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The Impact of the COVID-19 Outbreak on the Weak-Form Informational Efficiency of the Warsaw Stock Exchange

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The aim of this paper is to verify whether the COVID-19 outbreak negatively affected the weak-form informational efficiency of the Warsaw Stock Exchange (WSE). Applying a wild bootstrapped automatic variance ratio test and the rolling window methodology, we verify the martingale hypothesis for daily returns of 437 stocks listed on the Main Market of the WSE in a research period beginning on January 2nd, 2015 and ending on August 31st, 2020. The percentage of cases in which the martingale hypothesis cannot be rejected is our proxy for the weak-form informational efficiency that we come up with. Despite the rapid and significant price movements, as well as the rise of returns volatility (and thus a likely herd behavior of the market participants), the results obtained do not allow for stating unambiguously that the COVID-19 outbreak negatively affected the weak-form informational efficiency of the WSE. The results turned out to be sector-dependent. Future issue-related studies can apply other proxies of efficiency levels as a unique proxy applied in this study is based only on a wild bootstrapped automatic variance ratio test. The issue-related studies should be also continued as the pandemic is still an ongoing issue. This study comes up with a novel approach to approximating the weak-form informational efficiency, provides regulators, as well as other market participants with valuable information on the WSE efficiency changes in the COVID-19 pandemic times and even its long-term trends.

Keywords: COVID-19, stock market, efficient market hypothesis, weak-form efficiency, martingale hypothesis.

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Wpływ wybuchu epidemii COVID-19 na efektywność informacyjną Giełdy Papierów Wartościowych w Warszawie w formie słabej

Celem artykułu jest sprawdzenie czy wybuch epidemii COVID-19 negatywnie wpłynął na efektywność informacyjną Giełdy Papierów Wartościowych w Warszawie (GPW) w formie słabej. Za pomocą automatycznego testu wskaźnika ilorazu wariancji wykorzystującego procedurę niestabilnego bootstrapa oraz wykorzystując metodykę postępujących okien weryfikowana jest hipoteza martyngałowa dla dziennych stóp zwrotu 437 akcji notowanych na Głównym Rynku GPW w okresie badawczym rozpoczynającym się 2 stycznia 2015 r. i kończącym się 31 sierpnia 2020 roku. Odsetek przypadków, w których hipoteza martyngałowa nie może być odrzucona stanowi zaproponowaną w niniejszym badaniu miarę efektywności informacyjnej rynku w formie słabej. Pomimo znaczących i nagłych zmian cen na rynku oraz wzrostu zmien-

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ności stóp zwrotu (i stąd prawdopodobnych zachowań stadnych uczestników rynku), otrzymane wyniki nie pozwalają na wysunięcie jednoznacznego wniosku mówiącego, że wybuch epidemii COVID-19 negatywnie wpłynął na efektywność informacyjną GPW w formie słabej. Zachowanie efektywności po wybuchu epidemii różniło się między sektorami. Kolejne, ściśle powiązane badania mogą wykorzystywać inne miary efektywności, ponieważ unikalna miara zastosowana w niniejszym badaniu jest oparta jedynie na automatycznym teście wskaźnika ilorazu wariancji wykorzystującym procedurę niestabilnego bootstrapa. Badania powinny być również kontynuowane z uwagi na to, że pandemia jest ciągle trwającym zjawiskiem. Niniejsze badanie proponuje nowe podejście do szacowania efektywności informacyjnej rynku w formie słabej. Ponadto dostarcza regulatorom i innym uczestnikom rynku cennych informacji dotyczących zmian efektywności GPW w czasach pandemii COVID-19 oraz jej długoterminowych trendów.

Słowa kluczowe: COVID-19, rynek akcji, hipoteza rynku efektywnego, hipoteza w formie słabej, hipoteza martyngałowa.

JEL: G10, G14, G17, G40, G41

1. Introduction

The COVID-19 outbreak has drawn attention of researchers rapidly and has resulted in publishing many papers suggesting that the still ongoing pandemic outbreak constitutes an issue having an undisputedly significant impact on the markets, which does not have to be necessarily negative to some market participants. Some studies (e.g. Mazur et al., 2020; Dinget et al., 2020; He et al., 2020) found evidence that some stock market sectors turned out to be resilient to the pandemic outbreak or to even benefit from it. Nevertheless, the COVID-19 outbreak became harmful to stock markets and economies as a whole (e.g. Topcu & Gulal, 2020; Mazur et al., 2020; Baker et al., 2020; Shehzad et al., 2020; Khan et al., 2020; Ashraf, 2020; Erdem, 2020; Zhang et al., 2020; Lahmiri & Bekiros, 2020; Czech et al., 2020). Moreover, some studies report that the COVID-19 outbreak had the greatest impact on the markets among all previous infectious diseases (Baker et al., 2020), and even greater impact on some markets than the 2008 global financial crisis (Shehzad et al., 2020).

The majority of studies naturally investigates the impact of the coronavirus pandemic on such basic aspects of the markets as volatility and returns; nevertheless, a number of papers examining the weak-form informational efficiency of the markets in the pandemic times have already appeared. Some of them strictly pertain to stock markets (e.g. Aslam et al., 2020; Dias, Teixeira, et al., 2020; Dias, Heliodoro, et al., 2020; Ozkan, 2021; Lalwani, & Meshram, 2020; Choi, 2021). Despite the work which has been done in the area of changes of the weak-form informational efficiency of the stock markets in the pandemic period, not all markets have attracted much attention (for instance, the Polish one, according to our knowledge). What is more, the foregoing studies show that some differences in efficiency between the examined markets could be observed. The aforementioned constitutes a motivation for undertaking this study.

Every unprecedented shock to a market constitutes a test of its immunity, which is strictly connected with the concept of the market informational efficiency. Inefficient markets loose investors' trust due to inconvenient investing environment (Mensi et al., 2019). Most of the studies investigating how the markets coped with the past shocks suggest that the markets failed such tests (e.g. Anagnostidis et al., 2016; Sensoy & Tabak, 2015; Horta et al., 2014; Mensi et al., 2017; Kian-Ping et al., 2007; Cheong et al., 2007; Mensi et al., 2020; Aslam et al., 2020). Thus, this study may deliver valuable information to regulators and other market participants on whether the market has drawn conclusions from the past and whether any regulatory intervention has to take place to restore the market efficiency (Kian-Ping et al., 2007).

The aim of this paper is to verify whether the COVID-19 outbreak negatively affected the weak-form informational efficiency of the Warsaw Stock Exchange (WSE). Plunges and then rises (in some cases) on

the world's stock markets, which occurred in the early COVID-19 pandemic period (Mazur et al., 2020), might have been caused by the market overreaction and herding behavior, which constitutes a typical deviation from the efficient market hypothesis (Ding, 2020). Our research hypothesis states that the COVID-19 outbreak negatively affected the weak-form informational efficiency of the WSE. Following the rapid plunge and then a slower rise of the market, which took place in February and March 2020, we expect to observe a decreased level of the WSE efficiency, especially in the 1st quarter of 2020.

Applying a wild bootstrapped automatic variance ratio test (Choi, 1999; Kim, 2009; Charles et al., 2011), we verify the martingale hypothesis for daily returns of 437 companies listed on the Main Market of the WSE in 2- and 4-month rolling windows (with 2-month rolling), in the research period beginning on January 2nd, 2015 and ending on August 31st, 2020. The percentage of cases in which the martingale hypothesis cannot be rejected is our proxy for the weak-form informational efficiency that we came up with. The results will also be grouped into 8 different sectors as it is worth to verify whether there are any differences between them in terms of behavior of their weak-form efficiency in the pandemic-related period.

Section 2 of this paper discusses the issue-related studies. Section 3 presents the research methodology applied in our study. Section 4 presents the results and discusses them. Section 5 summarizes the paper.

2. Literature Review

The issue of the impact of financial crisis on the weak-form informational efficiency of the markets has already gained much attention of researchers, who especially favored the global financial crisis 2008 and the crisis on the Asian stock markets in 1997–1998. The researchers utilized various methods in order to verify if the financial crisis significantly affected the market efficiency, delivering ambiguous results and conclusions.

Referring to studies dedicated to the influence of the global financial crisis of 2008 on the weak-form efficiency of stock markets, a negative effect was suggested, for instance, by Anagnostidis et al. (2016), Sensoy and Tabak (2015), Horta et al. (2014), as well as by Mensi et al. (2017). No significant impact of the global financial crisis of 2008 was suggested, for instance, by Katris and Daskalaki (2013) as well as by Singh, Deepak and Kumar (2015). Smith (2012), instead, proposed that the impact of the crisis on the stock market's informational efficiency was country-dependent. When it comes to studies focusing on the Polish stock market, Goczek and Kania-Morales (2015) proposed that the WSE turned out to be more efficient comparing to other major European markets, even in the crisis-related period when the WSE remained weak-form informationally efficient. What is more, a study conducted by Karasiński (2019) did not allow for stating that the global financial crisis of 2008 negatively affected the weak-form efficiency of the WSE.

Moving onto the studies on the impact of the aforementioned Asian stock markets crisis of 1997–1998 on the weak-form efficiency of stock markets, no significant impact of the crisis on the informational efficiency of the markets was proposed, for example, by Hoque, Kim and Pyun (2007) as well as by Kim and Shamsuddin (2006). Different conclusions were proposed by Kian-Ping et al. (2007) and Cheong et al. (2007), who suggested that the crisis had a negative effect on the informational efficiency of the markets.

Even though the COVID-19 pandemic is a relatively new and still ongoing issue, a number of papers addressing the informational efficiency of markets during the coronavirus pandemic have already appeared. For instance, Lalwani and Meshram (2020) ran some statistical tests for daily returns of Fama-French 12 industry portfolios in two windows, namely the pre-coronavirus period and the coronavirus period. The results obtained were not unambiguous for all industries. Nevertheless, many of them turned out to be less weak-form efficient after the coronavirus outbreak. Similar conclusions can be drawn on the basis of the results obtained by Dias, Teixeira, et al. (2020) and Dias, Heliodoro, et al. (2020), who examined major world stock market indices in terms of the impact of the COVID-19 outbreak on stock markets' weak-form efficiency. Again, the results were not unambiguous for all indi-

ces; however, the majority of stock markets turned out to be less weak-form efficient after the COVID-19 outbreak. More unambiguous results were obtained in the study by Ozkan (2021), who tested changes in the weak-form informational efficiency of stock market in selected well-developed countries. According to a study by Ozkan (2021), the coronavirus outbreak decreased the efficiency in the examined markets. Aslam et al. (2020) aimed to assess the impact of the coronavirus pandemic on the weak-form efficiency of eight European stock markets. The researchers examined intra-day data of stock indices at the early stage of the pandemic with the use of multifractal detrended fluctuation analysis and the Hurst exponents. According to the results obtained, the efficiency of the examined markets generally decreased due to the pandemic outbreak. However, the impact of the pandemic outbreak varied among the markets. The intra-day data of some stock indices were also examined by Aslam et al. (2022) in terms of the impact of the coronavirus pandemic on the weak-form efficiency. The researchers examined three Asian and three European major stock indices in 2020 using multifractal detrended fluctuation analysis and the Hurst exponents. General conclusions coming from this study were that the examined markets were negatively affected by the coronavirus pandemic. However, the impact was time-varying and market-dependent. According to Aslam et al. (2021), the weak-form efficiency of three Central Eastern European stock markets was also negatively affected by the coronavirus outbreak. The study employed similar methods as in Aslam et al. (2022) and Aslam et al. (2020). The results of the study on the intra-day data suggested that the coronavirus outbreak had a negative impact on the efficiency of the examined markets, especially in the first months of the pandemic. Then, the efficiency recovered. The sample also included WIG20, the index of the Warsaw Stock Exchange. Wang and Wang (2021) examined the impact of the coronavirus outbreak on the efficiency of S&P 500 Index, gold, Bitcoin, and US Dollar Index, using multiscale entropy-based method. The researchers proposed that the efficiency of all examined markets decreased significantly and persistently in February and March 2020. The S&P 500 Index suffered the most. The Bitcoin market appeared to be the most resilient. Okorie and Lin (2021) made an attempt to examine the adaptive market hypothesis in relation to the weak-form efficiency of the major indices in the USA, Brazil, India, and Russia. The results of the martingale difference and conditional heteroscedasticity tests indicated that generally, the efficiency of the US and Brazilian markets did not change substantially in the short, medium, and long term due to the coronavirus outbreak. The Indian market appeared to be negatively affected in the long term. On the other hand, the Russian market appeared to be more efficient. Ferreira and Morais (2022) examined the impact of the coronavirus outbreak on the weak-form efficiency of some developed green equity markets. According to the results of the multifractal analysis, the coronavirus outbreak decreased the efficiency of the examined indices of green equity markets. Voon and Peng (2021) compared the reaction of the weak-form efficiency of two cryptocurrencies (Bitcoin and Ethereum) and two stock market indices (S&P500 and CSI300) on the coronavirus outbreak. The researchers employed the Hurst exponent to daily data. According to the results obtained, the efficiency of both cryptocurrencies and stock markets declined after the coronavirus outbreak. However, the efficiency of cryptocurrencies suffered more. Dias et al. (2021) made an attempt to examine the impact of the COVID-19 pandemic on the weak-form efficiency of several European banking sector indices. The authors proposed that the efficiency of the examined sector indices was negatively affected by the COVID-19 outbreak. Santos et al. (2020) focused on the major indices of six stock exchanges from the LAC region. The researchers proposed that the coronavirus pandemic negatively affected the weak-form efficiency of the examined stock indices.

3. Methodology

Methodology applied in this study has been developed in order to achieve the research objective which consists in verification whether the COVID-19 outbreak negatively affected the weak-form informational efficiency of the Warsaw Stock Exchange (WSE). As opposed to

some studies investigating the impact of the COVID-19 outbreak on the informational efficiency of the markets (e.g. Mnif et al., 2020; Mensi et al., 2020; Aslam et al., 2020), we do not distinguish pre-pandemic and pandemic periods, but instead we apply a rolling window method, enabling to observe how the efficiency changed over time (Borowski, 2017, 2018). We utilize 2 different rolling windows, i.e., 2- and 4-month windows with 2-month rolling. We assume that a 2-month window is the shortest one which can deliver reliable results of the applied test.

We cover the period from January 2nd, 2015 to August 31st, 2020. In each window, we calculate the standard deviation, mean, median and we run a wild bootstrapped automatic variance ratio test (Choi, 1999; Kim, 2009; Charles et al., 2011) for daily logarithmic returns of the closing prices of 437 WSE companies, active as at October 7th, 2020. Such a long period preceding the coronavirus outbreak and not related to any major turmoil on financial markets will allow for observing if the results obtained in the coronavirus-related period actually differ much from the ones received in relatively calm times.

Calculations in each window for particular companies are performed if maximally 20% of daily returns are missing. We draw conclusions on the basis of the average descriptive statistics and the average percentage of the wild bootstrapped automatic variance ratio tests, in which the null hypothesis could not be rejected (our weak-form informational efficiency proxy), calculated for all of the companies in each window. Following one of sector classifications of companies proposed by the WSE, the results of this study are also grouped into 8 sectors.

We test the weak-form informational efficiency proposed by Fama (1970) and Jensen (1978) by verifying the martingale hypothesis stating that the stocks' returns constitute the martingale increments. To test the martingale hypothesis, we use a wild bootstrapped automatic variance ratio test (Choi, 1999; Kim, 2009; Charles et al., 2011), assuming the occurrence of the heteroscedasticity and the autocorrelation in stocks' returns. The assumption stating that stocks' returns constitute the martingale increments is much more general and better suited to stocks' returns stylized facts than more often tested strict assumption stating that returns of securities are i.i.d. with a 0 expected value, referring to the random walk model, first proposed by Bachelier in 1900 (Campbell et al., 1997; Linton 2019; Zamojska, 2012; Osińska, 2006; Witkowska, Matuszewska-Janica, & Kompa, 2012; Czekaj, 2014). The wild bootstrapped automatic variance ratio test was also used in such issue-related studies as the ones by Ozkan (2021) and Lalwani and Meshram (2020). According to Kim (2009), a wild bootstrapped automatic variance ratio test presents no size distortion in small samples and in comparison to its competitors such as the wild bootstrap Chow–Denning test and the Chen–Deo test, it has substantially higher power.

A family of the variance ratio tests is based on the property of a purely random process, in which the variance of k-period return is k times the variance of the one-period return. Thus, the variance ratio should be statistically indistinguishable from 1. Nevertheless, the k parameter is arbitrarily chosen with a little statistical justification by most variance ratio tests. This problem is solved by the automatic variance ratio test proposed by Choi (1999), in which the optimal value of k is determined by a completely data-dependent procedure. However, small sample properties of this test for the returns following an i.i.d. process and completely unknown properties under the conditional heteroscedasticity, were reported by Choi (1999). The small sample properties of the automatic variance ratio test disappear when the test is wild bootstrapped. When wild bootstrapped, the power of this test is even higher for small samples than that of its competitors like the power-transformed joint test of Chen and Deo (2006) or the wild bootstrap version of the Chow–Denning test (Chow & Denning, 1993; Kim, 2006; Kim, 2009; Charles et al., 2011).

We use a percentage of the wild bootstrapped automatic variance ratio tests, in which the martingale hypothesis cannot be rejected (at the $\alpha = 0.05$ significance level), as our proxy for the weak-form informational efficiency. Our calculations and tests have been run in R. In order to run the wild bootstrapped automatic variance ratio tests with 500 wild bootstrap iterations, using a standard normal distribution, we apply the AutoBoot.test function from the vrtest package. Stocks' prices have been down-

loaded from the Thomson Reuters Eikon database.

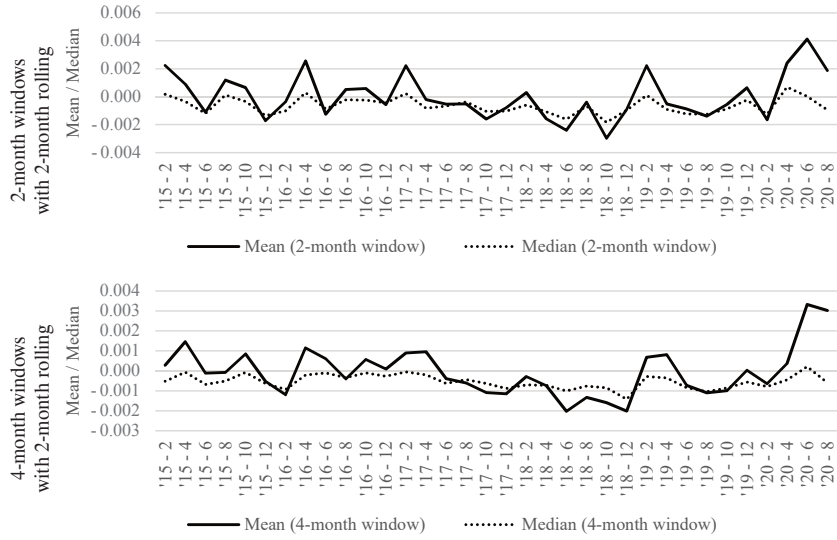
4. Results and Discussion

Figure 1 constitutes a set of line plots presenting the average descriptive statistics (arithmetic mean and median) calculated for daily returns of all companies from the WSE Main Market in each window. The results are presented at the end of the month in which a particular window ends. Referring to Figure 1, both rolling window types indicate that the first and the second quarter of 2020 had a substantial impact on the stocks' returns. The average returns dropped noticeably in the early stages of the pandemic outbreak; nevertheless, their decrease cannot be considered enormous. A lot more noticeable was a recovery of the WSE Main Market's returns in the following months. According to both rolling window types, the mean returns in the window ending in June 2020 were the greatest of all examined windows.

It is worth taking a look at the differences between the arithmetic mean and the median, which tended to get more significant in more volatile periods. The greatest differences between the aforementioned measures can be observed in the pandemic-related windows. The differences suggest that the returns distributions are highly asymmetrical and thus, testing their random walk under the assumption of i.i.d. and 0 expected value does not make any sense (Czekaj, 2014).

Figure 2 presents the average standard deviation of daily returns calculated for all companies as well as for separate sectors of the WSE Main Market. A similar presentation of results will be applied in Figure 3 referring to the wild bootstrapped automatic variance ratio tests. The results presented in Figure 2 suggest that early periods of the COVID-19 outbreak (mostly windows ending in February and April 2020) delivered a rapid increase of volatility, the highest one in the whole research period, in line with a study by Erdem (2020). Such evidence delivers grounds to suspect that an overreaction and a herd behavior could significantly contribute to rapid moves of stocks' prices. Nevertheless, in the following windows the volatility decreased. This pattern can be observed for the whole Main Market of the WSE and mostly for its all sectors.

Figure 1. A Set of Line Plots Presenting the Average Descriptive Statistics for Daily Returns (Arithmetic Mean and Median) Calculated for All Companies From the WSE Main Market in Each Window



Note. The results are presented at the end of the month in which a particular window ends.

Source: Author's own study.

Figure 2. A Set of Line Plots Presenting the Average Standard Deviation Calculated for Daily Returns of all Companies From the WSE Main Market in Each Window

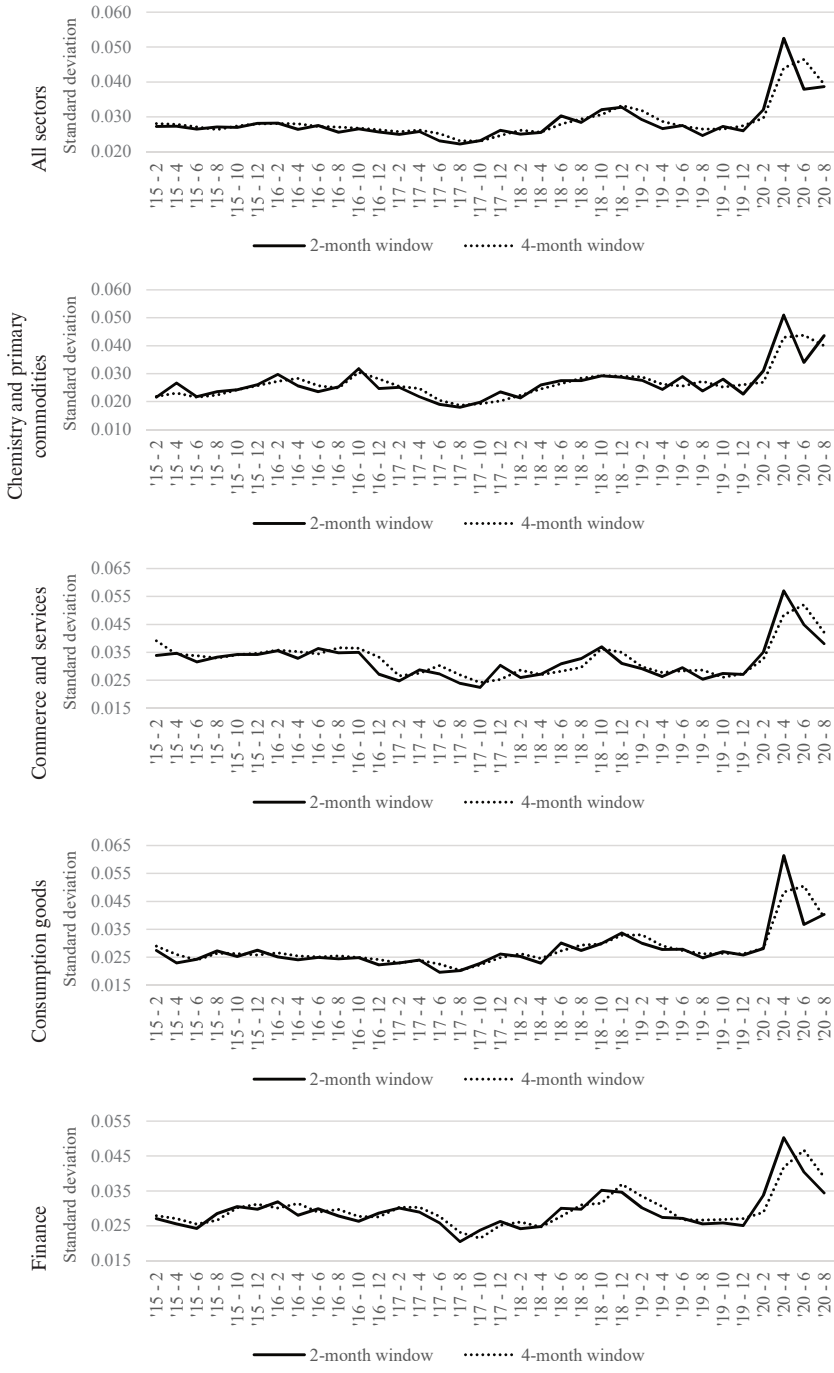
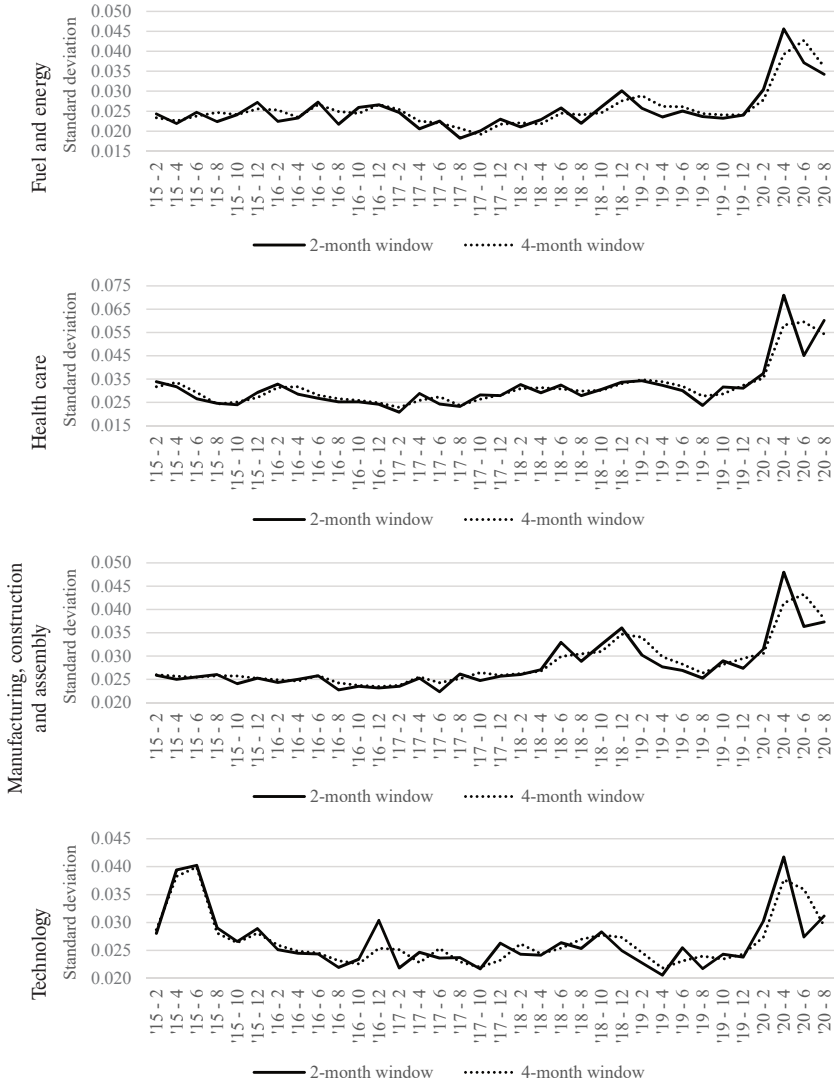


Figure 2 cont.



Note. The results are also presented for each sector separately. The results are presented at the end of the month in which a particular window ends.

Source: Author's own study.

Figure 3 presents results of the wild bootstrapped automatic variance ratio tests run for daily returns of companies from the Main Market of the WSE. The weak-form informational efficiency level is proxied by a percentage of the aforementioned tests, in which the null hypothesis could not be rejected. According to Figure 3, the efficiency levels shape differently across the examined samples. Unambiguous cases (suggested by both rolling window types) of the efficiency decrease in the coronavirus-related periods can be observed in the case of 4 samples, namely chemistry and primary commodities sector, consumption goods sector, fuel and energy sector, as well as health care sector. In chemistry and primary commodities sector, consumption goods sector, as well as fuel and energy sector, the efficiency fell moderately

in early stages of the pandemic outbreak and then recovered. When it comes to the whole research sample, commerce and services sector, as well as technology sector, only one rolling window type suggested that a decrease of efficiency took place in the coronavirus-related periods. The aforementioned decrease of efficiency was indicated by the 4-month rolling windows and it was rather moderate. According to 2-month rolling windows, the efficiency fell in the windows preceding the coronavirus outbreak. In the case of finance sector, as well as manufacturing, construction and assembly sector, a decrease of efficiency was observed in the windows prior to the coronavirus outbreak. In the periods related to COVID-19, their efficiency recovered instead.

The majority of papers devoted to the impact of various crises on the market efficiency, mentioned in the literature review

Figure 3. A Set of Line Plots Presenting the Average Percentage of the Wild Bootstrapped Automatic Variance Ratio Tests in Which the Null Hypothesis Could not be Rejected (Our Weak-Form Informational Efficiency Proxy)

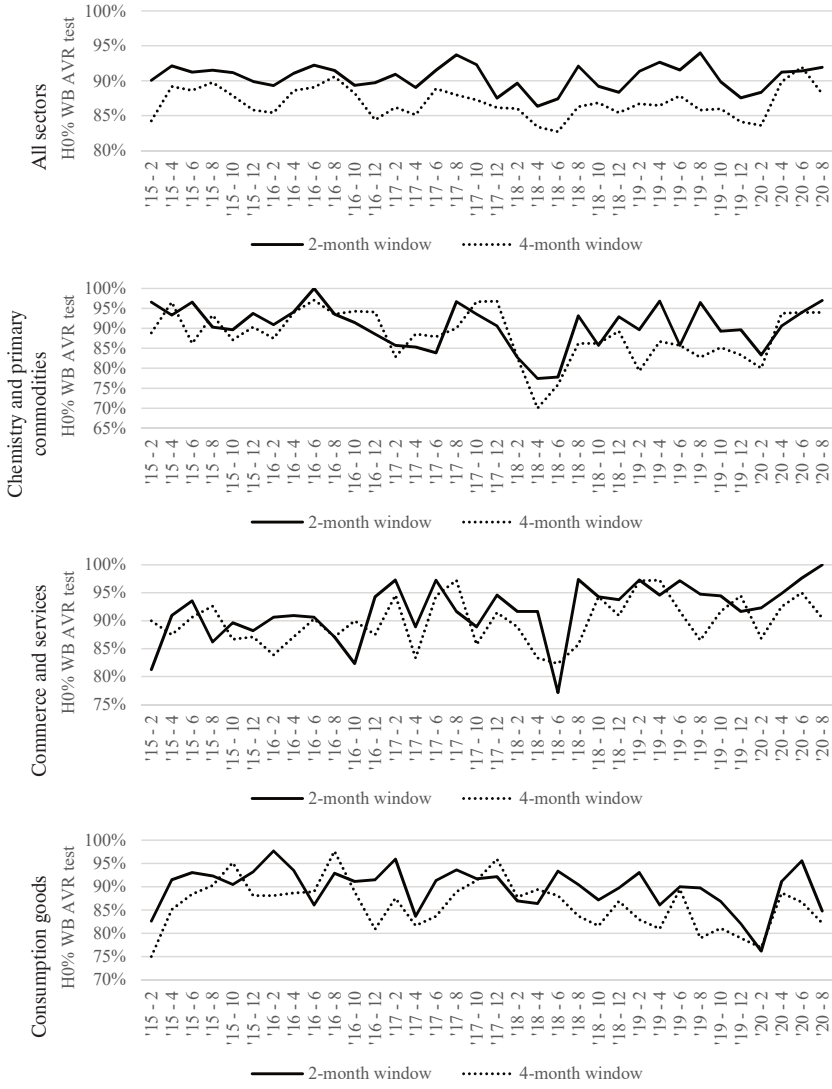
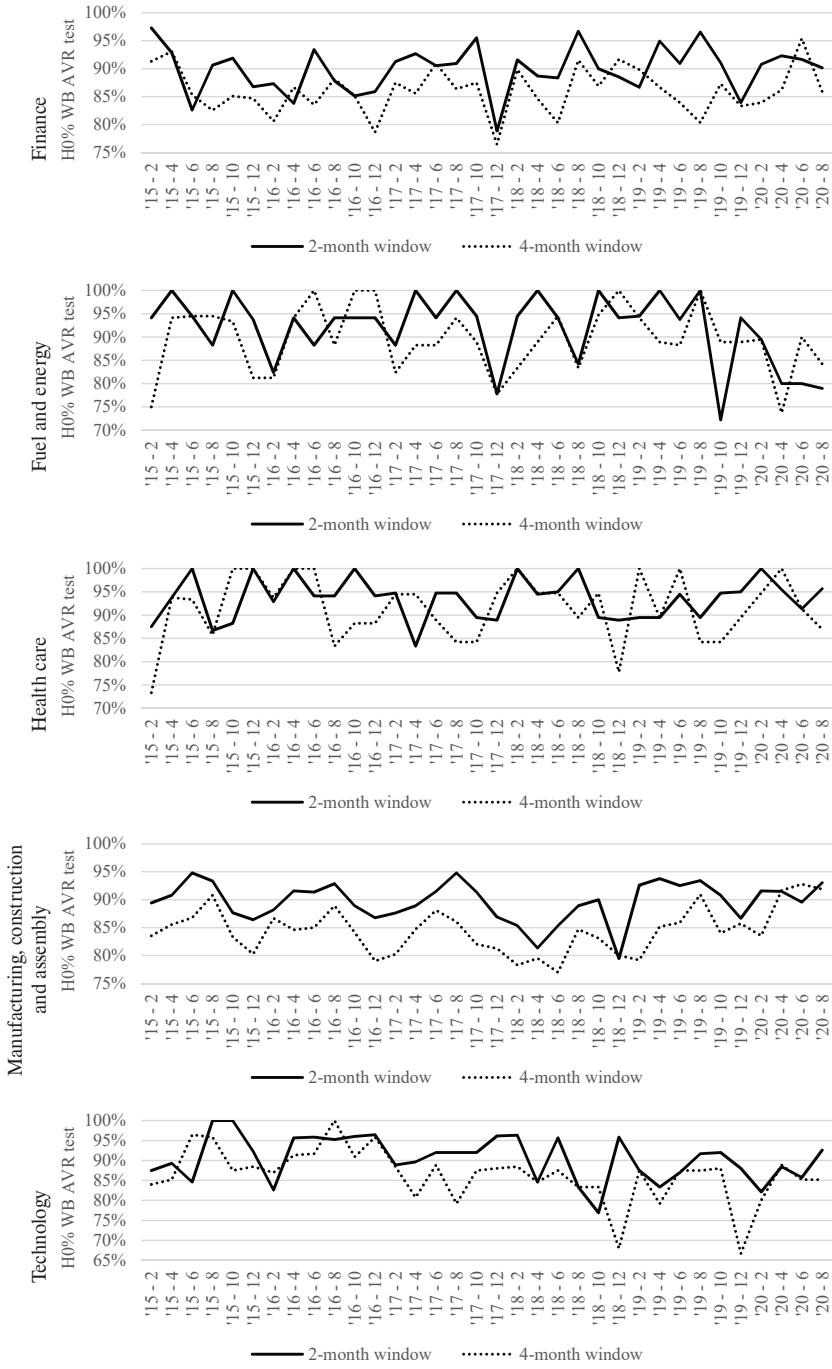


Figure 3 cont.



Note. The results are also presented for each sector separately. Results are presented at the end of the month in which a particular window ends.

Source: Author's own study.

section, suggested a negative influence of such unprecedented events on the market efficiency (e.g. Anagnostidis et al., 2016; Sensoy & Tabak, 2015; Horta et al., 2014; Mensi et al., 2017; Kian-Ping et al., 2007; Cheong et al., 2007, Dias, Teixeira, et al., 2020; Dias, Heliodoro, et al., 2020; Ozkan, 2021; Lalwani, & Meshram, 2020). Nevertheless, the results of our study do not unambiguously suggest that the coronavirus outbreak had a negative impact on the efficiency of the Main Market of the WSE. The results of this study turned out to be sector-dependent. In just 4 out of 8 examined WSE sectors, a moderate decrease of efficiency could be clearly observed in the periods related to the coronavirus outbreak. In other examined samples, the efficiency decreased in earlier windows or the results were ambiguous, namely one rolling window type indicated a decrease of efficiency in the coronavirus-related periods and the second rolling window type indicated a decrease of efficiency in the periods prior to the COVID-19 outbreak. What is more, in the majority of examined samples, the declines of efficiency (whether they happened in late 2019 or in 2020) were not spectacular and were followed by a relatively quick recovery. Some similarities to the results of this study can be seen in the studies by Dias, Teixeira, et al. (2020), Dias, Heliodoro, et al. (2020), as well as by Lalwani and Meshram (2020), in which some stock market indices and sectors (however, they were in a minority) turned out to be immune to the coronavirus-related turmoil. According to Okorie and Lin (2021), who also employed the MDS tests, the major US and Brazilian stock market indices were also resilient to the coronavirus pandemic. However, the results obtained in this study are not in line with the results of the studies by Ozkan (2021), Aslam et al. (2020), Aslam et al. (2022), Aslam et al. (2021), Wang and Wang (2021), Ferreira and Morais (2022), Voon and Peng (2021), Dias et al. (2021), and Santos et al. (2020). According to these studies, the coronavirus outbreak unambiguously negatively affected the weak-form efficiency of examined markets.

5. Conclusions

Despite the rapid and significant market prices movements, the rise of returns volatility, and thus a likely overreaction and herd behavior of the market participants, the results obtained in this study do not allow for stating unambiguously that the COVID-19 outbreak negatively affected the weak-form informational efficiency of the WSE. The results turned out to be sector-dependent. In just 4 out of 8 sectors, the efficiency decreased in the coronavirus-related periods according to both applied rolling window types. What is more, in the majority of examined samples, the declines of efficiency (whether they happened in late 2019 or in 2020) were not spectacular and were followed by a relatively quick recovery. We assume that this phenomenon could be caused by the market immunity increased due to conclusions drawn by regulators and other market participants from the past unprecedented shocks like the 2008 global financial crisis. In order to confirm this assumption, we suggest conducting an analogical study for the period covering the 2008 global financial crisis. What is more, the coronavirus pandemic constitutes a still ongoing issue; thus, repetition of this study after the end of the pandemic would bring a general view on behavior of the weak-form efficiency of the WSE during the whole pandemic period.

This study comes up with a novel approach to approximating the weak-form informational market efficiency (although it applies just one statistical test), provides the regulators and other market participants with the information on the WSE efficiency changes, and even long-term trends, and according to our knowledge, this paper is the first one raising an issue of the coronavirus outbreak's impact on the WSE efficiency. We encourage other authors to come up with their own ideas to approximating stock market efficiency levels and to continue on studying the impact of the COVID-19 outbreak, and other unprecedented shocks, on the weak-form efficiency of the WSE and other markets, as the pandemic situation is constantly changing.

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