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Changing Weak-Form Informational Efficiency: A Study on the World's Stock Markets

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Abstract

Purpose: The aim of this study is to answer the question whether weak-form informational efficiency of the world's stock markets tended to change over a long term.
Methodology: A proxy of weak-form informational efficiency applied in the study is based on Bachelier's random walk model. The research hypothesis states that over a long term weak-form informational efficiency of the world's stock markets, proxied by a percentage of the null hypotheses which could not be rejected in the normality tests of the indexes returns, tended to improve. The research sample includes 77 all-share indexes from all over the world and the analysed time-series of their returns cover the period from 02/01/2013 to 28/02/2020.
Findings: The conducted study allows for rejecting the stated research hypothesis as the changes of the efficiency turned out to be region-dependent. A long-term trend of the efficiency measure, calculated for all the indexes together, was flat, with a zero slope and the volatility of this measure was low. Hence, it suggests that when taking into account all the indexes examined, on a long-term basis, the world's stock markets' weak-form informational efficiency did not display neither any downward nor upward tendency.
Research limitations: Future issue-related research can test weak-form informational efficiency under less strict conditions than these proposed by Bachelier.
Value: As opposed to many other studies, which usually try to answer the question if the markets are efficient or not, this paper focuses its attention on the changes in efficiency over the years.

Keywords: efficient market hypothesis, weak-form efficiency, stock markets, random walk.

JEL G10, G12, G14

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Zmieniająca się efektywność informacyjna w formie słabej: badanie na światowych rynkach akcji

Streszczenie

Cel: celem badania jest odpowiedź na pytanie, czy efektywności informacyjna światowych rynków akcji w formie słabej podlegała zmianom w długim okresie.

Metodologia: miara efektywności informacyjnej w formie słabej zastosowana w badaniu oparta jest na modelu błądzenia losowego, zaproponowanym przez Bacheliera. Postawiona hipoteza badawcza mówi, że w długim okresie efektywność informacyjna w formie słabej, estymowana odsetkiem hipotez zerowych, które nie zostały odrzucone w testach normalności stóp zwrotu indeksów, wykazuje się tendencją wzrostową. Próba badawcza skupia 77 indeksów giełdowych szerokiego rynku z całego świata, a zbadane szeregi czasowe ich stóp zwrotu pochodzą z okresu od 2 stycznia 2013 r. do 28 lutego 2020 roku.

Wyniki: przeprowadzone badanie pozwala na odrzucenie postawionej hipotezy badawczej, ponieważ zmiany efektywności okazały się być zależne od badanego regionu. Długoterminowy trend kształtowania się miary efektywności, obliczonej dla wszystkich indeksów, był płaski, z zerowych nachyleniem, a zmienność tej miary była niska. W związku z powyższym, biorąc pod uwagę wszystkie badane indeksy, w długim okresie efektywność informacyjna w formie słabej nie wykazywała tendencji spadkowej czy wzrostowej.

Ograniczenia badawcze: przyszłe badania związane z poruszanym problemem mogą testować słabą formę efektywności informacyjnej z wykorzystaniem mniej restrykcyjnych warunków niż te proponowane przez Bacheliera.

Wartość: w przeciwieństwie do innych badań, które zwykle próbują odpowiedzieć na pytanie, czy rynki są efektywne, czy też nie, ten artykuł zwraca uwagę na zmiany efektywności na przestrzeni lat.

Słowa kluczowe: hipoteza rynku efektywnego, efektywność w formie słabej, rynki akcji, błądzenie losowe.

1. Introduction

Studies devoted to verification of the efficient market hypothesis (HFT), especially in a weak form, are incessantly willingly conducted. The science has developed many tools which can be used to examine informational efficiency. Moreover, markets constantly change, the same as the factors which affect the market efficiency (Lim & Brooks, 2011). These are some of the main reasons for taking up replication studies devoted to the issue of informational efficiency so often. Nevertheless, just a small percentage of these studies addresses the issue of informational efficiency changes. The majority of studies aims for answering the question whether the markets are efficient or not, without trying to check how efficiency changes over time. This knowledge would be helpful for instance to investors who would like to get to know how their chances to forecast the prices and gain abnormal returns change. The knowledge on the changes of market efficiency would be also helpful to policymakers who would like to know if their actions influenced efficiency positively as efficiency protects markets from external shocks and increases confidence of investors towards markets (Mensi, Tiwari, & Al-Yahyaee, 2019).

The purpose of this study is to answer the question whether weak-form informational efficiency of the world's stock markets tended to change over a long term. A proxy of weak-form informational efficiency applied in the study is based on Bachelier's random walk model, still treated by many researchers as a synonym of weak-form informational market efficiency (Czekaj, 2014). The research hypothesis states that over a long term weak-form informational efficiency of the world's stock markets, proxied by a percentage of the null hypotheses which could not be rejected in the normality tests of the indexes returns, tended to improve. Formalisation of the information transmission mechanisms, gradually implemented by policymakers, should improve transparency and safety of trading, as well as common and equal access to information (Dziawgo, 2011). Also algorithmic trading, which contributes to the majority of trades on the world's markets (and its share still increases), improves informational efficiency (Boehmer, Fong, & Wu, 2012). In order to verify whether the returns on the examined stock market indexes were a subject of the random walk, 3 different normality tests in 30, 60, 100 and 252-session rolling windows were performed for daily logarithmic returns, namely the Jarque-Barre test, the D'Agostino-Pearson test and the Expanded Shapiro-Wilk test. The research sample includes 77 all-share indexes from all over the world and the analysed time-series of their returns cover the period from 02/01/2013 to 28/02/2020.

The second section of this paper is devoted to a review of the literature pertaining to the changes of informational efficiency observed on stock markets. The third section describes the research methodology and sample. In the fourth section, the results of the study are presented. The last, fifth section summarises the paper.

2. Literature Review

Conducted studies which address the issue of changing informational weak-form efficiency deliver mixed conclusions. Arshad, Rizvi, Ghani and Duasa (2016) in the study on 11 stock markets of the Organization of the Islamic Conference, covering the period of 1998–2012, proposed that despite the varying efficiency across countries and years, the overall trend of efficiency over the years was positive. A study by Smith and Dyakova (2014) on 8 selected African stock markets brought mixed results. The researchers applied variance ratio tests and covered the period from February 1998 to December 2011. Abdmoulah (2010) found no evidence for any significant improvement of market informational efficiency. His study applied the GARCH-M (1 ,1) approach and was conducted on 11 Arab stock markets in a 10-year research period ending in March 2009. Neither did Jefferis and Smith (2004) observe any trend towards the efficiency. Their study was conducted on the Johannesburg Stock Exchange and applied the variance

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ratio tests, as well as the tests of evolving efficiency using the GARCH approach with time-varying parameters. Jefferis and Smith (2005) examined selected 7 African stock markets and proposed that the changes of efficiency were country-dependent. In the study on the Indian stock market, Samanta (2004) proposed that efficiency fluctuated from sub-period to sub-period. The study was conducted on the BSE-100 index, applied the spectral shape tests and covered the period of 1993–2001. Moving on to the studies devoted to the European markets, a study by Borges (2010), conducted on 6 selected European stock markets, covering the period of 1993–2007, also delivered diverse results. The author suggested that the changes were country- and period-dependent. The study tested efficiency with the runs test and the joint variance ratio tests, performed for daily and weekly data.

Informational efficiency has many factors and can change due to many reasons. One of the phenomena which can significantly affect the informational efficiency, and which has been well studied in the academic literature, is a financial crisis. According to Anagnostidis, Varsakelis and Emmanouilides (2016), the 2008 global financial crisis negatively affected weak-form efficiency of 12 selected stock markets of the Eurozone. Similar conclusions were drawn by Sensoy and Tabak (2015), who proposed that the 2008 global financial crisis negatively affected most of the European stock market indexes.

3. Research Methodology and Sample

The proposed research hypothesis states that over a long term weak-form informational efficiency of the world's markets tended to improve. Weak-form informational efficiency of the world's markets, for the needs of this study, is proxied by a percentage of the null hypotheses which could not be rejected in the normality tests of the indexes returns distributions. According to the research hypothesis proposed, it is expected that, over a long term, an increasing percentage of the null hypotheses which could not be rejected will be observed. The proxy of weak-form informational efficiency applied in the study is based on Bachelier's random walk model from 1900, still treated by many researchers as a synonym of weak-form informational market efficiency proposed by Fama (1970) and Jensen (1978). The random walk model proposed by Bachelier describes a non-stationary, stochastic process according to which short-term returns fluctuations are random by nature and any deviations from the equilibrium price are limited and unpredictable. Even though the random walk model of Bachelier is still willingly applied in research, it seems to be too strict as the distributions of the financial assets returns are usually fat-tailed and attribute more probability to losses (Czekaj, 2014). Weak-form informational efficiency is also commonly tested with the unit-root tests. Nevertheless, they only check whether returns are stationary or not. Due to their low explanatory

power, it was decided to apply the normality tests only and focus on the stochastic analysis of the returns generating processes.

In order to verify whether the returns on the examined stock market indexes were a subject of the random walk, 3 different normality tests were performed, namely the Jarque-Barre test, the D'Agostino-Pearson test and the Expanded Shapiro-Wilk test. Each test states the same null hypothesis saying that the empirical returns distribution is normal. The null hypothesis is rejected in favour of the alternative one, saying that the empirical returns distribution in not normal when the p-value is less than $\alpha = 0.05$, referring to a significance level (Borowski, 2017). Each normality test was run for daily logarithmic returns on the indexes qualified to the study, in 30, 60, 100 and 252-session rolling windows. The assumption made, pertaining to this part of the study, stated that the test was run for a particular window only if more than 80% of the returns in the window were available (some time-series downloaded from the Thomson Reuters Eikon database had missing data). The rolling window methodology applied in this study is based on the approach used by Borowski (2017, 2018), consisting in running a test for a K-session window, of which the first session is on day t_0 and the last session is on day t_{0+K}. The test returns p-value p_1. The next test is run for a K-session window, of which the first session is on day t_{0+1} and the last session is on day t_{0+K+n}. The test returns p-value p_2. This methodology is illustrated in Figure 1. The next assumption states that when for a given stock market index, less than 90% of the normality tests can be run (due to missing data), such an index is rejected from the research sample.

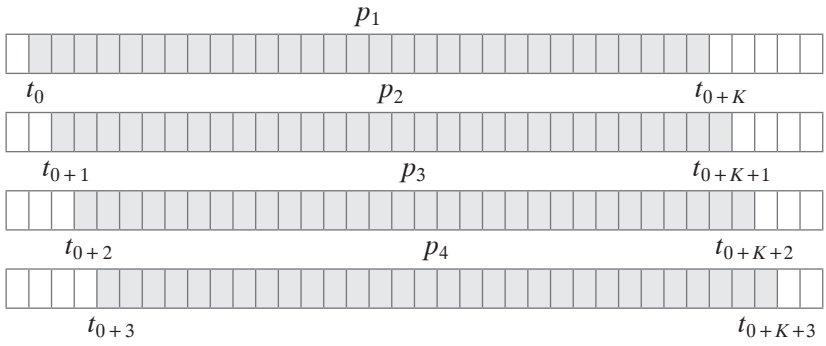

Fig. 1. The rolling window methodology applied for the indexes returns normality tests. Source: Author's own elaboration based on Borowski (2017, 2018).

All data collected for the purpose of this study were downloaded from the Thomson Reuters Eikon database. Calculations were done using The Real Statistics Resource Pack, a Microsoft Excel add-in. The normality tests were run in the period from 02/01/2013 to 28/02/2020. On 02/01/2013

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every test had its first session (t_0) and on 28/02/2020 every test had its last session t_{0+K+n} in the rolling window.

This study takes into account only world's all-share indexes as they include information about the prices of all stocks listed on a given market. Selection of the all-share indexes qualified to this study began with searching for the phrase "all-share" in the names of the equity indexes included in the Thomson Reuters Eikon database. Then, a careful analysis of each index name was conducted in order to select indexes which included all stocks from a particular market. Sometimes, constituents of an equity index with the phrase "all-share" in its name came from a single sector. Such indexes were rejected from the sample. Another assumption pertaining to the indexes qualified to the study stated that they had to be listed daily in the period from 02/01/2013 to 28/02/2020. Choosing an earlier start date would have extended the research period but it would also have significantly decreased the size of the research sample. After applying all the above-mentioned assumptions, the final research sample consisted of 77 all-share indexes available in the Thomson Reuters Eikon database. Taking into account the world region of the market to which a given index pertains, the selected indexes were divided into groups according to the United Nations (UN) geo-scheme. The count of the particular groups is presented in the Table 1.

UN region	Count
Western Europe	13
Eastern Europe	1
Northern Europe	14
Southern Europe	3
Northern America	3
South America	1
Caribbean	1
Eastern Asia	14
Southern Asia	2
South-eastern Asia	10
Australia and New Zealand	3
Western Africa	1
Eastern Africa	3
Northern Africa	1
Southern Africa	7
Total	77

Tab. 1. Count of the groups into which the all-share indexes were divided taking into account the world region of the market to which a given index pertains. The selected indexes were divided into groups according to the United Nations (UN) geo-scheme. Source: Author's own study.

Groups distinguished on the basis of the UN geo-scheme were connected in order to decrease the number of groups and increase clarity of the results presented. The final grouping used for the results presentation is presented in the Table 2.

Region	Count
Europe	31
Northern America	3
Latin America	2
Asia	26
Australia and New Zealand	3
Africa	12
Total	77

Tab. 2. The final grouping of the all-share indexes used for presentation of the results. Source: Author's own study.

4. Results

In this section, the results of the normality tests of the all-share indexes returns are presented in the form of time-series figures. In the case of the Figures 2, 3 and 4, the percentage of the null hypotheses which could not be rejected in the normality tests, in a particular half-year, is presented on the Y-axis. The X-axis indicates a particular half-year. The curves refer to the results of all indexes together or to a particular region according to the grouping presented above in Table 2. Systematisation of the results in the case of Figures 5, 6 and 7 is the same; however, they pertain to whole years, showing the percentage of the null hypotheses which could not be rejected in the normality tests in a particular year. Each half-year/year includes the result of the test of which the first session (t_0) is in a given half-year/year. As at the moment of collecting data, the first half-year of 2020 was not finished, the last presented half-year is the second half-year of 2019. The analysis of the results for the half-years and years separately will provide an answer to the question if the analysis of the results for different time-frames allows for drawing the same conclusions. Descriptive statistics and parameters of the time-series linear regression pertaining to the data presented in Figures 2, 3 and 5 are shown in Table 3. Descriptive statistics and parameters of the time-series linear regression pertaining to the data presented in Figures 6, 7 and 8 are shown in Table 4.

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Figure 2 shows the average percentage of cases in which there were no grounds to reject the null hypothesis in the indexes returns normality test in particular half-years of the research period, taking into account the whole research sample. In other words, the curve presents the results for all 77 all-share indexes together in each half-year. According to the research hypothesis proposed, it is expected that, over a long term, an increasing percentage of the null hypotheses which could not be rejected will be observed. If the research hypothesis was true, a trend of the curve presented in Figure 2 would have a positive slope.

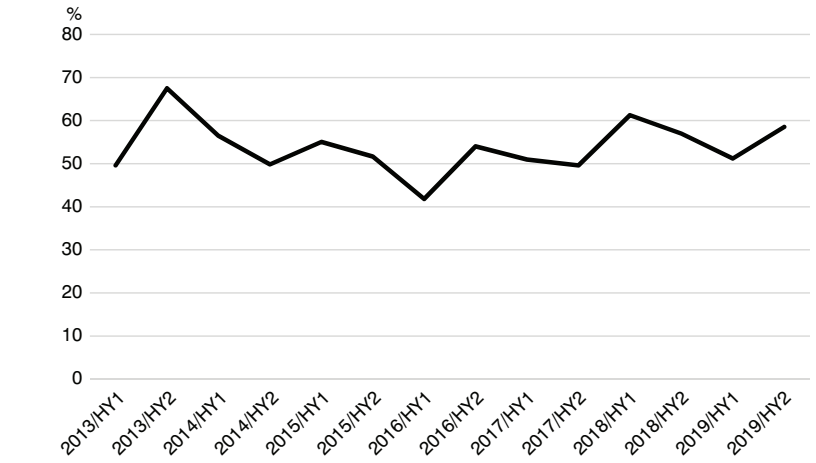

Fig. 2. The average percentage of cases in which there were no grounds to reject the null hypothesis in the indexes returns normality test in particular half-years of the research period, taking into account the whole research sample. Source: Author's own study.

The actual trend of the curve presented in Figure 2 is difficult to determine. Estimation of one-factor linear regression suggests that the slope of the trend equals zero. Nevertheless, a zero R-square and highly insignificant p-value indicate that the model does not explain well the empirical data. The parameters of this model can be found in the last column of Table 3. Even though the parameters suggest that the model is insignificant, looking at the data, it seems that over a long term efficiency calculated taking account all the indexes did not change. Also the volatility of weak-form efficiency proxies was low.

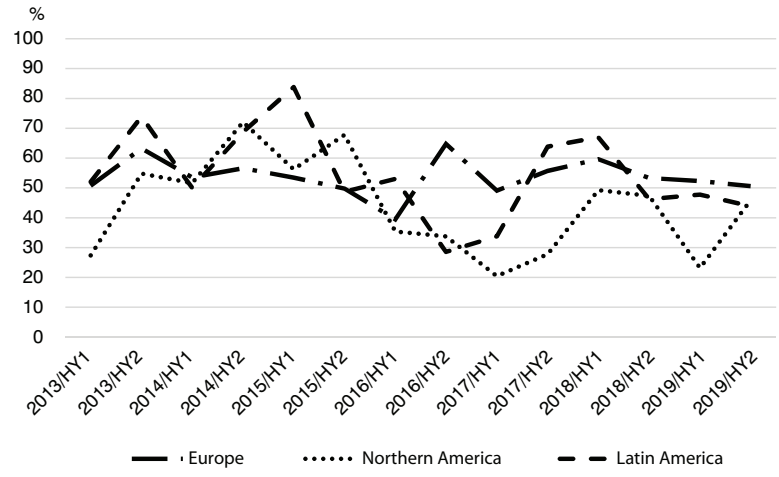

Fig. 3. The average percentage of cases in which there were no grounds to reject the null hypothesis in the indexes returns normality test in particular half-years of the research period, presented for Europe, North America and Latin America. Source: Author's own study.

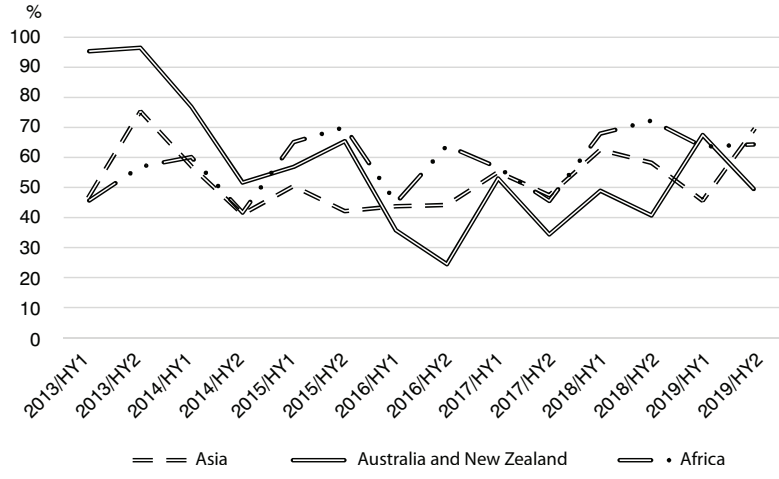

Fig. 4. The average percentage of cases in which there were no grounds to reject the null hypothesis in the indexes returns normality test in particular half-years of the research period, presented for Asia, Australia and New Zealand and for Africa. Source: Author's own study.

Looking at the data pertaining to particular regions, it is also not easy to determine long-term changes in weak-form efficiency. Data for Europe, Asia and Africa are the least volatile. Parameters of the linear regression

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suggest that efficiency of the markets in Europe and Asia did not change, in Africa efficiency increased and in the other regions efficiency decreased. Nevertheless, none of the models was significant at the significance level of $\alpha = 0.05$. It is probably caused by a low number of observations. Mostly the average values of the weak-form efficiency proxy vary from 0.53 to 0.58 and are close to the average value calculated taking into account all indexes. Just like in the case of Northern America, the average value is relatively lower and equals 0.44. In the case of Northern America and Australia and New Zealand, the results are the most volatile. Australia and New Zealand have the most visible downward trend confirmed with a relatively low p-value and high R-square.

Region / Statistics	Europe	Northern America	Latin America	Asia	Australia and New Zealand	Africa	All regions
Average	0.54	0.44	0.54	0.53	0.57	0.58	0.54
Minimum	0.39	0.20	0.29	0.41	0.25	0.42	0.42
Maximum	0.65	0.72	0.84	0.75	0.97	0.72	0.68
Stand. deviation	0.06	0.16	0.15	0.11	0.22	0.10	0.06
Variation coeff.	0.12	0.37	0.28	0.20	0.38	0.17	0.11
R-square	0.01	0.11	0.13	0.02	0.37	0.19	0.00
Slope	0.00	-0.01	-0.01	0.00	-0.03	0.01	0.00
Intercept	0.55	0.54	0.64	0.50	0.80	0.50	0.54
P-value	0.56	0.05	0.14	0.84	0.09	0.26	0.76

Tab. 3. Statistics pertaining to the time-series of the average percentage of cases in which there were no grounds to reject the null hypothesis in the indexes returns normality test in particular half-years of the research period, for each region and all indexes. The curves referring to the above-mentioned time-series are presented in Figures 2, 3 and 4. Source: Author's own study.

In the case of the time-frames with yearly intervals, the average result for data taking into account all indexes did not change at all. The shape of the curve as well as a zero slope of its trend suggest that over a long term average weak-form informational efficiency, calculated for all markets, did not change. At the level of particular regions, the trends became more visible. If the slope in the linear regression did not equal zero, it increased. In the case of the yearly intervals for Australia and New Zealand, it is easy to notice a downward long-term trend in years 2013–2016 and an

upward long-term trend in the following years. As in the case of the half-year intervals, the average results of most regions fluctuated around the average result calculated for all indexes together. Again, just in the case of Northern America, the average value is relatively lower and equals 0.44. In the case of Northern America and Australia and New Zealand, the results are the most volatile.

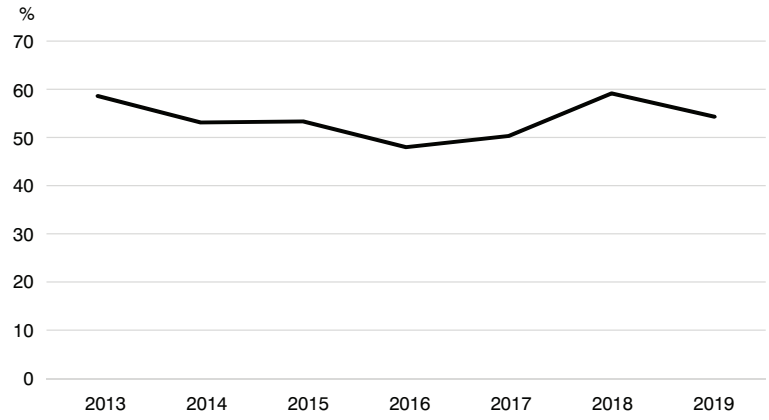

Fig. 5. The average percentage of cases in which there were no grounds to reject the null hypothesis in the indexes returns normality test in particular years of the research period, taking into account the whole research sample. Source: Author's own study.

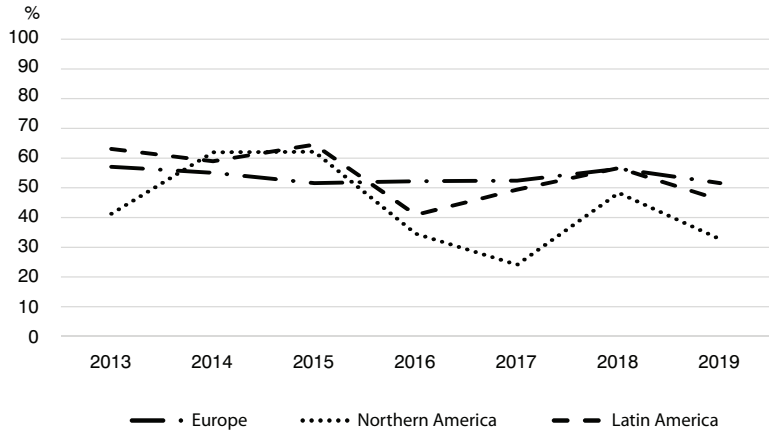

Fig. 6. The average percentage of cases in which there were no grounds to reject the null hypothesis in the indexes returns normality test in particular years of the research period, presented for Europe, North America and Latin America. Source: Author's own study.

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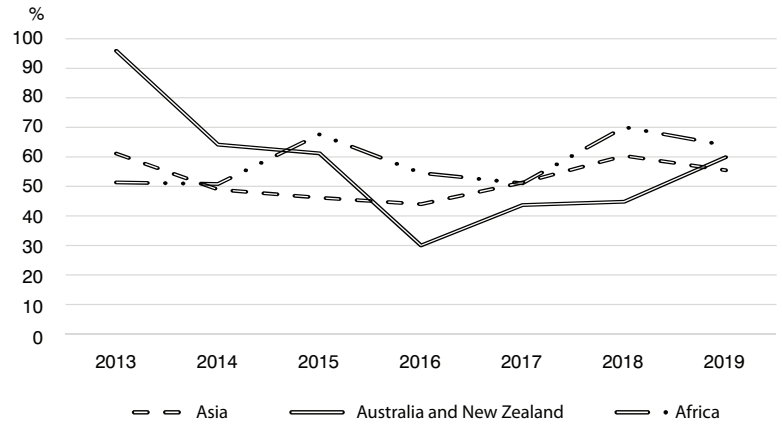

Fig. 7. The average percentage of cases in which there were no grounds to reject the null hypothesis in the indexes returns normality test in particular years of the research period, presented for Asia, Australia and New Zealand and for Africa. Source: Author's own study.

Region / Statistics	Europe	Northern America	Latin America	Asia	Australia and New Zealand	Africa	All regions
Average	0.54	0.44	0.54	0.53	0.57	0.59	0.54
Minimum	0.52	0.24	0.41	0.44	0.30	0.51	0.48
Maximum	0.57	0.62	0.65	0.61	0.96	0.70	0.59
Stand. deviation	0.02	0.15	0.09	0.07	0.21	0.08	0.04
Variation coeff.	0.04	0.34	0.17	0.13	0.37	0.14	0.08
R-square	0.17	0.23	0.38	0.02	0.36	0.30	0.01
Slope	0.00	-0.03	-0.03	0.00	-0.06	0.02	0.00
Intercept	0.56	0.57	0.64	0.51	0.81	0.50	0.54
P-value	0.90	0.15	0.33	0.10	0.66	0.39	0.48

Tab. 4. Statistics pertaining to the time-series of the average percentage of cases in which there were no grounds to reject the null hypothesis in the indexes returns normality test in particular years of the research period, for each region and all indexes. The curves referring to the above-mentioned time-series are presented in Figures 5, 6 and 7. Source: Author's own study.

The results of the study suggest that the research hypothesis should be rejected. In the case of both intervals, a long-term trend of the results calculated taking into account all indexes was flat, with a zero slope of linear regression. At the level of particular regions, for both intervals, a long-term trend seemed to be flat also for Europe and Asia. A long-term positively pitched trend occurred only in the case of Africa and Australia and New Zealand from the year 2016. In the case of the other regions, weak-form efficiency seemed to decrease.

5. Conclusions

The proposed research hypothesis stated that over a long term weak-form informational efficiency of the world's markets tended to improve. The results of the conducted study indicate that the research hypothesis should be rejected as only in the case of Africa and Australia and New Zealand from the year 2016 did weak-form informational efficiency tend to increase. The analysis of the results at the level of particular regions suggests that the trend of efficiency changes is region-dependent. When taking into account all the indexes examined, on a long-term basis, the world's stock markets' weak-form informational efficiency did not display neither any downward nor upward tendency.

As opposed to many other studies, which usually try to answer the question if the markets are efficient or not, this paper focuses its attention on the changes in efficiency over the years. This approach together with the application of the rolling window sub-periods, and taking into account such a broad sample of the world's all-share indexes, constitutes the most unique feature of this research.

This paper also aims for encouraging other researchers to engage more in conducting studies on the changes of efficiency which have more cognitive and practical value than studies focused only on answering the question if the markets are efficient or not.

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