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TESTING MARKET EFFICIENCY: EMPIRICAL INVESTIGATION OF POLISH CAPITAL MARKET

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ABSTRACT

The aim of the work is to verify the hypothesis of a weak form of efficiency of the Polish capital market using the autocorrelation test, series and variance ratio test. The research was conducted for the entire market representing the Warsaw Stock Exchange (using the WIG index covering all companies listed on the Main Market of the Warsaw Stock Exchange) and selected sector sub-indices of the WIG index calculated by the stock exchange. The analyzes were based on the daily logarithmic rates of return for data from the 2010-2016 period, which was divided into three sub-periods. The results indicate a weak form of market efficiency and cases of inefficiencies in its sectors.

Keywords: Weak form of efficiency; Autocreation test; Series test; Variance ratio test

1. INTRODUCTION

The efficient markets theory was formulated in the sixties of the twentieth century by a group of scientists gathered around Fama (1965). The pioneer in this field was Bachelier (1900), who proposed a model using a random process for price modeling. Further works in this field were conducted, among others, by Cowles (1933), Kendall (1953), Roberts (1959) and Samuelson (1965). However, Eugene Fama is considered the creator of the Efficient Market Theory. In his doctoral dissertation from 1964 he formulated the hypothesis of Effective Markets (EMH - Efficient Market Hypothesis).

Contemporary understanding of market information efficiency based is on the definition of Fama from 1970. According to him, an effective market is a market where prices always 'fully reflect' the available information (Fama 1970). Thus, the information coming from the market, publicly available or confidential, is immediately discounted in the price of assets. In such a market, it is not possible to achieve above-average rates of return, i.e. there are no fundamental or technical methods to build a 'market-winning' wallet.

When formulating the theory of efficient markets (called Efficient Market Hypothesis), Fama (1970) gave three conditions sufficient for the market to be called effective: lack of transaction

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costs and taxes, general availability of information for each market participant, the same way of assessing the impact of new information on the share price.

Fama also disseminated three forms of information efficiency of the capital market: weak, medium and strong form of effectiveness. The market is effective in a weak form, if current prices reflect all information contained in historical prices (Fama, 1970). The average form of market efficiency means that asset prices should also reflect all other publicly available information. The market is effective in a strong form if prices apart from historical and public records also reflect publicly unavailable and confidential information. With the weak form of market efficiency, the question is posed as to how much historical rates of return allow forecasting future rates of return, assuming the randomness of price changes. To verify the hypothesis about weak market efficiency, statistical tests to check whether prices are subject to the random walk process (autocorrelation tests, series tests, variance ratio test, calendar effects).

There are many studies in the world literature on the effectiveness of the capital market. The works of Bachelier, the Cowles and Samuelson Commissions, up to the latest from the late twentieth and early twenty-first century, can be mentioned here. Initial studies of the weak form of information efficiency focused on autocorrelation and series tests (Fama, 1965), and later they investigated efficiency using the variance ratio test (Lo & MacKinlay, 1988; Cochrane, 1988). Another way of testing a weak form is to check the effectiveness of strategies based on technical analysis (Alexander, 1964; Fama & Blume, 1966; Najmudin et al., 2017).

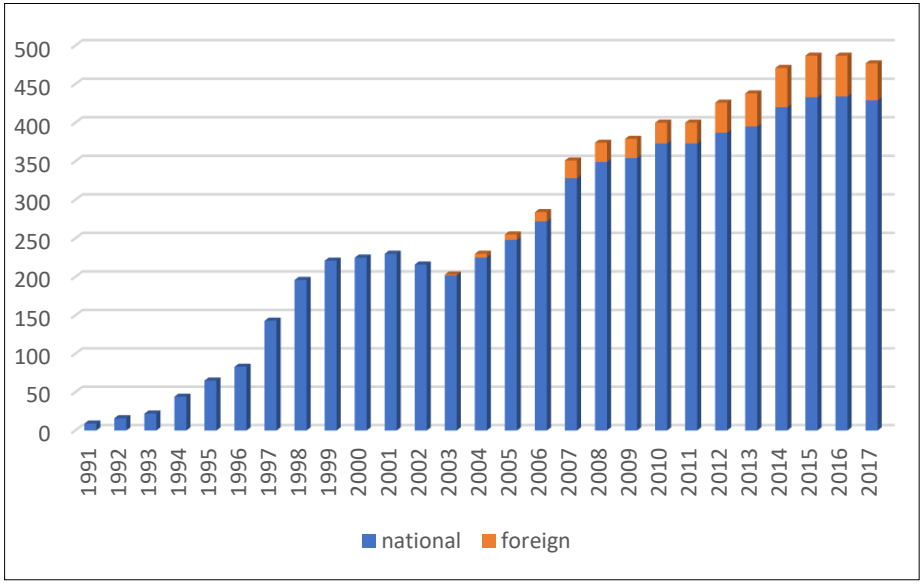
The information effectiveness research carried out in the world mainly concerns highly developed markets, and analyzes of emerging markets started to take place relatively recently. From Polish literature one can mention the work of Czekaj, Woś and Żarnowski (Czekaj, Woś and Żarnowski, 2001), who studied efficiency in 1994-2000 using technical analysis methods and statistical tests (ie series tests, variance ratio test, unit root tests) as well as Mentel and Radwański (Mentel & Radwański, 2015), who studied the said effectiveness in the context of risk share (Value-at-Risk). Their research indicates the possibility of above-average rates of return despite the occurrence of inefficiencies. Papla (Papla, 2003) finds a weak form of effectiveness of the Polish stock market in the years 1991-2002 for large companies with large capitalization and a large market share. Szyszka (Szyszka, 2003) shows that the market did not behave effectively in the initial stage of development. On the other hand, the conducted analyzes did not provide unambiguous arguments to reject the hypothesis of a weak form of effectiveness in the second period of the study, from October 1994 to October 1999. In turn, Buczek (Buczek, 2005) states the fulfillment of the assumptions of the weak form of the efficiency of stock prices of companies listed on the Warsaw Stock Exchange (except the initial period until 1994).

In the case of the Polish market, the efficiency tests were conducted for individual securities and main stock exchange indices (Blajer-Gołębiewska and Kos, 2016; Dorocáková, 2017; Mentel and Horváthová, 2016). Therefore, it seems interesting to examine the information effectiveness in terms of the sector, which is the subject of this study. The verification of the hypothesis of the weak form of information effectiveness of the entire capital market and its five sectors was carried out using the autocorrelation test, series test and the quotients of variances.

2. THE WARSAW STOCK EXCHANGE

The beginning of the stock exchange in Poland dates back to 1990, when a cooperation agreement was signed on the creation of the Warsaw Stock Exchange. At the first trading session (April 16, 1991) shares of 5 companies. There was the following companies: Tonsil S.A., Kable Śląskie S.A., Exbud S.A., Próchnik S.A. and Krosno S.A.. By the end of the first year of operation of the stock exchange, four companies had their debut, which gave the total number of nine companies[3]. The number of new companies has been growing very fast. In 1997, they appeared the most, as many as 62 (Figure 2). In 1999, the number of companies on the stock exchange exceeded 200 (Figure 1).

Figure 1: The number of companies listed on the Warsaw Stock Exchange in the years 1991-2017 (at the end of the year).



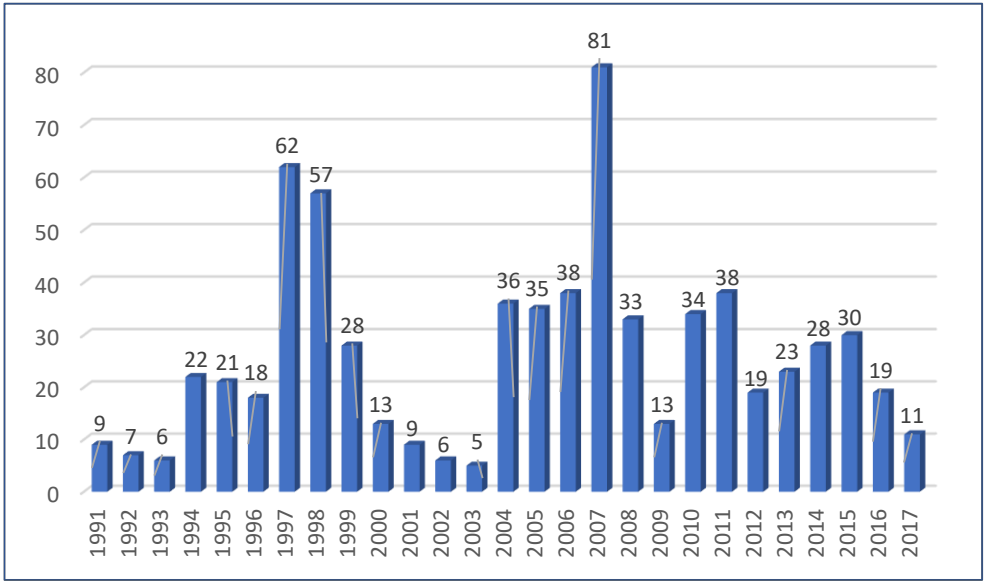
Source: own study based on data from the Warsaw Stock Exchange.

Initially, sessions were held once a week, but at the beginning of 1992, the second trading session was introduced. From 1993, the stock exchange sessions began three times a week, and at the end of 1994 - every day.

The number of orders was gradually increasing, so in 1992, the service of orders was introduced through the IBM platform, and when that was not enough, the Warset system was launched on November 17, 2000[4]. Thanks to the higher bandwidth it has become possible to extend the duration of the session.

[3] *Rynek kapitałowy coraz potężniejszy*, Rzeczpospolita of 19 April 2006.
[4] *Od peceta do Warsetu*, Puls Biznesu, from April 28, 2006.

Figure 2: Number of debuts in the years 1991-2017*.



Source: own study based on data from the Warsaw Stock Exchange.

*(at the end of the year).

After five years of the Warsaw Stock Exchange's operation, the industry structure began to evolve, initially represented by construction, food industry and light industry. Since 2004 there is a division of the quotation markets: basic and parallel, which operate on the Main Market. In addition, the WSE in Warsaw brings together the market of small NewConnect companies, the Catalyst bond market and the energy market. Since 1992, the Warsaw Stock Exchange has been cooperating with Federation of European Securities Exchanges (FESE), which became a member in 2004. In 1994, he was also a member of WFE[5].

The Warsaw Stock Exchange has reached the level of a major market in Central and Eastern Europe. It has also been recognized by the American Securities and Exchange Commission as an orderly and well regulated capital market and a market that complies with internationally recognized standards.

In the context of constant changes on the capital market, the study of its information effectiveness is still an important issue. This is mainly due to the fact that the changing economic situation or globalization of financial markets have a significant impact on the Polish capital market.

[5] WSE in Warsaw (http://www.gpw.pl/zrodla/gpw/rocznik2009/19_miedzynarodowaGPW.pdf).

3. RANDOM WALK TEST

The random walk model is described by the equation: (Szyszka, 2003)

$$p_t = \mu + p_{t-1} + \varepsilon_t \tag{1}$$

where

p_{t-1} and p_t - prices in the period *t-1* and *t*,
μ - expected price change,
ε_t - random element.

Depending on the component's property, there are three types of random walk: random walk of the first type (independent variables with identical distributions), random walk of the second type (independent variables), random walk of III type (uncorrelated variables) (Campbell et al., 1997; Papla, 2003).

From the truth of the hypothesis of random wandering, it follows that the capital market is informatively effective in a weak form. In order to make the analysis concerning the market efficiency in-depth, the following random walk tests were verified at work: autocorrelation test, series test, Random walk of the first type (RW1) variance ratio test. Autocorrelation is a relationship occurring in a time series between random variables separated from one another (delayed) by *k* periods. The autocorrelation test helps to determine if the autocorrelation coefficients are statistically insignificantly different from zero. At the significance level, the null hypothesis for the Quenouille test is rejected if the absolute value of $\rho(k)$ exceeds $1.96/\sqrt{T}$, where T is the number of observations.

The series is each sequence of changes in rates of return with the same mark, and its length the number of consecutive observations of the same type. The test hypothesis assumes that changes in the index prices are random. The test statistic is in the form (Papla 2003):

$$U = \frac{K - E\left(\tilde{K}\right)}{S\left(\tilde{K}\right)}, \tag{2}$$

where the mean and variance of a random variable are defined as follows:

$E\left(\tilde{K}\right) = \frac{2n_1n_2 + n}{n}$; $S^2\left(\tilde{K}\right) = \frac{2n_1n_2\left(2n_1n_2 - n\right)}{\left(n-1\right)n^2}$ for two types of series n_1 and n_2 .

The variable has a normal distribution. When it is higher as to the absolute value from 1.96 at the significance level of 0.05. The null hypothesis is rejected in favor of an alternative hypothesis. Lack of differences between the number of increases and decreases means that the number and length of the series is random, which proves the fulfillment of the assumptions of the weak market efficiency.

The statistic of the variance ratio test is described by the formula (Lo, MacKinlay, 1989):

$$Z = \frac{VR(k) - 1}{\sqrt{\phi(k)}} \tag{3}$$

where:

$\sigma^2(k)$ - variance of the series in which the observations are sums of k successive rates of return $y_t, \ldots, y_{t-k+1}$,

$$\sigma^2(k) = \frac{1}{T}\sum_{1=k}^{T}\left(y_t + y_{t-1} + \ldots + y_{t-k+1} - k \cdot \bar{\mu}\right)^2;$$

$$\phi(k) = \frac{2(2k-1)(k-1)}{3kT},\ \bar{\mu} = \frac{1}{T}\sum_{t=1}^{T} y_t \cdot$$

The statistics have a normal distribution, so H0 is rejected for $|U| > u_\alpha$. Such formulated statistics concerns the verification of the null hypothesis that the series is a series of random walks RW1.

4. EMPIRICAL RESULTS

In order to examine the information effectiveness of the entire market, the WIG index of the Warsaw Stock Exchange was adopted for research. It is an index covering all companies listed on the Main Market of the Warsaw Stock Exchange. The subject of the research were also sub-indexes containing quotations of companies from such sectors as: banks, construction, energy, food and telecommunication.

The research concerned the period from January, 2010 to December, 2016 (marked as P1). It has been divided into three sub-periods: P2 from January, 2010 to October, 2011; P3 from November, 2011 to June 2013 and P4 from July, 2013 to December, 2016 (ie the period of decline, lateral trend and index increase).
The tests were performed for daily closing prices. For the series test, autocorrelation, variance ratio test, the logarithmic rates of return were calculated using the following formula (Jajuga, 2000) .

$$r_t = \ln p_t - \ln p_{t-1} = \ln \frac{p_t}{p_{t-1}} \tag{4}$$

where:
p_t and p_{t-1} - are index values in period *t* and *t-1*,
r_t - logarithmic rate of return.

The calculations were made at the significance level of 0.05, while the computer programs Statistica and Gretl were used.

Compliance tests of the distribution of rates of return with normal distribution were verified using tests: Jarque-Bery and Shapiro-Wilk. This assumption can be considered unfulfilled in most cases, which may be caused by the occurrence of thick tails on the stock exchange.

In order to investigate the existence of a dependency, the calculations were made for the orders of delays k = 1, ..., 100. Table 1 gives the numbers of delays for which the results obtained were statistically significant for the Quenouille test.

Table 1: Quenouille test results

index	P1	P2	P3	P4
WIG	24	41	4, 46, 56	1, 6, 7, 12, 28, 33
WIG-banks	1, 16, 52	3, 4, 26	4, 16, 25, 52	1, 7, 8, 12, 15, 33, 35, 41
WIG-construction	1, 2, 7, 10, 18, 26, 35, 36, 38, 39	6, 7, 10, 30, 41, 48, 51, 52, 70	26, 53	1, 5, 36, 68, 94
WIG-IT	1, 6, 11, 15, 24, 31, 41, 67, 92	6, 11, 15, 41, 92	8, 56	1, 5, 43
WIG-food	2, 4, 9, 10, 11, 14, 30, 33, 38, 45, 63, 79, 97	1, 51, 55, 63, 66	2	1, 2, 7, 62, 97
WIG-telecommunication	6, 17, 19, 24, 31, 66, 67	6, 31	8, 19, 23, 33, 46, 73	66

Source: own study.

In the period of P1, statistically significant factors were: 1% of all WIG index coefficients, 3% for WIG-banks, 10% - WIG-construction, 9% for WIG-IT, 13% - WIG-food, 7% - WIG-telecommunication. Considering the total P2, P3 and P4 periods, statistically significant coefficients accounted for 3.33% of all coefficients for the WIG index, 5% WIG-banks, 5.33% WIG-construction, 3.33% WIG-IT, 3, 67% WIG-food, 3% WIG-telecommunication. The obtained results indicate the occurrence of the greatest number of medium-term dependencies.

Among statistically significant factors, Wig-construction and Wig-telecommunication subindexes were negative. In the case of WIG-IT and WIG-food, among the statistically significant coefficients the majority were positive coefficients. For the WIG and WIG-banks index, the same number of positive and negative statistically significant coefficients occurred.

The advantage of significant negative coefficients means that the price increase at the previous session meant a more likely drop in price at the next session. On the basis of the results obtained, it can also be noticed that as the order of autocorrelation increases, the number of statistically significant factors decreases.
The results of the series test are presented in Table 2, the rejection of the null hypothesis was marked with an asterisk.

Table 2: Series test results

index	P1	P2	P3	P4
WIG	-0,29	-1,09	1,07	-0,04
WIG-banks	-1,33	-0,76	-1,11	-0,43
WIG-construction	-2,42*	-1,8	-0,49	-1,38
WIG-IT	-2,22*	-0,98	0,32	-2,24*
WIG-food	-5,01*	-1,35	-2,82*	-3,22*
WIG-telecommunication	0,33	-1,83	0,38	1,65

Source: own study.

The null hypothesis on the independence of sub-index returns was largely met. It was rejected for the sub-indices WIG-construction, WIG-IT and WIG-food from the period P1 and for WIG-IT in the period P3 and WIG-food in periods P3 and P4. It seems that the statistically significant results affected the results of the entire P1 period in the case of WIG-IT and WIG-food indices. In all cases of rejection of the null hypothesis, the coefficients have negative values, which indicates a significant occurrence of trends in the data.

The results of the RW1 variance ratio test performed for the aggregation category k=5 confirmed previous results (Table 3). The null hypothesis that the examined series is a random walk was also rejected in the banking, construction, IT (in P1 and P4) and food (P1, P3, P4) sectors as well as the last sub-period for the WIG index.

Table 3: Results of the variance ratio test

index	P1	P2	P3	P4
WIG	1,66	-0,85	0,05	2,39*
WIG-banks	2,63*	-0,93	1,94	2,09*
WIG-construction	4,51*	1,19	1	3,32*
WIG-IT	2,82*	1,1	-0,83	3,17*
WIG-food	3,53*	-1,86	2,61*	6,81*
WIG-telecommunication	1,52	0,57	0,39	-0,43

Source: own study.

5. CONCLUSION

The results obtained for the entire market indicate that the hypothesis of random walk is fulfilled. It can therefore be concluded that the Polish capital market in 2000-2006 is effective in the weak form. However, considering the sectors included in the entire market, it turns out that there are some that were ineffective. They are WIG-construction, WIG-IT and WIG-food. This means that when investing in a portfolio made up of companies from the entire market, it is impossible to achieve an above-average return in the long run. However, such options exist in individual sub-periods of sectors: from the construction, IT or food industry.

When comparing the results obtained for the whole period of P1 with the results for the periods of the index's growth or fall, it can be concluded that it is advisable to perform all research and analyzes separately for periods with different stock market trends.

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