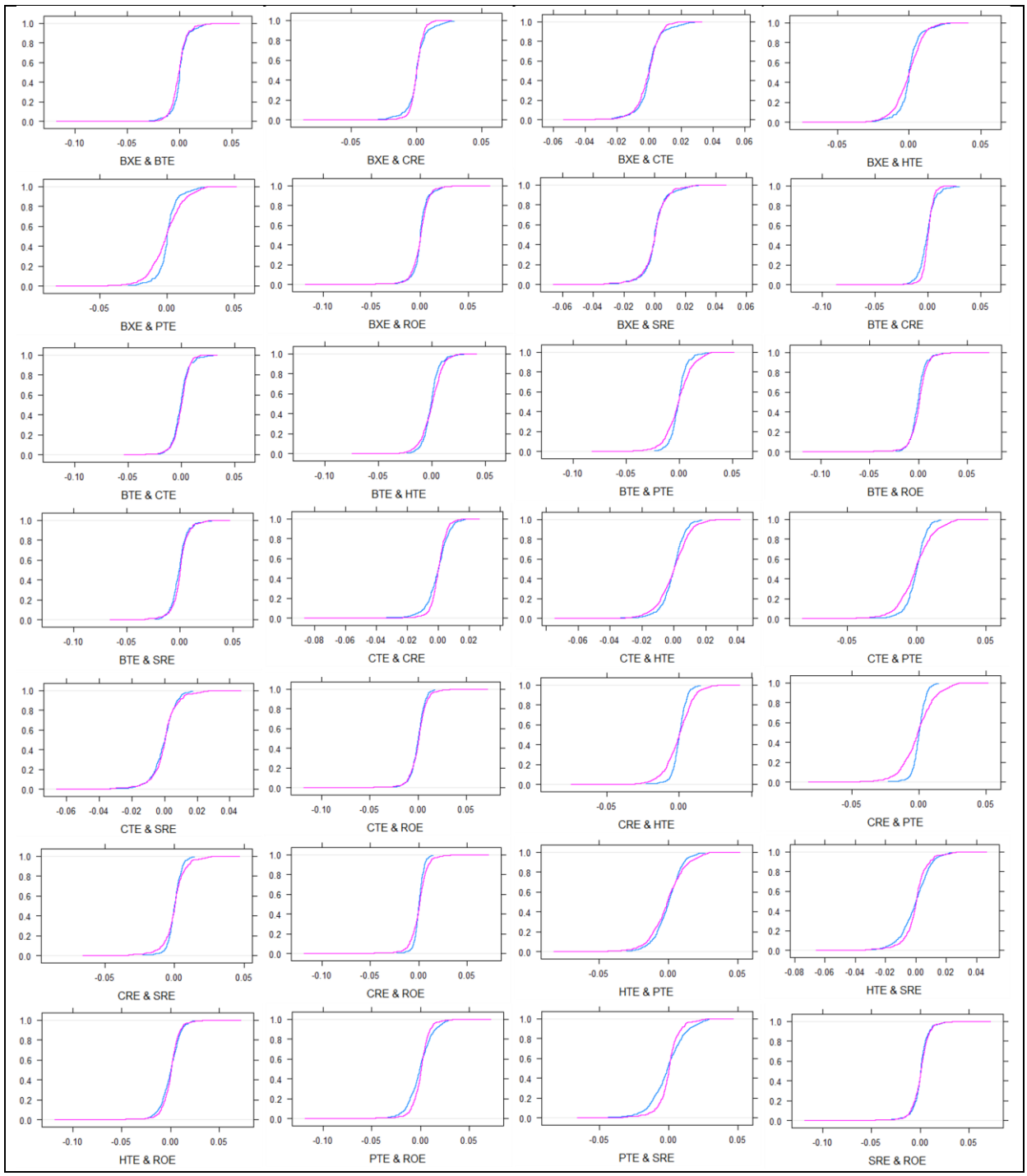

Figure 2 All pairs of return ECDFs before the pandemic in selected CEE markets
Source: Author.

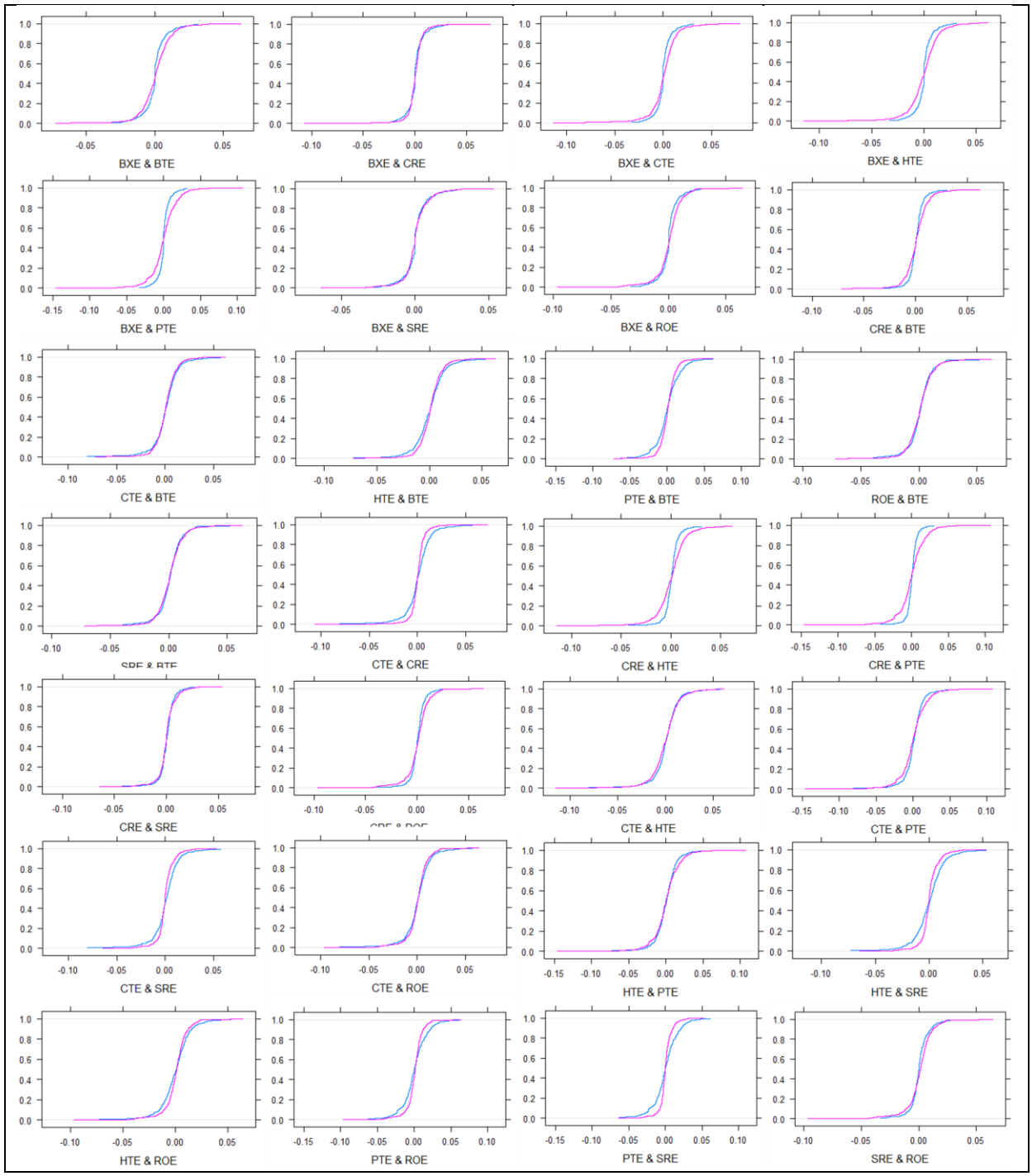

Figure 3 All pairs of return ECDFs during the pandemic in CEE markets
Source: Author.

Since there is no FSD between the observed series, SSD criteria are applied to find whether there are dominance relations for investors who prefer more to less and are risk-averters. Criteria for SSD has been tested for all pairs of distribution in the pre-pandemic and pandemic period and obtained by Vose Software ModelRisk. First, the pandemic and pre pandemic returns within a certain market are compared with SSD criteria. Table 3 shows that no dominance up to SSD can be concluded between pre and pandemic returns in any of the observed markets. Therefore, in terms of SD (and expected utility), investors in the pandemic period are not in significantly better nor worse position than in the previous 2-years period. This

indicates that the investments prospective on these markets have not changed for all investors who prefer more to less and are risk averse, implying that the pandemic did not harm the stock markets in the midrun.

Table 3 SD results in the pre pandemic period March 11, 2020 – March 11, 2022

Pre BXE vs Post BXE	Inconclusive
Pre BTE vs Post BTE	Inconclusive
Pre CTE vs Post CTE	Inconclusive
Pre CRE vs Post CRE	Inconclusive
Pre HTE vs Post THE	Inconclusive
Pre PTE vs Post PTE	Inconclusive
Pre ROE vs Post ROE	Inconclusive
Pre SRE vs Post SRE	Inconclusive

Source: Authors calculations.

Secondly, selected CEE stock markets are compared pair-wisely with SSD criteria. This procedure is divided for the pre-pandemic and the pandemic period. Table 4 presents SSD results over pairs of market returns between CEE countries in the pre-pandemic period. Slash indicates that no stochastic dominance could be concluded between the two return distributions. These results indicate that PTE is dominated by 4 out of 7 other markets. Also, BTE and ROE are also dominated by other markets. This indicates that PTE, BTE and ROE are inefficient investments and investors exhibit smaller utility for investing in PTE, ROE and BTE over other alternatives. In all other markets, all investors with assumed preferences do not have smaller utility. Therefore, in the pre-pandemic period, BXE, CTE, CRE, THE and SSD are SSD-efficient and present dominant investment alternatives over PTE, ROE and BTE.

Table 4 SD results in the pre-pandemic period

PRE	BXE	BTE	CTE	CRE	HTE	PTE	SRE	ROE
BXE	\	\	\	\	\	\	\	\
BTE	\		CTE D_2 BTE	CRE D_2 BTE	\	\	\	\
CTE	\	\	\	\	\	\	\	\
CRE	\	\	\	\	\	\	\	\
HTE	\	\	\	\	\	\	\	\
PTE	BXE D_2 PTE	\	CTE D_2 PTE	\	HTE D_2 PTE	\	SRE D_2 PTE	\
SRE	\	\	\	\	\	\	\	\
ROE	BXE D_2 ROE	\	\	\	\	\	SRE D_2 ROE	\

Source: Authors calculations.

Referring to the results presented in Table 5, more dominance relations could be found between the pairs of the observed markets in the pandemic period. Precisely, both HTE and PTE are dominated by most of the other markets and CTE is dominated by BTE. Other markets (BXE, CTE, CRE, ROE and SRE) are not dominated by any other investment alternative when returns during the pandemic are observed. Therefore, CTE, HTE and PTE are SSD inefficient and all other markets are in the efficient set. Even though SSD criteria did not differentiate pre and post CTE, HTE, BTE and ROE returns, when other markets are included in the analysis, investors' in the Czech and Hungarian markets during the pandemic are in a relatively worse position than before, while the opposite holds for Bulgarian and Romanian markets which improved their position regarding the others.

The presented results are obtained when the whole empirical distribution is evaluated. However, we can evaluate SD for the trimmed data, where we trim the values smaller than the 2.5%-th percentile and greater than the 97.5%-th percentile

of the distributions. Therefore, we concentrate on the middle 95% of the returns. In case when SD criteria are applied on the trimmed series, we can say the one investment alternative dominates the other in *n*-th degree of SD in 95% of the cases.

Table 5 SD results in the pandemic period

	BXE	BTE	CTE	CRE	HTE	PTE	SRE	ROE
BXE		\	\	\	\	\	\	\
BTE	\		\	\	\	\	\	\
CTE	\	BTE D_2 CTE		\	\	\	\	\
CRE	\	\	\		\	\	\	\
HTE	BXE D_2 HTE	BTE D_2 HTE	\	CRE D_2 HTE		\	SRE D_2 HTE	ROE D_2 HTE
PTE	BXE D_2 PTE	BTE D_2 PTE	CTE D_2 PTE	CRE D_2 PTE			SRE D_2 PTE	ROE D_2 PTE
SRE	\		\	\	\	\		\
ROE	\		\	\	\	\	\	

Source: Authors calculations.

Table 6 shows that no FSD can be found in the comparisons of the pre-pandemic and the pandemic returns distribution in the trimmed dataset. However, SSD can be found between pre and post pandemic returns of SRE. Hence, investors in SRE in the pandemic period are in a better position than before in terms of the expected utility in 95% of the cases.

Table 6 SD results in the pre and post pandemic period for the trimmed data

Pre BXE vs Post BXE	Inconclusive
Pre BTE vs Post BTE	Inconclusive
Pre CTE vs Post CTE	Inconclusive
Pre CRE vs Post CRE	Inconclusive
Pre HTE vs Post THE	Inconclusive
Pre PTE vs Post PTE	Inconclusive
Pre ROE vs Post Roe	Inconclusive
Pre SRE vs Post SRE	Post SRE D_2 Pre SRE

Source: Authors calculations.

Table 7 presents SSD results over pairs of trimmed market returns for selected CEE markets in the pre-pandemic period. PTE remained the least attractive investment for average investor, dominated by all other except by BTE. In comparison to the results in Table 4 in this case both HTE and CTE can be also attributed as inefficient in 95% together with PTE and BTE. BXE, CRE, SRE and ROE are SSD-efficient investment options in 95% of the cases. Therefore, investors in Bosnian, Croatian, Serbian and Romanian market were better off compared to the investors in other CEE markets.

Table 7 SD results in the pre pandemic period for the trimmed data

PRE	BXE	BTE	CTE	CRE	HTE	PTE	SRE	ROE
BXE								
BTE				CRE D_2 BTE				
CTE				CRE D_2 CTE				
CRE								
HTE	BXE D_2 HTE			CRE D_2 HTE			SRE D_2 HTE	ROE D_2 HTE
PTE	BXE D_2 PTE		CTE D_2 PTE	CRE D_2 PTE	HTE D_2 PTE		SRE D_2 PTE	ROE D_2 PTE
SRE								
ROE								

Source: Author's calculations.

Table 8 SD results during the pandemic period for the trimmed data

PAN	BXE	BTE	CTE	CRE	HTE	PTE	SRE	ROE
BXE				CRE D_2 BXE				
BTE								
CTE		BTE D_2 CTE						ROE D_2 CTE
CRE								
HTE	BXE D_2 HTE	BTE D_2 HTE		CRE D_2 HTE			SRE D_2 HTE	ROE D_2 HTE
PTE	BXE D_2 PTE	BTE D_2 PTE	CTE D_2 PTE	CRE D_2 PTE			SRE D_2 PTE	ROE D_2 PTE
SRE				CRE D_2 SRE				
ROE								

Source: Author's calculations

By comparing the trimmed series in the pandemic period by the SD criteria up to second degree, the results indicate that only BTE, CRE and ROE are SSD-inefficient while all others are inefficient, which hold for 95% of the cases.

Conclusion

The paper uses stochastic dominance criteria for determining the changes in the investors' prospective in selected CEE markets in the period before and after the official declaration of the COVID-19 pandemics. Stochastic dominance criteria up to the second degree are used to find dominant investments period and dominant markets for all investors who prefer more to less and are risk averters, without the need for specification of the shape of the return distribution or the shape of investors' utility functions. By comparing the return distributions of pre-pandemic and pandemic returns within the same market using the stochastic dominance criteria up to the second degree, only one dominance relation was found: pandemic returns in the Serbian stock market dominate over the pre-pandemic returns. This indicates that the pandemics did not harm the investors in the observed CEE markets significantly in the mid-run and that the investors regained (or even improved) their positions after dips in March 2020 over the following 2-years period.

Additionally, the stochastic dominance criteria up to the second degree revealed the inferior position of Polish and Hungarian markets in comparison to other markets in both pre-pandemic period and the pandemic period. Bulgarian and Romanian markets improved their position regarding the others in the pandemics. When the return series are trimmed for the lower and upper 2,5%, then more dominance relations could be determined. However, even in that setting, Bulgarian, Croatian and Romanian markets are found to be non-dominated and therefore SSD efficient in the pandemic period, implying that all risk averse investors had greater utility for investing in these markets than in the other selected CEE markets in that particular period.

The findings show that stock markets in the observed CEE countries recuperated from the shocks caused by the pandemics in a relatively short period. This suggest that the monetary policy combined with fiscal measures was effective for the economic recovery in these countries. Businesses in general picked up quickly and succeeded to grasp the new market opportunities caused by the pandemics. The inferior position of particular markets regarding the others signalizes a worrying situation for policy makers and investors in these markets.

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