Problemy Zarządzania – Management Issues, vol. 16, no. 2(74): 11–45
ISSN 1644-9584, © Wydział Zarządzania UW
DOI 10.7172/1644-9584.74.1

Normal Distribution of Returns of Warsaw Stock Exchange Indexes

Submitted: 20.09.17 | Accepted: 04.04.18

Krzysztof Borowski*

The paper verified the hypothesis regarding a normal distribution of returns of Warsaw Stock Exchange indexes for the following time intervals: daily, weekly, monthly, quarterly and yearly. The analyzed rates of return were calculated in the following outlines: closing-closing, opening-opening, opening-closing and overnight. The verification of statistical hypotheses was conducted with the use of the following seven statistical tests: Kolmogorov-Smirnov, Lilliefors, Shapiro-Wilk, Chi-squared, Cramer von Mises, Watson, Anderson-Darling. The analyzed indexes were ranked due to the convergence of their return to the normal distribution with the use of the following tests: Jarque-Bera, Shapiro-Wilk and D'Agostino-Pearson.

Keywords: normal distribution, return rates, stock indexes, ranking of equity indexes.

Rozkład normalny stóp zwrotu indeksów Giełdy Papierów Wartościowych w Warszawie

Nadesłany: 20.09.17 | Zaakceptowany do druku: 04.04.18

W artykule zweryfikowano hipotezę o normalności rozkładu stóp zwrotu indeksów publikowanych przez Giełdę Papierów Wartościowych w Warszawie. Badanie przeprowadzono dla stóp zwrotu: dziennych, tygodniowych, miesięcznych, kwartalnych i rocznych oraz uwzględniono stopy zwrotu liczone w ujęciu: zamknięcie–zamknięcie, zamknięcie–otwarcie, otwarcie–otwarcie i otwarcie–zamknięcie (*overnight*). Weryfikacja hipotez statystycznych została przeprowadzona za pomocą następujących siedmiu testów: Kolmogorova-Smirnova, Lillieforsa, Shapiro-Wilka, Chi-kwadrat, Cramera von Misesa, Watsona, Andersona-Darlinga. Stworzony został również ranking analizowanych indeksów giełdowych z wykorzystaniem trzech testów statystycznych: Jarque-Bera, Shapiro-Wilka and D'Agostino-Pearsona.

Słowa kluczowe: rozkład normalny, stopy zwrotu, indeksy giełdowe, ranking indeksów giełdowych.

JEL: G14, G15

* **Krzysztof Borowski** – Professor, PhD (habilitated); Warsaw School of Economics.

Correspondence address: Warsaw School of Economics, Al. Niepodległości 162, 02-594 Warszawa; e-mail: krzysztof.borowski@sgh.waw.pl.

Ministry of Science and Higher Education
Republic of Poland

The creation of the English-language version of these publications is financed in the framework of contract No. 607/P-DUN/2018 by the Ministry of Science and Higher Education committed to activities aimed at the promotion of education.

1. Introduction

One of the most important assumptions in theoretical and empirical research in finance is that relevant variables (e.g. rates of return) are characterized by a normal distribution. In the process of mean-variance efficiency, small sample results have been derived under the assumption of a normal distribution of returns (Affleck-Graves & McDonalds, 1989; Bookstaber & McDonalds, 1973; Clark, 1973; Fama, 1965, 1976; Harris, 1986; Richardson & Smith, 1993). Some authors underline that violation of the assumption may lead to incorrect inference (MacKinlay & Richardson, 1991). The general conclusion of many studies has pointed out that equity returns are not normally distributed, putting into doubt all obtained results relying on the assumption of the normal returns distribution.

The aim of this paper is to verify the hypothesis of the normal distribution of daily stock index returns, published by the Warsaw Stock Exchange (WSE).

2. Literature Review

One of the earliest works dedicated to the distribution of rates on the financial markets was Bachelier's study, which proved that price differences in subsequent periods were normally distributed variables, using random walk model of financial instrument prices (Bachelier, 1900). The expected value of the instrument price change was zero, and the variance of price change was a function of the length of the analyzed period. A more advanced study of time series carried out by Kendall proved, on the basis of weekly rates of return from the British market, not only the normal distribution of price changes but also their leptokurtosis (Kendall, 1953). Another important study was published by Osborne, who proved the normal distribution of returns of companies listed on the American Stock Exchange and the New York Stock Exchange (Osborne, 1959). Fama rejected the hypothesis that the monthly returns of 14 out of 30 Dow Jones Industrial components were normally distributed in the period of 1951–1968 (Fama, 1976).

Amongst the more contemporary works, special consideration should be given to Scalas and Kim who, using a stable distribution, approximated daily rates of return for the DJIA and MIBTEL indexes (Scalas & Kim, 2007). For this first index, the Kolmogorov and chi-square tests confirmed, and for the second index they denied, the hypothesis that index returns could be approximated by a stable distribution. In the work of Barunik et al., the hypothesis of the normal distribution of returns for the following indexes: WIG, PX and BUX in the period March 2005 – March 2009 was rejected (Barunik, Vacha, & Vosvrda, 2010). Ghahfarokhi and Ghahfarokhi showed that in the case of returns of the following indexes: CAC40, DAX, DJAC, FTSE 100, ISEQ and S&P 500, the Value at Risk

DOI 10.7172/1644-9584.74.1

(VaR) determined with the use of a stable distribution was closer to a real distribution of these indexes than the above mentioned index distribution, obtained with the use of the normal or t-student distribution (Ghahfarokhi & Ghahfarokhi, 2009).

Barunik et al. analyzed the normality of returns distribution in the period from March 2005 to March 2009 for the following equity indexes: Czech PX, Polish WIG, Hungarian BUX, German DAX and U.S. S&P 500 (Barunik, Vacha, & Vosvrda, 2010). The analyzed period was divided into two subperiods – the first half of the data represented the pre-crisis period and the second half comprised post-crisis data. The first period, in comparison with the second period, was better described by the normal distribution (except for the PX index). Otherwise, the real data was characterized by fatter-than-normal but lighter-than-stable tails.

Bołt and Miłobędzki, analyzing the rates of return for the WIG index and 21 stocks listed on the Warsaw Stock Exchange in the period 1991–1993, concluded that they were not normally distributed (Bołt & Miłobędzki, 1994). In turn, Fiszeder conducted a study of the WIG index returns and 12 other world indexes in the period 2 January 1997 – 30 June 1999 with the following compliance tests: Pearson, Kolmogorov-Lilliefors and Shapiro-Wilk (Fiszeder, 2000). The first two tests allowed for rejecting the null hypothesis regarding the normal returns distribution for all tested indexes. In the case of the Shapiro-Wilk test, there was no reason to reject the null hypothesis only for the NIKK index. Rokita, calculating rates of return for the WIG20 index in the period of 13 September 1997 – 15 February 2000, came to the conclusion that they were not normally distributed (Rokita, 2000). These results were confirmed by Osińska, who analyzed the rates of return of two indexes: WIG20, WIG and the 18 components of the latter index, in the period of January 1999 – July 2001 (Osińska, 2006). Also. in the paper by Witkowska and Kompa, the returns analyzed for 12 companies and two WSE indexes in Warsaw, in the period 2 January 2003 – 31 December 2005, did not appear to follow the normal distributions path (Witkowska & Kompa, 2007).

3. Methodology

The paper consists of four parts:

In the first part, the hypothesis of the normality of return rates for all stock indexes published by the Warsaw Stock Exchange will be verified. On 17 October 2000, the Warsaw Stock Exchange introduced the WARSET continuous trading system and prior to this date the quotation system was only partially continuous. The implementation of the WARSET system on the WSE brought its trading system closer to the systems used in developed markets. The date of the first publishing of each index is revealed in Table 1.

In the case of an index for which the date of its first publication is earlier than the date of the implementation of the WARSET system (17 October 2000), the rates of return were analyzed in two periods:
A) Full, i.e. from the date of first publication of the index to 31 March 2017 (index name given with the extension: all),
B) Between 17 October 2000 and 31 March 2017 (index name given with the extension: WARSET).

For other indexes, the calculation was effected from the date of their first publication to 31 March 2017 (index name given with the extension: WARSET) except three cases:
a) WIG20TR index – the first date of publishing all four courses (open, high, low and close) was 3 December 2012 (index name given with the extension: WARSET2),
b) WIG30 index – the first date of publishing all four courses (open, high, low and close) was 23 September 2013 (index name given with the extension: WARSET2),
c) WIG30TR index – the first date of publishing all four courses (open, high, low and close) was 3 December 2012 (index name given with the extension: WARSET2).

For each of the analyzed indexes, the following rates of return were calculated (daily rates of return):

a) Close – Close (C-C): $\ln\left(\frac{C_t}{C_{t-1}}\right)$ (last session close vs. previous session close),
b) Overnight (OV): $\ln\left(\frac{O_t}{C_{t-1}}\right)$ (last session open vs. previous session close),
c) Open – Open (O-O): $\ln\left(\frac{O_t}{O_{t-1}}\right)$ (last session open vs. previous session open),
d) Open – Close (O-C): $\ln\left(\frac{C_t}{O_t}\right)$ (last session close vs. last session open),

where:
C_t – closing price in the period t,
C_{t-1} – closing price in the period $t - 1$,
O_t – open price in the period t,
O_{t-1} – open price in the period $t - 1$.

The choice of the above rates of return results from two premises. The first is the investment premise – a transaction takes place at strictly defined moments of the session at the opening or closing prices. The other derives from earlier scientific articles because most research concentrates solely on close-close returns. The author is not familiar with

 DOI 10.7172/1644-9584.74.1

the scientific papers referring to different than the close-close returns on the Polish market.

The hypothesis H_0 was formulated as follows: the distribution of the analyzed index returns is a normal distribution. In turn, the alternative hypothesis H_1 takes the following form: the distribution of the analyzed index returns does not follow the path of a normal distribution.

The verification of statistical hypotheses was conducted with the use of the following seven statistical tests: Kolmogorov-Smirnov, Lilliefors, Shapiro-Wilk, Chi-squared, Cramer von Mises, Watson, Anderson-Darling. In all analyzed cases, p-values were calculated. If the p-value is less than or equal to 0.05, then the hypothesis H_0 is rejected in favor of the hypothesis H_1. Otherwise, there is no reason to reject the hypothesis H_0.

In the second part, the hypothesis of the normalization of return rates for four indexes: WIG, WIG20, mWIG40 and sWIG80 was verified in the annual time horizons, i.e. for the following years: 2001–2016, as well as for selected up and down waves with the use of the succeeding tests: Jarque-Bera, Kolmogorov-Smirnov, Lilliefors, Cramer von Mises, Watson and Anderson--Darling. The purpose of this part is to demonstrate that the distribution of rates of return for individual indexes can be normal at shorter time intervals. Part two of the study can be considered as an introduction to the third part.

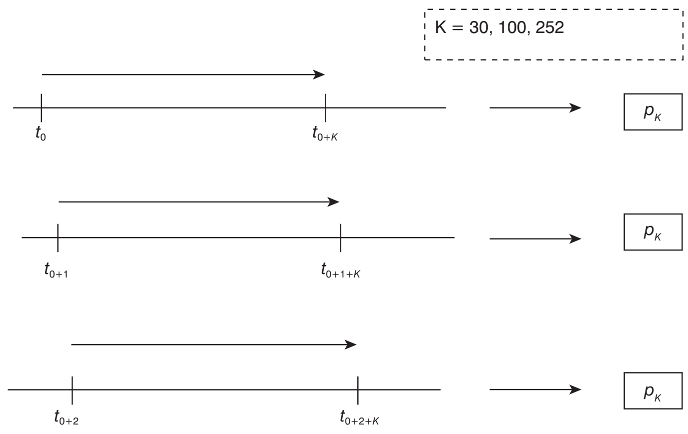

Fig. 1. Determining the parameter p in K session time horizon

In the third part of the analysis, the verification of the hypothesis of normal distribution of returns was carried out according to the following scheme. The parameter p was calculated at the moment K, i.e. for the first K trading session of the analyzed index on the Warsaw Stock Exchange. If t_0 is the date of the first quotation of the index on the Warsaw Stock

Exchange, then the parameter p_k was calculated for the following sessions: t_0, t_{0+1}, t_{0+2}, …, t_{0+K}. The next parameter p_k was determined for the K session time horizon but moved forward by one session, i.e. for sessions held at times: t_{0+1}, t_{0+2}, …, t_{0+K+1}. Similarly, the value of the parameter p_k for the remaining K series sessions was calculated, i.e. until the last session in the time frame, i.e. until 31 March 2017. For all the analyzed indexes, the values p_k were determined with the use of the following tests: Jarque-Bera, Shapiro-Wilk and D'Agostino-Pearson (first degree of freedom), as well as for three different time horizons of K: 30, 100 and 252 sessions (second degree of freedom) and for four types of interest rates: C-C, O-O, O-C and overnight (third degree of freedom). The next step of the research was to provide statistics for each of the analyzed indexes, which include, in particular, the frequency for a given value K and the type of test when there was no reason to reject the null hypothesis. As a result of this procedure, the frequency of $p>0.05$ is calculated for each of the tested returns, for different K and for different statistical tests.

Due to the fact that the parameter p can be treated as the probability that the analyzed distribution can be regarded as a normal distribution and, hence, the higher its value, the given distribution is more similar to the normal distribution; thus, the parameter p can be used to create a ranking list of indexes taking into account the proximity of the distribution of the index returns relative to the normal distribution. Such an index ranking was compiled for different: types of returns (C-C, O-O, C-O and overnight), values K (K = 30, K = 100 and K = 252 sessions) and the types of statistical test (Jarque-Bera, Shapiro-Wilk and D'Agostino-Pearson). In the next step, for the given rates of return, for the given value of K, the sum of the ranking of an analyzed index was calculated according to the following equation:

$$S_{I+II+II} + S_I + S_{II} + S_{III}$$

where:
S_I – position in the ranking of a given index for Jarque-Bera test,
S_{II} – position in the ranking of a given index for Shapiro-Wilk test,
S_{III} – position in the ranking of a given index for D'Agostino-Pearson test,

As a result,12 rankings were obtained: (four rates of return: C-C, O-O, O-C and overnight) x (three investment horizons K: 30, 100 and 252 sessions). Then, on the basis of these 12 ratings, the following sum of the ratings was calculated for each of the analyzed indexes:

 DOI 10.7172/1644-9584.74.1

$$S_{I+\cdots XII} = \frac{K=30}{C-C}S + \frac{K=30}{O-O}S + \frac{K=30}{O-C}S \frac{K=30}{OV}S + \frac{K=100}{C-C}S + \\ + \frac{K=100}{O-O}S + \frac{K=100}{O-C}S + \frac{K=100}{OV}S + \frac{K=252}{C-C}S + \frac{K=252}{O-O}S + \\ + \frac{K=252}{O-C}S + \frac{K=252}{OV}S$$

where:

${}^{K}_{X}S$ – position of a given index in the ranking for a specific time horizon K (K = 30, 100 and 252 sessions) and return type X (C-C, O-O, O-C and overnight).

The sums $S_{I+\cdots XII}$ for each of the analyzed indexes were used in the process of global ranking construction.

In the last part of the study, based on the statistics computed in part three, the average, maximum and minimum values for all index statistic were calculated when K was equal to 30, 100 and 252 sessions and for each type of statistical test.

The main thesis of the analysis was formulated as follows: at long time intervals, the returns distributions are not normal distributions. As a long time interval, an investment horizon covering several years was assumed. In turn, the secondary thesis of the research may be expressed as follows: in the shorter investment horizons, the distribution of WSE indexes returns may be normal. The auxiliary thesis can also be written in a slightly different way: returns of WSE indexes are serially normal.

4. Analysis of Results

4.1. Verification of the Hypothesis of Normal Distribution of Returns of Stock Exchange Indexes in the Period From Their First Publishing Date Until 31 March 2017

The results of the hypothesis H_0 testing for all indexes are provided in Table 1 (index names according to the ones officially published by WSE). Only in a few cases there was no reason to reject the null hypothesis in favor of the alternative hypothesis ("*" means that the null hypothesis was not rejected with the use of only one test – e.g. the result was not confirmed by other tests):

a) C-C: WIG-Budownictwo-All*, WIG-Energia-Warset*, WIG-Górnictwo-Warset, WIG-Leki-Warset, WIG-Nieruchomości-Warset, WIG-Odzieżowy-Warset;

b) O-O: WIG-Górnictwo-Warset, WIG-Leki-Warset, WIG-Moto-Warset, WIG-Nieruchomości-Warset, WIG-Odzieżowy-Warset, WIG20TR-Warset2*, WIG39TR-Warset*;
c) O-C:WIG-Chemia-Warset*, WIG-Developerzy-Warset*, WIG-Górnictwo-Warset, WIG-Leki-Warset, WIG-Moto-Warset, WIG-Nieruchomości-Warset, WIG-Odzieżowy-Warset, WIG-Paliwa-Warset*;
d) Overnight: WIG-Budownictwo-Warset*, WIG-Górnictwo-Warset, WIG-Leki-Warset, WIG-Moto-Warset, WIG-Nieruchomości-Warset-WIG-Odzieżowy-Warset, WIG-Paliwa-Warset, WIG20-Warset*, WIG20-TR-Warset2*, WIG30-Warset2, WIG30TR-Warset*.

Many of the above mentioned indexes were launched at the end of 2016: WIG-Górnictwo-Warset, WIG-Leki-Warset, WIG-Leki-Warset, WIG-Nieruchomości-Warset.

Only in the case of the WIG30-Warset2 index, i.e. the index for which continuous quotation covers a longer period than the first quarter of 2017, the null hypothesis was not rejected for overnight rates of return with the use of the following tests: Kolmogorov-Smirnov (0.0876) and Chi-squared (0. 3206).

4.2. Verification of the Hypothesis of Normal Distribution of Returns for the Following Indexes: WIG, WIG20, mWIG40 and sWIG80 When the Investment Horizon is Equal to One Year and During Up and Down Waves

The results of testing the null hypothesis for the main indexes of the Warsaw Stock Exchange in particular years are presented in Tables 2–5. In case of many annual periods, there was no reason to reject the hypothesis that the distribution of the analyzed returns was normal. Let us assume that if at least two of the six tests do not allow for rejecting the null hypothesis, then the distribution of returns for individual indexes in the analyzed years represents a normal distribution. The numbers of cases when $p>0.05$ are presented in Table 6. The results higher than or equal to 2 are marked out in bold.

For example, there was no reason to reject the null hypothesis in the following years (rates of return C-C):
a) WIG: 2001, 2005, 2007, 2009, 2012, 2013;
b) WIG20: 2005, 2006, 2007, 2009, 2010, 2013 and 2014;
c) mWIG40: 2001, 2002 and 2009;
d) sWIG80: 2001, 2002, 2003 and 2005.

For all the four analyzed main WSE indexes, there were no reason to reject the null hypothesis with the use of at least two tests for the following years and rates of return:
a) 2003: O-C,
b) 2005: O-O and O-C,
c) 2009: O-C.

 DOI 10.7172/1644-9584.74.1

The results of testing the null hypothesis for the main indexes of the Warsaw Stock Exchange in particular up and down waves are presented in Tables 7–10. The upward (downward) wave of the index occurs when the value of the index changes between extreme points by at least 15%. For example, in the case of the WIG index, during the first three waves there was no reason to reject the null hypothesis (for C-C, O-O and O-C rates of return) as well as for the 9th downward wave in the period: 8 May 2015 – 21 January 2016 (only for O-C rates of return). For WIG and WIG20 indexes, in all rising and falling waves for overnight returns, the null hypothesis was rejected – see Tables 7 and 8. For the sWIG80 and mWIG40 indexes, it is possible to indicate upward and downward waves for overnight return rates when there was no reason to reject the null hypothesis:

a) mWIG40: 1–4, 12, 15 and 16 – see Table 9;
b) sWIG80: 10 and 12 – see Table 10.

	Date of the first quotation	C-C							O-O						
		K-S	Lilliefors	Shapiro--Wilk	Chi--squared	Cramer--Von Mises	Watson	Anderson Darling	K-S	Lilliefors	Shapiro--Wilk	Chi--squared	Cramer--Von Mises	Watson	Anderson Darling
WIG-All	16-04-1991	0.01	0.01	0.01	0.0001	0.0000	0.0000	0.0000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
WIG-Warset	17-10-2000	0.01	0.01	0.01	0.0001	0.0000	0.0000	0.0000	0.01	0.01	0.01	0.0004	0.0000	0.0000	0.0000
WIG-Banki – All	31-12-1997	0.01	0.01	0.01	0.0001	0.0000	0.0000	0.0000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
WIG-Banki-Warset	17-10-2000	0.01	0.01	0.01	0.0001	0.0000	0.0000	0.0000	0.01	0.01	0.01	0.0001	0.0000	0.0000	0.0000
WIG-Budownictwo-Warset	31-12-1997	0.01	0.01	0.01	0.0001	0.0000	0.0000	0.0000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
WIG-Budownictwo-All	17-10-2000	0.01	0.01	0.01	**0.3307**	0.0000	0.0000	0.0000	0.01	0.01	0.01	0.0006	0.0000	0.0000	0.0000
WIG-CEE-Warset	31-05-2012	0.01	0.01	0.01	0.0001	0.0000	0.0000	0.0000	0.01	0.01	0.01	0.0001	0.0000	0.0000	0.0000
WIG-Chemia-Warset	22-09-2008	0.0203	0.01	0.01	0.0001	0.0000	0.0000	0.0000	0.0302	0.01	0.01	0.0001	0.0000	0.0000	0.0000
WIG-Developerzy-Warset	18-06-2007	0.01	0.01	0.01	0.0001	0.0000	0.0000	0.0000	0.01	0.01	0.01	0.0001	0.0000	0.0000	0.0000
WIG-Energia-Warset	04-01-2010	0.01	0.01	0.01	**0.1198**	0.0000	0.0000	0.0000	0.01	0.01	0.01	0.0205	0.0000	0.0000	0.0000
WIG-Górnictwo-Warset	02-01-2017	**0.2013**	**0.2035**	**0.1794**	**0.2374**	**0.2431**	**0.2998**	**0.3471**	0.0245	0.0278	0.01	**0.0849**	**0.3748**	**0.3575**	**0.4185**
WIG-Informatyka-All	31-12-1997	0.01	0.01	0.01	0.0001	0.0000	0.0000	0.0000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
WIG-Informatyka-Warset	17-10-2000	0.01	0.01	0.01	0.0001	0.0000	0.0000	0.0000	0.01	0.01	0.01	0.0001	0.0000	0.0000	0.0000
WIG-Leki-Warset	02-01-2017	**0.2034**	**0.2678**	**0.3102**	**0.1201**	**0.2797**	**0.2450**	**0.2681**	**0.2345**	**0.2684**	**0.1836**	**0.3872**	**0.2677**	**0.2344**	**0.2803**
WIG-Media-Warset	31-12-2004	0.01	0.01	0.01	0.0092	0.0000	0.0000	0.0000	0.01	0.01	0.01	0.0012	0.0000	0.0000	0.0000
WIG-Moto-Warset	02-01-2017	**0.2056**	**0.2367**	0.5925	0.4010	0.191	0.1732	0.2606	0.2897	0.2348	0.2722	0.6357	0.1554	0.1326	0.1299
WIG-Nieruchomości-Warset	02-01-2017	**0.2678**	**0.1867**	**0.0744**	0.0349	0.0328	0.0227	0.0409	**0.2489**	**0.1978**	**0.2119**	**0.1504**	0.0475	0.0449	**0.078**
WIG-Odzieżowy-Warset	02-01-2017	0.0235	**0.0879**	**0.1981**	0.0134	0.0427	0.0394	**0.0546**	**0.2457**	**0.1467**	**0.1194**	0.0076	**0.0639**	**0.0508**	0.0481
WIG-Paliwa-Warset	03-01-2006	0.01	0.01	0.01	0.0001	0.0000	0.0000	0.0000	0.01	0.01	0.01	0.0001	0.0000	0.0000	0.0000
WIG-Poland-All	16-04-1991	0.01	0.01	0.01	0.0001	0.0000	0.0000	0.0000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
WIG-Poland-Warset	17-10-2000	0.01	0.01	0.01	0.0121	0.0000	0.0000	0.0000	0.01	0.01	0.01	0.0001	0.0000	0.0000	0.0000
WIG-Spożywczy-All	31-12-1997	0.01	0.01	0.01	0.0001	0.0000	0.0000	0.0000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
WIG-Spożywczy-Warset	17-10-2000	0.01	0.01	0.01	0.0231	0.0000	0.0000	0.0000	0.01	0.01	0.01	0.0001	0.0000	0.0000	0.0000
WIG-Surowcowy-Warset	31-12-2010	0.01	0.01	0.01	0.0232	0.0000	0.0000	0.0000	0.01	0.01	0.01	0.0001	0.0000	0.0000	0.0000
WIG-Telekom-All	31-12-1997	0.01	0.01	0.01	0.0001	0.0000	0.0000	0.0000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
WIG-Telekom-Warset	17-10-2000	0.01	0.01	0.01	0.0231	0.0000	0.0000	0.0000	0.01	0.01	0.01	0.0001	0.0000	0.0000	0.0000

	Overnight							O-C						
	K-S	Lilliefors	Shapiro--Wilk	Chi--squared	Cramer--Von Mises	Watson	Anderson Darling	K-S	Lilliefors	Shapiro--Wilk	Chi--squared	Cramer--Von Mises	Watson	Anderson Darling
WIG-All	0.01	0.01	0.01	0.0001	0.0000	0.0000	0.0000	0.0001	0,0000	0,0000	0,0000	0,0000		0,0000
WIG-Warset	0.01	0.01	0.01	0.0000	0.0000	0.0000	0.0000	0.01	0.01	0.01	0.0002	0.0000	0.0000	0.0000
WIG-Banki – All	0.01	0.01	0.01	0.0071	0.0000	0.0000	0.0000	0,0000	0,0000	0,0000	0,0000	0,0000		0,0000
WIG-Banki-Warset	0.01	0.01	0.01	0.0031	0.0000	0.0000	0.0000	0.01	0.01	0.01	0.0041	0.0000	0.0000	0.0000
WIG-Budownictwo-Warset	0.01	0.01	0.01	0.0001	0.0000	0.0000	0.0000	**0.3874**	0,0000	0,0000	0,0000	0,0000		0,0000
WIG-Budownictwo-All	0.01	0.01	0.01	0.0000	0.0000	0.0000	0.0000	0.01	0.01	0.01	0.0000	0.0000	0.0000	0.0000
WIG-CEE-Warset	0.01	0.01	0.01	0.0000	0.0000	0.0000	0.0000	0.01	0.01	0.01	0.0001	0.0000	0.0000	0.0000
WIG-Chemia-Warset	0.0099	0.01	0.01	**0.1047**	0.0000	0.0000	0.0000	0.0217	0.01	0.01	0.0013	0.0000	0.0000	0.0000
WIG-Developerzy-Warset	0.01	0.01	0.01	**0.1867**	0.0000	0.0000	0.0000	0.01	0.01	0.01	0.0028	0.0000	0.0000	0.0000
WIG-Energia-Warset	0.01	0.01	0.01	0.0001	0.0000	0.0000	0.0000	0.01	0.01	0.01	0.0007	0.0000	0.0000	0.0000
WIG-Górnictwo-Warset	**0.2879**	**0.2345**	**0.7595**	**0.8373**	**0.6678**	**0.6259**	**0.7575**	**0.2589**	**0.2567**	**0.1794**	**0.3432**	**0.1671**	**0.212**	**0.144**
WIG-Informatyka-All	0.01	0.01	0.01	0.0001	0.0000	0.0000	0.0000	0,0000	0,0000	0,0000	0,0000	0,0000		0,0000
WIG-Informatyka-Warset	0.01	0.01	0.01	0.0000	0.0000	0.0000	0.0000	0.01	0.01	0.01	0.0023	0.0000	0.0000	0.0000
WIG-Leki-Warset	**0.1837**	0.0053	0.0004	0.0018	0.0003	0.0002	0.0001	**0.2478**	**0.2987**	**0.6191**	**0.5599**	**0.3463**	**0.3587**	**0.4685**
WIG-Media-Warset	0.01	0.01	0.01	0.0007	0.0000	0.0000	0.0000	0.01	0.01	0.01	0.0001	0.0000	0.0000	0.0000
WIG-Moto-Warset	0.2089	0.2769	0.2915	0.5174	0.2662	0.2788	0.2794	0.2754	**0.2356**	**0.3563**	**0.7575**	**0.2945**	**0.2697**	**0.3211**
WIG-Nieruchomości-Warset	**0.2897**	**0.2016**	0.0087	**0.0646**	0.0454	0.0474	0.0274	**0.2013**	**0.2056**	**0.8228**	**0.9025**	**0.9438**	**0.9340**	**0.9000**
WIG-Odzieżowy-Warset	**0.2389**	**0.2245**	**0.4161**	0.0275	**0.2096**	**0.1856**	**0.2228**	**0.2018**	**0.2189**	**0.4884**	**0.5933**	**0.4019**	**0.3724**	**0.3951**
WIG-Paliwa-Warset	0.01	0.01	0.01	**0.0583**	0.0000	0.0000	0.0000	0.01	0.01	0.01	**0.0718**	0.0000	0.0000	0.0000
WIG-Poland-All	0.01	0.01	0.01	0.0000	0.0000	0.0000	0.0000	0,0000	0,0000	0,0000	0,0000	0,0000		0,0000
WIG-Poland-Warset	0.01	0.01	0.01	0.0000	0.0000	0.0000	0.0000	0.01	0.01	0.01	0.0001	0.0000	0.0000	0.0000
WIG-Spożywczy-All	0.01	0.01	0.01	0.0000	0.0000	0.0000	0.0000	0,0000	0,0000	0,0000	0,0000	0,0000		0,0000
WIG-Spożywczy-Warset	0.01	0.01	0.01	0.0000	0.0000	0.0000	0.0000	0.01	0.01	0.01	0.0001	0.0000	0.0000	0.0000
WIG-Surowcowy-Warset	0.01	0.01	0.01	0.0000	0.0000	0.0000	0.0000	0.01	0.01	0.01	0.0001	0.0000	0.0000	0.0000
WIG-Telekom-All	0.01	0.01	0.01	0.0000	0.0000	0.0000	0.0000	0,0000	0,0000	0,0000	0,0000	0,0000		0,0000
WIG-Telekom-Warset	0.01	0.01	0.01	0.0001	0.0000	0.0000	0.0000	0.01	0.01	0.01	0.0001	0.0000	0.0000	0.0000

DOI 10.7172/1644-9584.74.1

	Date of the first quotation	C-C							O-O						
		K-S	Lilliefors	Shapiro--Wilk	Chi--squared	Cramer--Von Mises	Watson	Anderson Darling	K-S	Lilliefors	Shapiro--Wilk	Chi--squared	Cramer--Von Mises	Watson	Anderson Darling
WIG-Ukraina-Warset	31-12-2010	0.01	0.01	0.01	0.0001	0.0000	0.0000	0.0000	0.01	0.01	0.01	0.0001	0.0000	0.0000	0.0000
WIG20-All	14-04-1994	0.01	0.01	0.01	0.0001	0.0000	0.0000	0.0000							
WIG20-Warset	17-10-2000	0.01	0.01	0.01	0.0074	0.0000	0.0000	0.0000	0.01	0.01	0.01	0.0001	0.0000	0.0000	0.0000
WIG20TR-All	31-12-2004	0.01	0.01	0.01	0.0010	0.0000	0.0000	0.0000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
WIG20TR-Warset2	03-12-2012	0.0456	0.01	0.01	0.0001	0.0000	0.0000	0.0000	**0.2319**	0.0113	0.01	0.0498	0.0013	0.0012	0.0001
WIG30-All	28-12-2012	0.01	0.01	0.01	0.0001	0.0000	0.0000	0.0000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
WIG30-Warset2	23-09-2013	0.0482	0.01	0.01	0.0001	0.0000	0.0000	0.0000	0.0425	0.01	0.01	0.0003	0.0000	0.0000	0.0000
WIG30TR-All	28-12-2012	0.01	0.01	0.01	0.0001	0.0000	0.0000	0.0000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
WIG30TR-Warset	23-09-2013	0.0434	0.01	0.01	0.0001	0.0000	0.0000	0.0000	**0.2215**	0.0112	0.0001	0.0194	0.0035	0.0032	0.0005
WIG-DIV-Warset	03-01-2011	0.01	0.01	0.01	0.0001	0.0000	0.0000	0.0000	0.01	0.01	0.01	0.0001	0.0000	0.0000	0.0000
mWIG40-All	31-12-1997	0.01	0.01	0.01	0.0001	0.0000	0.0000	0.0000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
mWIG40-Warset	17-10-2000	0.01	0.01	0.01	0.0001	0.0000	0.0000	0.0000	0.01	0.01	0.01	0.0001	0.0000	0.0000	0.0000
sWIG80-All	29-12-1994	0.01	0.01	0.01	0.0001	0.0000	0.0000	0.0000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
sWIG0-Warset	17-10-2000	0.01	0.01	0.01	0.0001	0.0000	0.0000	0.0000	0.01	0.01	0.01	0.0001	0.0000	0.0000	0.0000
NCIndex-Warset	24-06-2013	0.01	0.01	0.01	0.0001	0.0000	0.0000	0.0000	0.01	0.01	0.01	0.0001	0.0000	0.0000	0.0000
Investorms	31-12-2002	0.01	0.01	0.01	0.0001	0.0000	0.0000	0.0000	0.01	0.01	0.01	0.0001	0.0000	0.0000	0.0000
Respect	31-12-2008	0.01	0.01	0.01	0.0001	0.0000	0.0000	0.0000	0.01	0.01	0.01	0.0001	0.0000	0.0000	0.0000

	Date of the first quotation	Overnight							O-C						
		K-S	Lilliefors	Shapiro--Wilk	Chi--squared	Cramer--Von Mises	Watson	Anderson Darling	K-S	Lilliefors	Shapiro--Wilk	Chi--squared	Cramer--Von Mises	Watson	Anderson Darling
WIG-Ukraina-Warset	31-12-2010	0.01	0.01	0.01	0.0001	0.0000	0.0000	0.0000	0.01	0.01	0.01	0.0001	0.0000	0.0000	0.0000
WIG20-All	14-04-1994	0.01	0.01	0.01	0.0000	0.0000	0.0000	0.0000							
WIG20-Warset	17-10-2000	0.01	0.01	0.01	0.0001	0.0000	0.0000	0.0000	0.01	0.01	0.01	**0.5518**	0.0000	0.0000	0.0000
WIG20TR-All	31-12-2004	0.01	0.01	0.01	0.0041	0.0000	0.0000	0.0000	0,0000	0,0000	0,0000	0,0000	0,0000		0,0000
WIG20TR-Warset2	03-12-2012	0.0367	0.01	0.01	0.0001	0.0000	0.0000	0.0000	**0.1426**	0.0028	0.01	0.0001	0.0000	0.0000	0.0000
WIG30-All	28-12-2012	0.01	0.01	0.01	0.0001	0.0000	0.0000	0.0000	0,0000	0,0000	0,0000	0,0000	0,0000		0,0000
WIG30-Warset2	23-09-2013	0.01	0.01	0.01	0.0001	0.0000	0.0000	0.0000	**0.0876**	0.0012	0.01	**0.3206**	0.0000	0.0000	0.0000
WIG30TR-All	28-12-2012	0.01	0.01	0.01	0.0001	0.0000	0.0000	0.0000	0,0000	0,0000	0,0000	0,0000	0,0000		0,0000
WIG30TR-Warset	23-09-2013	0.01	0.01	0.0001	0.0001	0.0000	0.0000	0.0000	**0.2318**	0.0456	0.01	0.0005	0.0003	0.0003	0.0001
WIG-DIV-Warset	03-01-2011	0.01	0.01	0.01	0.0001	0.0000	0.0000	0.0000	0.01	0.01	0.01	0.0001	0.0000	0.0000	0.0000
mWIG40-All	31-12-1997	0.01	0.01	0.01	0.0001	0.0000	0.0000	0.0000	0,0000	0,0000	0,0000	0,0000	0,0000		0,0000
mWIG40-Warset	17-10-2000	0.01	0.01	0.01	0.0001	0.0000	0.0000	0.0000	0.01	0.01	0.01	0.0001	0.0000	0.0000	0.0000
sWIG80-All	29-12-1994	0.01	0.01	0.01	0.0001	0.0000	0.0000	0.0000	0,0000	0,0000	0,0000	0,0000	0,0000		0,0000
sWIG0-Warset	17-10-2000	0.01	0.01	0.01	0.0001	0.0000	0.0000	0.0000	0.01	0.01	0.01	0.0001	0.0000	0.0000	0.0000
NCIndex-Warset	24-06-2013	0.01	0.01	0.01	0.0001	0.0000	0.0000	0.0000	0.01	0.01	0.01	0.0001	0.0000	0.0000	0.0000
Investorms	31-12-2002	0.01	0.01	0.01	0.0001	0.0000	0.0000	0.0000	0.01	0.01	0.01	0.0001	0.0000	0.0000	0.0000
Respect	31-12-2008	0.01	0.01	0.01	0.0001	0.0000	0.0000	0.0000	0.01	0.01	0.01	0.0001	0.0000	0.0000	0.0000

Tab. 1. Results of testing the null hypothesis from the first quotation date until 31 March 2017

	C-C						O-O						O-C						Overnight					
	Jarque--Bera	K-S	Lilliefors	Cramer--Von Mises	Watson	Anderson--Darling	Jarque--Bera	K-S	Lilliefors	Cramer--Von Mises	Watson	Anderson--Darling	Jarque--Bera	K-S	Lilliefors	Cramer--Von Mises	Watson	Anderson--Darling	Jarque--Bera	K-S	Lilliefors	Cramer--Von Mises	Watson	Anderson--Darling
2001	**0.1071**	**0.1**	**0.1**	**0.967**	**0.1313**	**0.097**	0.0018	**0.1**	**0.11**	0.0185	0.012	0.0115	0.0039	**0.1**	**0.12**	**0.1289**	**0.1494**	**0.1137**	0	0.0085	0.0086	0.0013	0.0014	0.0005
2002	0.00002	0.0031	0.0032	0.0032	0.0032	0.0025	0	**0.1**	**0.13**	**0.1494**	**0.1252**	**0.0613**	0.0008	0.0246	0.0249	0.0137	0.0121	**0.159**	0	0.0084	0.0085	0.0008	0.0004	0.0006
2003	**0.1442**	0.0008	0.0007	0.0016	0.0012	0.0015	**0.1898**	**0.1**	**0.11**	0.01156	**0.115**	**0.0697**	**0.2491**	0.0445	0.0445	**0.0576**	0.0483	0.0436	**0.1526**	0.01	**0.12**	0.0149	0.0101	0.0141
2004	0.0003	0.0067	0.0062	0.0021	0.0011	0.0020	0.0013	**0.1**	**0.11**	**0.1098**	**0.0887**	**0.1155**	0.0169	**0.0598**	**0.0595**	**0.0502**	0.0412	**0.415**	0	0.0031	0.0036	0	0	0
2005	0	**0.0585**	**0.0589**	**0.0719**	**0.1459**	0.0279	0.0084	0.0147	**0.156**	**0.0524**	**0.0685**	0.0328	0.0023	**0.1**	**0.12**	**0.7515**	**0.8411**	**0.5734**	0	0.0001	0.0002	0	0	0
2006	0	0.0373	0.0372	0.0189	0.0238	0.0045	0	**0.055**	**0.0562**	0.0095	0.0281	0.0028	0.0001	0.0227	0.0226	0.014	0.0176	0.0066	0	0.0001	0	0	0	0
2007	0	**0.1**	**0.103**	**0.3967**	**0.3883**	**0.2082**	0	0.0016	0.0017	0.0001	0.0001	0	**0.1287**	**0.12**	**0.123**	**0.3715**	**0.3491**	**0.2726**	0	0	0	0	0	0
2008	0	0.0282	0.0283	0.0019	**12**	0.0007	0	0.0002	0.0001	0	0	0	0	0.0074	0.0075	0.0004	0.0002	0.0002	0	0	0	0	0	0
2009	0.0161	**0.1**	0.012	**0.1241**	**0.1222**	**0.0855**	**0.2848**	**0.11**	**0.12**	**0.361**	**0.625**	**0.22**	0.0373	**0.11**	**0.13**	**0.3205**	**0.2894**	**0.2694**	**0.1036**	**0.1**	**0.12**	**0.5568**	**0.5716**	**0.4224**
2010	0	0.0032	0.0031	0.0004	0.0003	0.0001	0	0.0006	0.0005	0.0016	0.0014	0.0012	0	0.0444	0.0454	0.0109	0.0081	0.0038	0	0.0018	0.0019	0.0001	0.0001	0
2011	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	0.0127	**0.1**	**0.12**	0.0391	0.0299	0.0350	0.0033	**0.1**	**0.12**	**0.0892**	**0.07**	**0.0905**	**0.1374**	**0.13**	**0.11**	**0.1532**	**0.1313**	**0.192**	0	0.0097	0.0095	0.0005	0.0003	0.0003
2013	0	**0.051**	**0.0512**	0.012	0.0006	0.0003	0	0.0088	0.0089	0.0006	0.0003	0.0001	0	0	0	0	0	0	0	0.0046	0.0047	0.0001	0	0
2014	0	0.0487	0.0485	0.017	**0.117**	0.0085	0.0116	**0.11**	**0.12**	**0.3782**	**0.4272**	**0.2503**	**0.4868**	**0.12**	**0.12**	**0.411**	**0.3704**	**0.5076**	0	0	0	0	0	0
2015	0	0.0003	0.0002	0	0	0	0	0.0082	0.0085	0.0011	0.0021	0.0001	0.0001	0.0043	0.0043	0.0024	0.0019	0.0027	0	0	0	0	0	0
2016	0	0	0	0.0002	0.0001	0.0004	0	0	0	0	0	0	0	**0.0871**	**0.0873**	0.0032	0.0017	0.0014	0	0	0	0	0	0

Tab. 2. Results of testing the null hypothesis for each year – WIG index

WIG20	C-C						O-O						O-C						Overnight					
	Jarque--Bera	K-S	Lilliefors	Cramer--Von Mises	Watson	Anderson--Darling	Jarque--Bera	K-S	Lilliefors	Cramer--Von Mises	Watson	Anderson--Darling	Jarque--Bera	K-S	Lilliefors	Cramer--Von Mises	Watson	Anderson--Darling	Jarque--Bera	K-S	Lilliefors	Cramer--Von Mises	Watson	Anderson--Darling
2001	0	0	0	0	0	0	0	0	0	0	0	0	0.1962	0.1	0.12	0.282	0.307	0.312	0	0	0	0	0	0
2002	0.0083	0.0161	0.0162	0.0203	0.0238	0.0152	0	**0.0896**	**0.0892**	0.0467	0.0379	0.0099	0	**0.0929**	**0.0925**	0.0049	0.0046	0.0035	0	0.0049	0.0052	0.0006	0.0003	0.0004
2003	0.041	0.0046	0.0047	0.0036	0.0033	0.0033	**0.2434**	**0.13**	**0.125**	**0.1252**	**0.1225**	**0.1122**	**0.2397**	**0.13**	**0.135**	**0.0556**	0.0451	0.0303	**0.0732**	0.0181	0.0183	0.0095	0.0069	0.0109
2004	0.002	0.0024	0.0025	0.0018	0.0009	0.0013	0.0022	**0.11**	**0.12**	**0.3191**	**0.3053**	**0.286**	0.0455	0.012	**0.13**	**0.1666**	**0.1407**	**0.1564**	0	0.0015	0.0015	0.0005	0.0003	0.0003
2005	0.0001	**0.12**	**0.13**	**0.1193**	**0.1619**	**0.062**	**0.0671**	0.0281	0.0285	**0.0885**	**0.0925**	**0.067**	**0.1338**	**0.1**	**0.11**	**0.9696**	**0.9818**	**0.855**	0	0.0067	0.0068	0.0004	0.0004	0.0001
2006	0.004	0.0289	0.0292	**0.0582**	**0.0631**	0.031	0	**0.1**	**0.1**	**0.0711**	**0.1499**	0.0377	0.0226	**0.0773**	**0.0778**	0.0236	0.0207	0.0203	0	0.0003	0	0	0	0
2007	**0.1536**	**0.123**	**0.125**	**0.2994**	**0.3012**	**0.2449**	0.0267	**0.1**	**0.1**	0.0394	0.046	0.0191	**0.5676**	**0.1**	**0.1**	**0.888**	**0.9031**	**0.9419**	0	0.0007	0.0007	0.0007	0.0014	0.0003
2008	0.0001	0.0308	0.0308	0.0083	0.0055	0.0031	0	0.0003	0.0003	0	0	0	0	0.0054	0.0054	0	0	0	0	0	0	0	0	0
2009	**0.221**	**0.15**	**0.13**	**0.3798**	**0.3935**	**0.381**	**0.1491**	**0.1**	**0.1**	**0.3419**	**0.348**	**0.357**	**0.4204**	**0.1**	**0.1**	**0.1972**	**0.1746**	**0.1896**	**0.135**	**0.1**	**0.1**	**0.2233**	**0.2223**	**0.2034**
2010	**0.2022**	**0.16**	**0.15**	**0.6036**	**0.6191**	**0.5384**	0	0.0244	0.0254	0.0274	0.0237	0.0369	0	**0.0756**	**0.759**	**0.0533**	0.0461	0.022	0	0.0069	0.0072	0.0081	0.0058	0.0031
2011	0	0.0164	0.0165	0.0047	0.0028	0.0017	0	0.0236	0.0245	0.0274	0.0256	0.0356	0	**0.0895**	**0.0865**	**0.0596**	**0.0521**	0.0352	0	0.0023	0.0026	0.0079	0.0026	0.0036
2012	0	0.0003	0.0001	0	0	0	0	0.0003	0.0002	0	0	0	0	0.0001	0.0001	0	0	0	0	0.0001	0.0001	0	0	0
2013	0	**0.1**	**0.11**	**0.1159**	0.0034	0.0013	0.0001	**0.0604**	**0.0652**	0.0051	0.0029	0.0015	0	0.0001	0	0	0	0	0	0.0152	0.0153	0.0019	0.0011	0.0003
2014	0	**0.11**	**0.12**	**0.2949**	**0.2719**	**0.2093**	**0.1455**	**0.1**	**0.1**	**0.3368**	**0.3336**	**0.3298**	**0.8964**	**0.1**	**0.1**	**0.4868**	**0.4467**	**0.5412**	0	0	0	0	0	0
2015	0	0.0027	0.0028	0.0002	0.0001	0.0002	0	0.002	0.0019	0.0016	0.0025	0.001	0	0.0001	0.0001	0.0012	0.0012	0.0021	0	0	0	0	0	0
2016	0.0044	**0.0587**	**0.0589**	0.0168	0.0115	0.0161	0	0.004	0.0039	0	0	0	0	**0.0579**	**0.0589**	0.0147	0.0111	0.0153	0	0	0	0	0	0

Tab. 3. Results of testing the null hypothesis for each year – WIG20 index

DOI 10.7172/1644-9584.74.1

mWIG40	C-C						O-O						O-C						Overnight					
	Jarque--Bera	K-S	Lilliefors	Cramer--Von Mises	Watson	Anderson--Darling	Jarque--Bera	K-S	Lilliefors	Cramer--Von Mises	Watson	Anderson--Darling	Jarque--Bera	K-S	Lilliefors	Cramer--Von Mises	Watson	Anderson--Darling	Jarque--Bera	K-S	Lilliefors	Cramer--Von Mises	Watson	Anderson--Darling
2001	0.001		**0.1**	**0.3469**	**0.3125**	**0.3199**	0		0.0497	0.0017	0.001	0.0005	0		0.1	0.2698	**0.3259**	**0.1992**	0		0	0	0	0
2002	0		**0.1**	**0.1319**	**0.1193**	**0.0767**	0		0.0021	0.0021	0.0013	0.0007	0		**0.1**	0.0236	0.0157	0.016	0		0.0005	0	0	0
2003	0.0047		**0.0513**	0.0143	0.0092	0.021	0		0.0151	0.0003	0.0002	0.0001	0.0166		**0.1**	**0.1161**	**0.0955**	**0.1278**	0		0	0	0	0.0002
2004	0		0.0086	0.0019	0.0046	0.0003	0		0.0286	0.0204	0.0169	0.0082	0.0009		**0.1**	0.0269	0.0222	0.0144	0		0.0007	0	0	0
2005	0.0007		**0.0617**	0.0281	0.0345	0.0167	**0.5113**		**0.1**	**0.2478**	**0.2379**	**0.2526**	0.0423		0.1	0.1423	**0.1615**	**0.0729**	0		0.00192	0.0011	0.0007	0.0003
2006	0		0.0036	0	0	0	0		0.0005	0	0	0	0		0.0157	0.0028	0.004	0.0021	0		0	0	0	0
2007	0		0.0075	0.0009	0.0008	0.0001	0		0	0	0	0	0		0.0012	0.0001	0	0	0		0	0	0	0
2008	0		0.0003	0	0	0	0		0.0003	0	0	0	0		0	0	0	0	0		0	0	0	0
2009	0		0.039	**0.0786**	**0.0632**	0.0456	0		0.0496	0.0443	0.0467	0.0084	0.0356		0.1	0.2205	**0.2055**	**0.1352**	0		0.0412	0.0134	0.0134	0.0053
2010	0		0.024	0.0006	0.0004	0.0001	0		0.023	0.0002	0.0001	0	0		**0.0887**	0.0082	0.0049	0.0051	0		0	0	0	0
2011	0		0	0	0	0	0		0	0	0	0	0		0	0	0	0	0		0	0	0	0
2012	0.0001		0.0043	0.003	0.0021	0.001	0.0214		0.0212	0.0294	0.0289	0.0399	0.0139		0.0345	0.0068	0.0039	0.0065	0		0.0035	0.0001	0	0
2013	0		0.0479	0.0024	0.0029	0.0016	0		**0.0822**	0.0279	0.0272	0.0099	0		0.0145	0.0008	0.0006	0.0002	0		0	0	0	0
2014	0		0.01	0.0057	0.0033	0.0019	0		0.1	0.232	0.2008	**0.0829**	0		**0.1**	**0.4303**	**0.4091**	**0.346**	0		0	0	0	0
2015	0		0.0015	0.0003	0.0002	0.0002	0		0	0	0	0	0		0.0115	0.0025	0.0014	0.0014	0		0	0	0	0
2016	0		0.0032	0.001	0.0012	0.001	0		0.004	0	0	0	0.0041		**0.0893**	0.0079	**0.52**	0.006	0		0	0	0	0

Tab. 4. Results of testing the null hypothesis for each year – mWIG40 index

sWIG80	C-C						O-O						O-C						Overnight					
	Jarque--Bera	K-S	Lilliefors	Cramer--Von Mises	Watson	Anderson--Darling	Jarque--Bera	K-S	Lilliefors	Cramer--Von Mises	Watson	Anderson--Darling	Jarque--Bera	K-S	Lilliefors	Cramer--Von Mises	Watson	Anderson--Darling	Jarque--Bera	K-S	Lilliefors	Cramer--Von Mises	Watson	Anderson--Darling
2001	0.0032		0.1	**0.129**	**0.1055**	**0.1**	0.0024		**0.1**	**0.1827**	**0.1546**	**0.2262**	0.0002		0.0066	0.008	0.0096	0.0038	0		0.001	0.0127	0.0249	0.013
2002	**0.4336**		0.0051	0.0386	0.0289	**0.0586**	0		0.0261	0.0054	0.0033	0.0054	0		0.0001	0	0	0	0		0.0056	0.0044	0.0028	0.0012
2003	0.0052		**0.1**	**0.1294**	**0.1061**	**0.0879**	0.0334		**0.1**	**0.347**	**0.3164**	**0.2411**	0.0192		**0.0716**	**0.2177**	**0.1904**	**0.2013**	0.0173		**0.1**	**0.0741**	**0.0579**	0.0316
2004	0		0.0002	0	0.0001	0	0		0.0001	0	0	0	0		0.0126	0.0033	0.002	0.0017	0		0.0001	0	0	0
2005	**0.1007**		0.1	0.1508	0.1633	0.1169	0.9008		0.1	0.8843	0.8759	0.9226	0.2735		**0.1**	**0.545**	**0.5112**	**0.4615**	0		0.1	0.1662	0.2506	**0.1165**
2006	0		0	0	0	0	0		0	0	0	0	0		0	0	0	0	0		0	0	0	0
2007	0		0	0	0	0	0		0	0	0	0	0		0.0005	0	0	0	0		0	0	0	0
2008	0		0.0003	0	0	0	0		0.0002	0	0	0	0		0	0	0	0	0		0	0	0	0
2009	0		0.0877	0.0109	0.0067	0.0036	0		**0.1**	**0.0553**	0.0419	0.021	0.0017		**0.0565**	**0.148**	**0.123**	**0.0575**	0		0.0089	0.0024	0.0029	0.0008
2010	0		0	0	0	0	0		0.0001	0	0	0	0		0.0037	0.0007	0.0003	0.0001	0		0	0	0	0
2011	0		0	0	0	0	0		0	0	0	0	0		0	0	0	0	0		0	0	0	0
2012	0		0.0143	0.0014	0.0009	0.0004	0		0.0072	0.0011	0.0008	0.0006	0		0.0387	0.0006	0.0003	0.0002	0		0.0172	0.0007	0.0004	0.0002
2013	0		0.0004	0	0	0	0		0.0021	0	0	0	0		0	0	0	0	0		**0.0631**	0.0045	0.0046	0.0026
2014	0		0.0004	0	0	0	0		0.0009	0.0002	0.0002	0	0		0.0015	0	0	0	0		0	0	0	0
2015	0		0	0	0	0	0		0	0	0	0	0		0.0061	0.0001	0	0	0		0	0	0	0
2016	0		0	0	0	0	0		0	0	0	0	0		0	0	0	0	0		0	0	0	0

Tab. 5. Results of testing the null hypothesis for each year – sWIG80 index

DOI 10.7172/1644-9584.74.1

	WIG				WIG20				mWIG40			
	C-C	O-O	O-C	Overnight	C-C	O-O	O-C	Overnight	C-C	O-O	O-C	Overnight
2001	**6**	**2**	**5**	0	0	0	**6**	0	**4**	0	**4**	0
2002	0	**5**	1	0	0	**2**	**2**	0	**4**	0	1	0
2003	1	**5**	**2**	**2**	0	**6**	**4**	1	1	0	**4**	0
2004	0	**5**	**4**	0	0	**5**	**4**	0	0	0	1	0
2005	**4**	**3**	**5**	0	**5**	**4**	**6**	0	1	**5**	**4**	0
2006	0	**2**	0	0	**2**	**4**	**2**	0	0	0	0	0
2007	**5**	0	**6**	0	**6**	**2**	**6**	0	0	0	0	0
2008	1	0	0	0	0	0	0	0	0	0	0	0
2009	**4**	**6**	**5**	**6**	**6**	**6**	**6**	**6**	**2**	0	**4**	0
2010	0	0	0	0	**6**	0	**3**	0	0	0	1	0
2011	0	0	0	0	0	0	**4**	0	0	0	0	0
2012	**2**	**5**	**6**	0	0	0	0	0	0	0	0	0
2013	**2**	0	0	0	**3**	**2**	0	0	0	1	0	0
2014	1	**5**	**6**	0	**5**	**6**	**6**	0	0	**4**	**4**	0
2015	0	0	0	0	0	0	0	0	0	0	0	0
2016	0	0	**2**	0	**2**	0	**2**	0	0	0	**2**	0

	sWIG80				For each index the null hypothesis is confirmed by at least 2 tests			
	C-C	O-O	O-C	Overnight	C-C	O-O	O-C	Overnight
2001	**4**	**4**	0	0	FALSE	FALSE	FALSE	FALSE
2002	**2**	0	0	0	FALSE	FALSE	FALSE	FALSE
2003	**4**	**4**	**4**	**3**	FALSE	FALSE	**TRUE**	FALSE
2004	0	0	0	0	FALSE	FALSE	FALSE	FALSE
2005	**5**	**5**	**5**	**4**	FALSE	**TRUE**	**TRUE**	FALSE
2006	0	0	0	0	FALSE	FALSE	FALSE	FALSE
2007	0	0	0	0	FALSE	FALSE	FALSE	FALSE
2008	0	0	0	0	FALSE	FALSE	FALSE	FALSE
2009	1	**2**	**4**	0	FALSE	FALSE	**TRUE**	FALSE
2010	0	0	0	0	FALSE	FALSE	FALSE	FALSE
2011	0	0	0	0	FALSE	FALSE	FALSE	FALSE
2012	0	0	0	0	FALSE	FALSE	FALSE	FALSE
2013	0	0	0	1	FALSE	FALSE	FALSE	FALSE
2014	0	0	0	0	FALSE	FALSE	FALSE	FALSE
2015	0	0	0	0	FALSE	FALSE	FALSE	FALSE
2016	0	0	0	0	FALSE	FALSE	FALSE	FALSE

Tab. 6. Number of cases when the null hypothesis cannot be rejected (numbers higher than or equal to 2 are in bold)

Number	The wave beginning	The wave end	Up or down wave	C-C					
				Jarque--Bera	K-S	Lilliefors	Cramer--Von Mises	Watson	Anderson--Darling
1	19-12-2000	24-29-2001	↓	0.9189		**0.1**	**0.7832**	**0.7665**	**0.8296**
2	24-29-2001	25-01-2002	↑	0.9936		0.1	0.3118	0.284	0.2439
3	25-01-2002	26-07-2002	↓	0.7043		**0.1**	**0.2418**	**0.2099**	**0.3222**
4	26-07-2002	09-07-2007	↑	0		0	0	0	0
5	09-07-2007	18-02-2009	↓	0		0.0008	0.0006	0.0003	0.0001
6	18-02-2009	08-04-2011	↑	0		0	0	0	0
7	08-04-2011	23-09-2011	↓	0		0	0	0	0
8	23-09-2011	08-05-2015	↑	0		0	0	0	0
9	08-05-2015	21-01-2016	↓	0		0.0083	0.0013	0.001	0.0022
10	21-01-2016	30-04-2017	↑	0		0.0005	0.0002	0.0001	0.0003

Number	O-O						O-C						Overnight					
	Jarque--Bera	K-S	Lilliefors	Cramer--Von Mises	Watson	Anderson--Darling	Jarque--Bera	K-S	Lilliefors	Cramer--Von Mises	Watson	Anderson--Darling	Jarque--Bera	K-S	Lilliefors	Cramer--Von Mises	Watson	Anderson--Darling
1	0.029		0.1	0.1811	0.2358	0.1325	0.5924		0.1	0.465	0.4225	**0.5138**	0		0.0005	0.0001	0.0002	0.0001
2	0.1482		0.1	0.0315	0.0317	0.0289	0.0143		0.0495	0.0267	0.0354	0.0138	0.0083		0.0021	0.0001	0.0001	0
3	0		**0.1**	**0.087**	**0.0704**	0.0454	**0.0843**		**0.1**	**0.4676**	**0.4276**	**0.4268**	0		0.015	0.0005	0.0002	0.0001
4	0		0	0	0	0	0		0	0	0	0	0		0	0	0	0
5	0		0.0001	0	0	0	0		0.0008	0	0	0	0		0	0	0	0
6	0		0.0001	0	0	0	0		0.0008	0	0	0	0		0	0	0	0
7	0		0	0	0	0	0		0	0	0	0	0		0	0	0	0
8	0		0	0	0	0	0		0	0	0	0	0		0	0	0	0
9	0		0.0067	0.0069	0.0116	0.0022	**0.2796**		**0.1**	**0.4359**	**0.4262**	**0.5024**	0		0	0	0	0
10	0		0.001	0	0	0	0		0.0185	0.0002	0.0001	0	0		0	0	0	0

Tab. 7. Results of testing the null hypothesis for up and down waves – WIG index

Number	The wave beginning	The wave end	Up or down wave	C-C					
				Jarque-Bera	K-S	Lilliefors	Cramer--Von Mises	Watson	Anderson--Darling
1	18-10-2000	19-12-2000	↑	0.5249		0.1	0.5601	0.6083	0.5364
2	19-12-2000	25-09-2001	↓	0.0744		0.01	**0.8185**	**0.8345**	**0.8848**
3	25-09-2001	25-01-2002	↑	0.7790		0.0908	0.856	0.079	0.0719
4	25-01-2002	26-07-2002	↓	0.4855		**0.1**	**0.3812**	**0.3478**	**0.4947**
5	26-07-2002	26-10-2007	↑	0		0	0	0	0
6	26-10-2007	18-02-2009	↓	0		0.0085	0.0036	0.0022	0.0012
7	18-02-2009	08-04-2011	↑	0		0.0001	0	0	0
8	08-04-2011	24-05-2012	↓	0		0	0	0	0
9	24-05-2012	02-01-2013	↑	0.0931		**0.1**	**0.3027**	**0.2726**	**0.3169**
10	02-01-2013	21-01-2016	↓	0		0.0004	0	0	0
11	21-01-2016	28-04-2017	↑	0.0007		0.0219	0.0058	0.0037	0.0056

Number	O-O						O-C						Overnight					
	Jarque--Bera	K-S	Lilliefors	Cramer--Von Mises	Watson	Anderson--Darling	Jarque--Bera	K-S	Lilliefors	Cramer--Von Mises	Watson	Anderson--Darling	Jarque--Bera	K-S	Lilliefors	Cramer--Von Mises	Watson	Anderson--Darling
1	0.5793		0.1	0.4207	0.4828	0.3743	0.4452		**0.1**	**0.6613**	**0.7219**	**0.4048**	0.0336		0.005	0.002	0.0014	0.0043
2	**0.2936**		0.1	0.3581	0.3724	0.4787	0.6749		**0.1**	**0.8836**	**0.8689**	**0.8835**	0.0019		0.0001	0.0001	0.0001	0.0001
3	0.1349		**0.1**	0.0186	0.0202	0.0218	0.0393		0.0452	0.0129	0.0213	0.0115	0.0064		0	0	0	0
4	0		**0.1**	**0.1163**	**0.0972**	**0.0544**	0.0114		0.1	0.7465	**0.705**	**0.5094**	0		0.0028	0.0004	0.0002	0.0001
5	0		0.0001	0	0	0	0		0.0009	0	0	0	0		0	0	0	0
6	0		0.0008	0	0	0	0		0.0009	0	0	0	0		0	0	0	0
7	0		0	0	0	0	0		0	0	0	0	0		0.0005	0	0	0
8	0		0.0002	0	0	0	0		0.0012	0	0	0	0		0.0001	0	0	0
9	0		0.0109	0.0025	0.0013	0.0016	0.0233		0.1	0.1527	**0.1317**	**0.115**	0		0.0001	0	0	0
10	0		0.0005	0	0	0	0		0	0	0	0	0		0	0	0	0
11	0		0.0007	0	0	0	0		0.0136	0.0016	0.0013	0.001	0		0	0	0	0

Tab. 8. Results of testing the null hypothesis for up and down waves – WIG20 index

Number	The wave beginning	The wave end	Up or down wave	C-C					
				Jarque-Bera	K-S	Lilliefors	Cramer--Von Mises	Watson	Anderson--Darling
1	18-10-2000	02-02-2001	↑	0.1965		**0.1**	**0.3894**	**0.3498**	**0.3723**
2	02-02-2001	14-03-2001	↓	0.3454		0.1	0.6739	0.7357	0.6582
3	14-03-2001	26-04-2001	↑	0.5317		0.0898	0.3165	0.3217	0.2867
4	26-04-2001	16-08-2001	↓	0.7578		0.1	0.6772	0.6297	0.7268
5	16-08-2001	25-01-2002	↑	0.0016		0.1	**0.2114**	**0.2988**	**0.172**
6	25-01-2002	08-10-2002	↓	0.1891		**0.1**	**0.6**	**0.7101**	**0.5243**
7	08-10-2002	27-06-2007	↑	0		0	0	0	0
8	27-06-2007	23-02-2009	↓	0		0	0	0	0
9	23-02-2009	07-04-2011	↑	0		0.0004	0	0	0
10	07-04-2011	10-08-2011	↓	0		0	0	0	0
11	10-08-2011	19-03-2012	↑	0		0.0001	0	0	0
12	19-03-2012	05-06-2012	↓	0.2987		0.1	0.11	0.1328	0.1409
13	05-06-2012	11-05-2015	↑	0		0	0	0	0
14	11-05-2015	20-01-2016	↓	0		0.0229	0.0239	0.0219	0.0266
15	20-01-2016	25-04-2016	↑	0.5924		0.1	**0.5678**	**0.5308**	**0.5155**
16	25-04-2016	23-06-2016	↓	0.8316		0.1	0.3738	0.3431	0.436
17	23-06-2016	02-03-2017	↑	0		0.0151	0.0006	0.0004	0.0003

Number	O-O						O-C						Overnight					
	Jarque--Bera	K-S	Lilliefors	Cramer--Von Mises	Watson	Anderson--Darling	Jarque-Bera	K-S	Lilliefors	Cramer--Von Mises	Watson	Anderson--Darling	Jarque--Bera	K-S	Lilliefors	Cramer--Von Mises	Watson	Anderson--Darling
1	0.0015		**0.0788**	**0.0799**	**0.0918**	0.0386	**0.3019**		0.1	0.196	0.2492	0.1989	0.135		0.0357	0.009	0.0067	0.0124
2	0.53		0.1	0.4977	0.5089	0.5443	0.4551		0.1	0.384	0.3445	0.3947	0.9941		**0.1**	**0.9726**	**0.9674**	**0.9634**
3	0.5134		0.0624	0.1121	0.1061	0.1827	0.5155		0.0364	**0.124**	**0.1219**	**0.1387**	**0.2274**		0.0163	**0.0742**	**0.102**	**0.0719**
4	0.706		0.1	0.8146	0.7862	0.7177	0.3164		0.1	0.2322	0.2394	0.2617	0.0928		**0.1**	**0.5391**	**0.6425**	**0.3785**
5	0		0.0113	0.0006	0.0003	0.0002	0		0.0136	0.0106	0.02	0.0048	0		0	0	0	0
6	0		0.009	0.0059	0.0068	0.0032	0.0008		0.1	0.0427	0.0408	0.0431	0		0.0029	0.0003	0.0002	0
7	0		0	0	0	0	0		0	0	0	0	0		0	0	0	0
8	0		0	0	0	0	0		0	0	0	0	0		0	0	0	0
9	0		0.0017	0	0	0	0		0.0001	0	0	0	0		0	0	0	0
10	0		0	0	0	0	0		0	0	0	0	0		0	0	0	0
11	0		0.0014	0.0001	0	0	0		0.0034	0.0006	0.0003	0.0003	0		0	0	0	0
12	0.7921		0.1	0.8627	0.8505	0.8626	0.7313		**0.1**	**0.7806**	**0.7249**	**0.6791**	0		**0.0919**	0.0219	0.0451	0.0086
13	0		0.0029	0.0001	0	0	0		0.0001	0.0001	0	0	0		0	0	0	0
14	0		0.0003	0	0	0	0.0008		**0.1**	**0.1105**	**0.0993**	**0.0813**	0		0	0	0	0
15	0.0001		**0.1**	**0.0517**	0.0385	0.029	0.0019		**0.0672**	0.0215	0.0149	**0.197**	**0.1476**		0.1	0.1722	0.1826	**0.1757**
16	0.6338		0.01	**0.8046**	**0.7835**	**0.7589**	**0.853**		0.1	**0.5926**	**0.5543**	**0.5638**	0.0193		**0.1**	**0.0804**	**0.119**	**0.0817**
17	0		0.0232	0.0008	0.0004	0.0001	0.0195		**0.1**	**0.1588**	**0.1382**	**0.1199**	0		0	0	0	0

Tab. 9. Results of testing the null hypothesis for up and down waves – mWIG40 index

DOI 10.7172/1644-9584.74.1

Problemy Zarządzania – Management Issues vol. 16, no. 2(74), 2018

Number	The wave beginning	The wave end	Up or down wave	C-C						O-O						O-C						Overnight					
				Jarque-Bera	K-S	Lilliefors	Cramer--Von Mises	Watson	Anderson--Darling	Jarque--Bera	K-S	Lilliefors	Cramer--Von Mises	Watson	Anderson--Darling	Jarque--Bera	K-S	Lilliefors	Cramer--Von Mises	Watson	Anderson--Darling	Jarque--Bera	K-S	Lilliefors	Cramer--Von Mises	Watson	Anderson--Darling
1	20-10-2000	26-08-2002	↓	0.0028		0.0446	0.0095	0.0057	0.0068	0		0.0167	0.0027	0.0015	0.0027	0		0.0002	0	0	0	0		0	0.0002	0.0002	0.0001
2	26-08-2002	06-07-2007	↑	0		0	0	0	0	0		0	0	0	0	0		0	0	0	0	0		0	0	0	0
3	06-07-2007	18-02-2009	↓	0		0	0	0	0	0		0	0	0	0	0		0	0	0	0	0		0	0	0	0
4	18-02-2009	17-02-2011	↑	0		0	0	0	0	0		0	0	0	0	0		0	0	0	0	0		0	0	0	0
5	17-02-2011	20-12-2011	↓	0		0	0	0	0	0		0	0	0	0	0		0	0	0	0	0		0	0	0	0
6	20-12-2011	25-11-2013	↑	0		0.0002	0	0	0	0		0	0	0	0	0		0	0	0	0	0		0.0003	0	0	0
7	25-11-2013	08-08-2014	↓	0		0.0173	0.0015	0.0016	0.0003	0		**0.086**	**0.1146**	**0.1024**	0.0287	0		0.0243	0.011	0.0067	0.0015	0		0	0	0	0
8	08-08-2014	11-05-2015	↑	0.0913		0.0287	**0.0609**	**0.0587**	**0.0712**	0.0027		0.1	0.3205	0.471	0.1767	0.3202		**0.1**	**0.857**	**0.8506**	**0.6666**	0		0.0002	0	0	0
9	11-05-2015	25-08-2015	↓	0		0.0001	0	0	0	0		0.0003	0	0	0	0	0.0001	0	0	0	0	0		0	0	0	0
10	25-08-2015	03-11-2015	↑	0.3004		**0.1**	**0.4297**	**0.4518**	**0.3028**	0		0.0069	0.0014	0.0017	0.0003	**0.5692**		**0.1**	**0.8057**	**0.837**	**0.7958**	0.013		**0.1**	**0.4507**	**0.5879**	**0.2418**
11	03-11-2015	21-01-2016	↓	0.2845		**0.1**	0.0395	0.048	0.0389	**0.3916**		0.1	0.3157	0.3731	0.3238	0.855		**0.1**	**0.7211**	**0.6696**	**0.7249**	0.0037		0.0004	0.0003	0.0007	0.0001
12	21-01-2016	17-05-2016	↑	0.3987		**0.1**	**0.4177**	**0.4285**	**0.4688**	0.0086		**0.1**	**0.1541**	**0.1284**	**0.1113**	0		**0.1**	**0.2428**	**0.2265**	**0.1826**	0		**0.0804**	0.0161	0.0104	0.0098
13	17-05-2016	24-06-2016	↓	0.0016		0.029	0.0071	0.0139	0.004	0		0.0079	0.0003	0.0005	0.0001	0.0364		0.0326	**0.0799**	**0.0618**	0.0427	0		0	0	0	0
14	24-06-2016	07-03-2017	↑	0		**0.1**	0.045	0.038	0.0287	0		0.0056	0.0039	0.0031	0.0011	0		**0.1**	0.0251	0.0173	0.0084	0		0.0002	0	0	0

Tab. 10. Results of testing the null hypothesis for up and down waves – sWIG80 index

	30 sessions											
	Jarque-Barre				Shapiro-Wilk				D'Agostino-Pearson			
	C-C	O-O	O-C	OV	C-C	O-O	O-C	OV	C-C	O-O	O-C	OV
WIG-All	89	86	91	75	88	86	92	76	84	81	84	67
WIG-Warset	91	86	91	71	90	87	92	72	85	81	84	62
WIG-Banki – All	90	90	85	82	89	90	87	82	85	85	79	77
WIG-Banki-Warset	90	91	86	82	90	91	87	82	85	86	79	76
WIG-Budownictwo-Warset	81	83	79	78	84	83	82	81	75	76	69	72
WIG-Budownictwo-All	83	83	79	80	86	85	82	83	77	77	70	74
WIG-CEE-All	80	85	70	59	85	83	63	62	73	73	60	50
WIG-Chemia-Warset	89	86	76	80	90	88	76	84	84	78	68	74
WIG-Developerzy-Warset	87	84	89	76	89	88	90	80	82	78	82	72
WIG-Energia-Warset	90	83	85	74	90	87	87	75	84	74	80	67
WIG-Informatyka-All	88	86	80	79	89	89	82	82	82	79	74	72
WIG-Informatyka-Warset	87	84	81	77	87	88	82	79	80	77	74	69
WIG-Media-Warset	86	86	79	85	90	89	84	86	78	79	74	79
WIG-Paliwa-Warset	90	89	91	87	91	90	92	88	86	82	85	83
WIG-Poland-All	90	88	86	85	88	88	89	84	84	82	78	79
WIG-Poland-Warset	92	90	86	85	91	90	89	84	86	84	79	79

	100 sessions											
	Jarque-Barre				Shapiro-Wilk				D'Agostino-Pearson			
	C-C	O-O	O-C	OV	C-C	O-O	O-C	OV	C-C	O-O	O-C	OOV
WIG-All	64	59	64	37	64	61	70	35	60	55	60	34
WIG-Warset	61	54	64	24	64	60	71	24	57	50	60	22
WIG-Banki – All	68	70	59	54	73	73	61	57	65	66	54	51
WIG-Banki-Warset	69	70	60	52	73	73	62	55	66	66	55	49
WIG-Budownictwo-Warset	52	55	51	40	58	59	56	44	48	51	45	37
WIG-Budownictwo-All	55	55	51	43	63	61	55	48	51	52	45	41
WIG-CEE-All	45	47	33	10	51	51	31	5	40	41	25	8
WIG-Chemia-Warset	59	54	40	43	66	61	38	56	53	50	37	38
WIG-Developerzy-Warset	52	52	59	37	52	61	66	46	49	50	53	35
WIG-Energia-Warset	65	43	56	45	77	58	59	46	60	36	53	42
WIG-Informatyka-All	54	62	44	46	61	65	45	53	49	58	40	42
WIG-Informatyka-Warset	48	57	44	40	56	61	46	47	43	54	40	35
WIG-Media-Warset	59	53	51	54	71	63	65	61	54	48	45	48
WIG-Paliwa-Warset	69	64	66	61	77	80	66	66	65	60	62	56
WIG-Poland-All	64	64	58	54	64	63	61	56	60	60	53	50
WIG-Poland-Warset	63	64	59	49	66	64	62	55	58	58	54	46

	252 sessions											
	Jarque-Barre				Shapiro-Wilk				D'Agostino-Pearson			
	C-C	O-O	O-C	OV	C-C	O-O	O-C	OV	C-C	O-O	O-C	OV
WIG-All	22	21	19	12	18	24	26	10	20	19	18	11
WIG-Warset	14	14	19	2	12	22	26	3	11	13	18	2
WIG-Banki – All	25	24	22	21	32	29	28	21	23	22	20	19
WIG-Banki-Warset	26	25	23	22	35	31	29	21	25	24	21	20
WIG-Budownictwo-Warset	8	18	12	8	13	22	11	11	6	16	8	8
WIG-Budownictwo-All	10	17	11	8	12	18	9	10	8	15	8	8
WIG-CEE-All	8	5	0	0	4	11	0	0	6	2	0	0
WIG-Chemia-Warset	21	18	3	7	33	28	5	24	21	17	2	5
WIG-Developerzy-Warset	4	9	12	5	5	15	15	4	4	8	9	4
WIG-Energia-Warset	26	0	16	8	39	1	24	9	24	0	16	7
WIG-Informatyka-All	14	34	7	9	13	33	8	10	12	32	5	7
WIG-Informatyka-Warset	9	31	7	6	7	30	8	7	7	30	5	4
WIG-Media-Warset	16	11	17	7	32	14	25	12	14	11	15	6
WIG-Paliwa-Warset	31	26	26	16	53	40	28	23	26	22	24	15
WIG-Poland-All	23	27	14	17	19	27	13	17	20	25	13	16
WIG-Poland-Warset	15	23	14	10	14	27	13	14	13	22	13	9

DOI 10.7172/1644-9584.74.1

	30 sessions											
	Jarque-Barre				Shapiro-Wilk				D'Agostino-Pearson			
	C-C	O-O	O-C	OV	C-C	O-O	O-C	OV	C-C	O-O	O-C	OV
WIG-Spożywczy-All	81	85	77	73	80	85	78	73	73	78	69	65
WIG-Spożywczy-Warset	81	86	78	71	81	87	78	72	73	78	70	64
WIG-Surowcowy-Warset	87	80	80	80	87	83	84	80	81	74	73	74
WIG-Telekom-All	86	89	82	87	89	89	81	86	79	82	73	82
WIG-Telekom-Warset	84	87	82	85	87	88	82	85	77	80	73	80
WIG-Ukraina-Warset	83	81	74	71	83	83	78	72	77	72	65	61
WIG20-All	92	91	91	77	91	91	90	78	86	85	87	70
WIG20-Warset	94	91	91	75	92	91	91	76	88	85	86	68
WIG20TR-Warset	93	95	87	94	94	95	90	93	87	90	81	88
WIG30-Warset	87	85	83	62	87	86	84	63	79	75	77	55
WIG30TR-Warset	86	88	84	85	87	92	88	87	80	83	81	77
WIG-DIV-Warset	84	85	83	65	82	85	83	70	78	81	75	60
mWIG40-All	86	83	87	67	86	85	88	68	79	76	80	59
mWIG40-Warset	85	83	86	65	85	86	88	66	78	76	79	57
sWIG80-All	82	79	79	74	83	81	80	74	77	72	72	68
sWIG0-Warset	79	75	80	68	80	77	81	68	73	67	72	61
NCIndex-Warset	90	88	88	67	88	87	89	68	84	82	82	61
Investorms	81	82	79	71	82	81	81	71	75	75	72	66
Respect	85	86	82	74	87	86	86	77	78	80	71	64

	100 sessions											
	Jarque-Barre				Shapiro-Wilk				D'Agostino-Pearson			
	C-C	O-O	O-C	OV	C-C	O-O	O-C	OV	C-C	O-O	O-C	OOV
WIG-Spożywczy-All	45	44	40	27	46	46	41	30	39	40	36	23
WIG-Spożywczy-Warset	43	42	40	23	45	44	42	26	38	39	36	20
WIG-Surowcowy-Warset	55	40	37	49	66	49	49	57	53	37	35	46
WIG-Telekom-All	63	67	46	62	67	69	49	67	60	64	42	59
WIG-Telekom-Warset	58	63	47	58	63	66	50	63	56	60	42	55
WIG-Ukraina-Warset	58	35	38	25	59	35	51	33	54	34	35	20
WIG20-All	71	68	68	37	73	75	73	37	67	65	65	34
WIG20-Warset	71	65	67	29	73	74	73	29	66	62	64	26
WIG20TR-Warset	66	73	54	65	72	76	60	72	63	70	50	61
WIG30-Warset	46	44	53	12	50	44	63	13	44	41	48	10
WIG30TR-Warset	46	60	59	42	51	63	62	48	44	56	57	37
WIG-DIV-Warset	48	54	54	18	52	55	58	20	46	50	49	17
mWIG40-All	45	41	54	17	50	50	59	20	42	37	49	15
mWIG40-Warset	43	40	52	15	46	48	58	18	39	36	46	13
sWIG80-All	47	45	40	36	49	49	43	39	43	42	36	34
sWIG0-Warset	40	37	41	25	43	42	44	30	37	34	37	24
NCIndex-Warset	64	66	60	32	70	70	68	35	60	65	58	31
Investorms	36	35	38	17	37	39	42	18	31	32	35	15
Respect	56	56	48	27	63	64	54	34	51	51	42	24

	252 sessions											
	Jarque-Barre				Shapiro-Wilk				D'Agostino-Pearson			
	C-C	O-O	O-C	OV	C-C	O-O	O-C	OV	C-C	O-O	O-C	OV
WIG-Spożywczy-All	10	6	6	1	14	7	7	5	9	5	5	1
WIG-Spożywczy-Warset	11	6	6	0	14	6	8	4	10	5	5	0
WIG-Surowcowy-Warset	16	1	5	9	14	13	6	15	15	1	4	8
WIG-Telekom-All	38	33	11	30	40	33	14	36	37	32	10	29
WIG-Telekom-Warset	37	31	12	32	39	31	15	36	35	30	11	30
WIG-Ukraina-Warset	13	6	1	0	25	8	4	1	11	4	0	0
WIG20-All	26	27	31	8	31	33	37	10	23	25	30	7
WIG20-Warset	22	22	28	5	27	28	35	6	18	21	26	3
WIG20TR-Warset	17	23	17	13	26	35	29	23	14	20	16	11
WIG30-Warset	16	11	12	0	14	12	21	0	15	11	9	0
WIG30TR-Warset	15	28	26	2	14	46	28	11	13	26	24	2
WIG-DIV-Warset	18	14	26	0	19	22	35	0	16	13	24	0
mWIG40-All	8	7	15	0	9	9	21	0	7	7	14	0
mWIG40-Warset	7	8	11	0	8	10	17	0	7	8	10	0
sWIG80-All	17	14	8	8	21	17	12	9	17	14	7	8
sWIG0-Warset	13	6	9	0	17	9	13	1	13	6	8	0
NCIndex-Warset	29	32	35	7	36	40	45	8	28	31	34	7
Investorms	0	4	4	0	1	3	4	0	0	3	4	0
Respect	16	13	16	3	22	27	23	3	14	12	15	3

Tab. 11. The percentage of cases where there was no reason to reject the null hypothesis for K = 30, K = 100 and K = 252 sessions

4.3. Testing Hypotheses for *K* = 30, *K* = 100 and *K* = 252 Sessions, and Related Statistics

The tests for all indexes for $K = 30$, 100 and 252 sessions were performed with the application of Jarque-Bera, Shapiro-Wilk and D'Agostino-Pearson tests. The choice of $K = 30$ is due to the fact that, with a sample size of about 30 elements, it is assumed that the t-student distribution is close to the normal distribution. In turn, $K = 252$ corresponds to approximately the number of sessions per year, and $K = 100$ is the intermediate between $K = 30$ and $K = 252$ and corresponds to the number of sessions in about 4 months (assuming 25 sessions per month). In technical analysis, 100 sessions moving average represents a medium term investment horizon. The results are shown in Table 11 and in Figures 2–6.

Increasing the parameter K leads to a decrease in the percentage of cases where there was no reason to reject the null hypothesis. This tendency is especially noticeable in the case of overnight rates of return. This fact is in line with the expectations because only in very few cases significant events taking place in the company's environment result in a meaningful deviation of the opening price in relation to the last closing price. In this case, a significant percentage of returns is close to zero. For C-C, O-O and O-C rates of return, a broader horizon of observation was required to increase the percentage of cases where there was no reason to reject the null hypothesis. This drift was common for all four main WSE indexes: WIG, WIG20, mWIG40 and sWIG80.

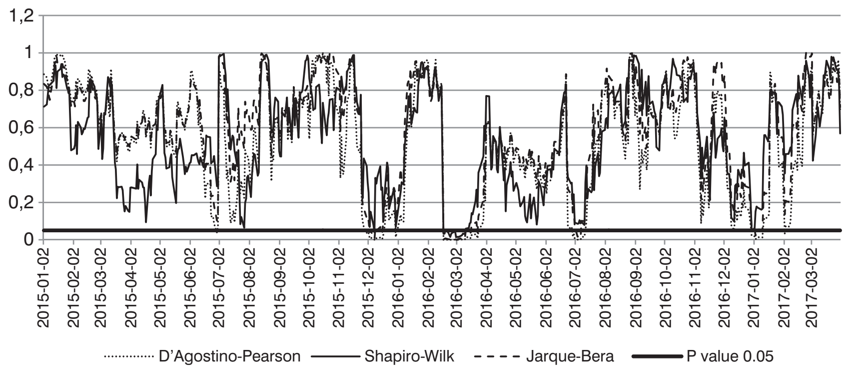

Fig. 2. Value of the parameter p for the WIG index in the period 2 January 2015 – 31 March 2017 when carrying out three different tests and K = 30

DOI 10.7172/1644-9584.74.1

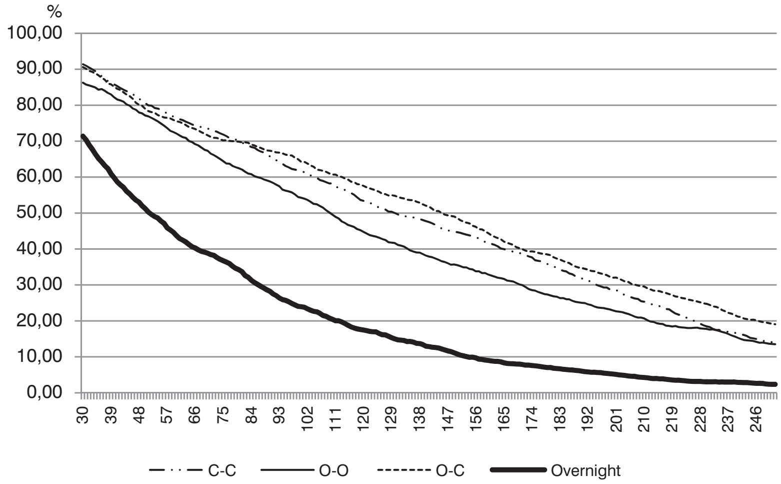

Fig. 3. The percentage of cases where there was no reason for rejecting the null hypothesis for WIG index returns with the use of Jarque-Bera test, depending on K (change of K: every 1 unit)

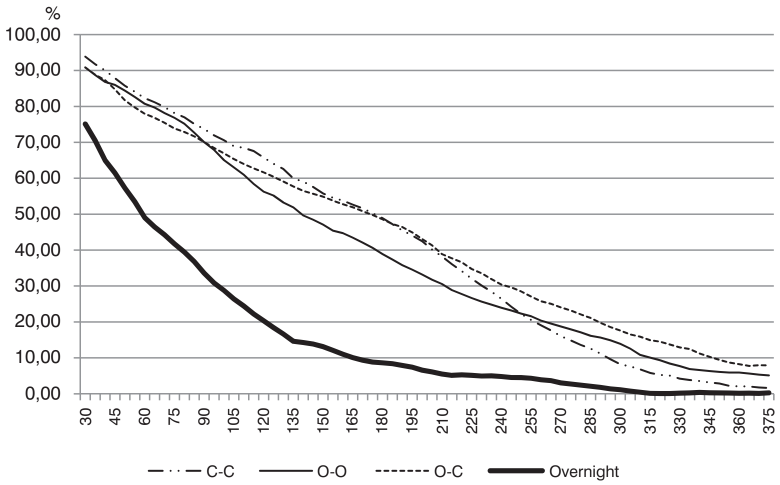

Fig. 4. The percentage of cases where there was no basis for rejecting the null hypothesis for WIG20 index returns with the use of Jarque-Bera test, depending on K (change of K: every 5 units)

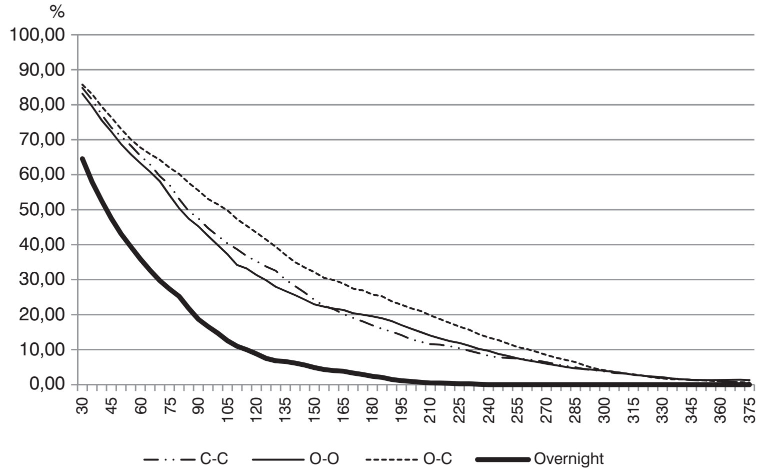

Fig. 5. The percentage of cases where there was no basis for rejecting the null hypothesis for mWIG40 index returns with the use of Jarque-Bera test, depending on K (change of K: every 5 units)

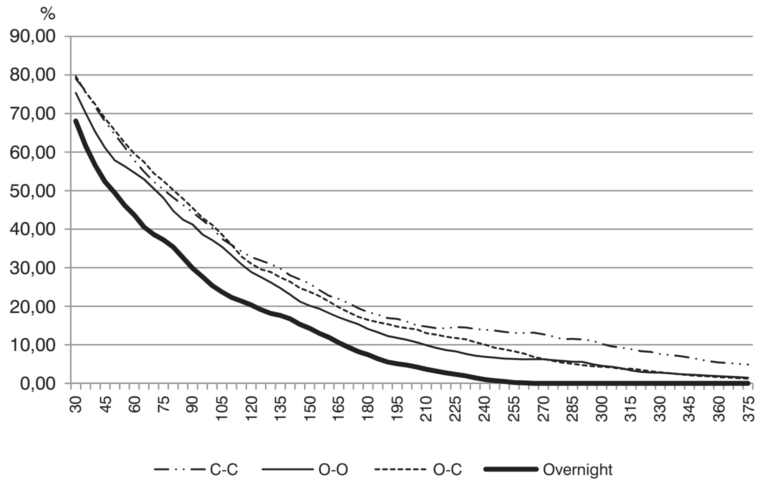

Fig. 6. The percentage of cases where there was no basis for rejecting the null hypothesis for sWIG80 index returns with the use of Jarque-Bera test, depending on K (change of K: every 5 units)

DOI 10.7172/1644-9584.74.1

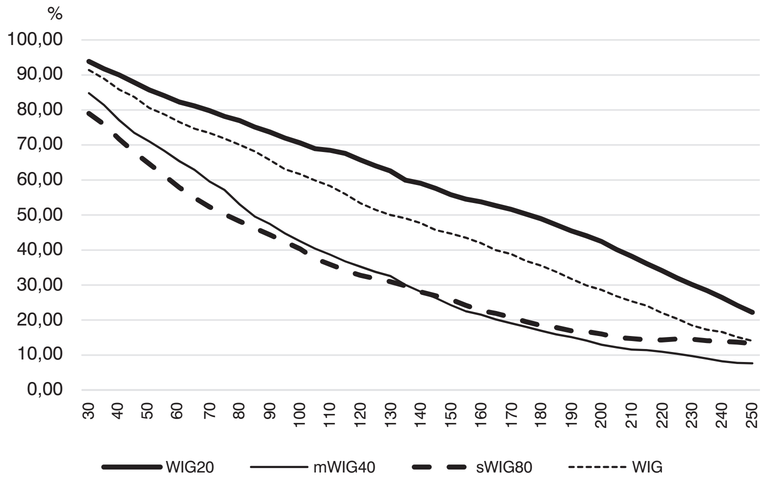

Fig. 7. The percentage of cases where there was no basis for rejecting the null hypothesis for the returns of the four main indexes with the use of Jarque-Bera test, depending on K (change of K: every 5 units) and C-C rates of return

For a small *K*, the highest percentage of cases where the null hypothesis was not rejected was observed for the WIG20 index, followed by WIG, mWIG40 and sWIG80 – see Figure 7. With the increase of the parameter *K*, this order has changed to: WIG20, WIG, sWIG80 and mWIG40. For $K = 250$, the percentage of instances of non-rejection of the null hypothesis was roughly the same for sWIG80 and WIG, while for $K = 30$ the difference was equal to 12.4 percentage points.

Table 12 presents indexes according to the proximity of the distribution of return rates of these indexes to the normal distribution. The ranking was prepared only for the indexes the publishing of which by WSE began before 31 December 2016.

	30 sessions				100 sessions				252 sessions				Global ranking
	C-C	O-O	O-C	OV	C-C	O-O	O-C	OV	C-C	O-O	O-C	OV	
WIG-All	13	18	4	20	11	16	5	21	12	16	10	10	12
WIG-WARSET	7	14	5	27	14	21	3	28	27	22	11	26	16
WIG-Banki – All	9	5	16	9	6	2	11	5	8	12	8	4	5
WIG-Banki-WARSET	6	3	14	10	4	3	8	8	6	9	7	3	3
WIG-Budownictwo-WARSET	30	29	30	15	22	18	20	17	29	17	23	11	24
WIG-Budownictwo-All	26	25	28	12	20	17	21	14	28	19	25	14	22
WIG-CEE-All	32	30	35	35	30	24	35	35	33	30	35	35	35

	30 sessions				100 sessions				252 sessions				Global ranking
	C-C	O-O	O-C	OV	C-C	O-O	O-C	OV	C-C	O-O	O-C	OV	
WIG-Chemia-WARSET	11	16	34	11	15	19	32	12	9	15	33	14	18
WIG-Developerzy-WARSET	15	21	6	16	23	23	8	18	34	25	21	23	19
WIG-Energia-WARSET	8	28	15	22	6	26	13	14	5	35	13	18	15
WIG-Informatyka-All	14	15	24	14	21	12	26	11	24	3	28	14	17
WIG-Informatyka-WARSET	18	22	20	17	25	16	25	17	31	5	27	20	21
WIG-Media-WARSET	18	14	23	6	13	20	17	6	14	24	12	17	14
WIG-Paliwa-WARSET	5	8	1	2	4	8	4	3	3	8	6	5	1
WIG-Poland-All	12	10	13	8	10	11	12	7	11	10	16	6	7
WIG-Poland-WARSET	4	7	11	7	12	11	10	10	21	13	18	8	10
WIG-Spożywczy-All	33	23	32	24	31	28	33	26	27	29	30	26	30
WIG-Spożywczy-WARSET	34	19	31	27	33	31	29	29	25	33	29	27	33
WIG-Surowcowy-WARSET	16	32	23	13	17	31	32	9	18	33	31	9	25
WIG-Telekom-All	19	9	25	3	9	8	24	2	1	3	22	2	8
WIG-Telekom-WARSET	23	12	21	6	16	9	23	4	3	6	18	1	11
WIG-Ukraina-WARSET	28	33	33	28	18	35	29	27	20	33	34	29	33
WIG20-All	3	4	2	18	1	4	1	19	8	8	2	15	4
WIG20-WARSET	1	2	4	19	2	6	2	24	10	14	3	22	6
WIG20TR-WARSET	2	1	8	1	7	1	15	1	16	11	10	7	2
WIG30-WARSET	20	24	17	34	28	28	15	34	19	24	20	35	27
WIG30TR-WARSET	21	6	12	4	26	13	9	15	22	4	6	21	13
WIG-DIV-WARSET	27	20	18	31	24	23	18	30	15	19	4	30	23
mWIG40-All	22	26	9	32	30	29	16	31	30	27	15	35	28
mWIG40-WARSET	25	27	11	33	32	32	19	33	32	26	20	35	29
sWIG80-All	29	34	29	22	28	25	30	21	13	22	26	16	26
sWIG0-WARSET	35	35	26	29	34	33	27	25	23	28	24	28	33
NCIndex-WARSET	10	12	7	31	8	5	6	22	4	3	1	19	9
Investorms	31	31	27	25	35	35	34	32	35	34	32	31	34
Respect	24	18	19	23	20	14	22	23	17	20	14	24	20

Table 12. Ranking of WSE indexes according to the proximity of their rates of return to the normal distribution

For example, for $K = 30$ sessions and C-C rates of return, the first three places were ranked as follows: WIG20-Warset, WIG20TR-Warset and WIG20-All, while the last three were listed in the following order: WIG-Spożywczy-All, WIG-Spożywczy-Warset and sWIG80-Warset.

DOI 10.7172/1644-9584.74.1

In turn, in the global ranking, the top three places were: WIG-Paliwa-WARSET, WIG20TR-WARSET and WIG-BANKI-WARSET, and the last three: sWIG80-WARSET, Investorms and WIG-CEE-All.

4.3. Average, Maximum and Minimum Values for All Index Statistics for *K* = 30, *K* = 100 and *K* = 252 Sessions

The mean, maximum and minimum values for all indexes published by the Warsaw Stock Exchange, for three types of tests and for three values of the parameter *K* (30, 100 and 252 sessions) and for different rates of return (CC, OO, OC and Overnight) are presented in Figures 8–11. The average, maximum and minimum values were the smallest for *K* = 30. In turn, for *K* = 100 and 252, these differences become higher but comparable. On the other hand, the average, maximum and minimum frequency values tend to decrease with increasing parameter *K*.

The following scheme of abbreviations is used for the values on the horizontal axis: the first two letters are the abbreviation for the appropriate test (JB – Jarque-Bera, SW – Shapiro-Wolf, DP – D'Agostino-Pearson) followed by numbers representing the parameter *K* (30, 100 or 252). So, the shortened from JB30 stands for a Jarque-Bera test for *K* = 30 sessions.

Fig. 8. Average, maximum and minimum values for all analyzed indexes, different test types, different parameters K and C-C rates of return

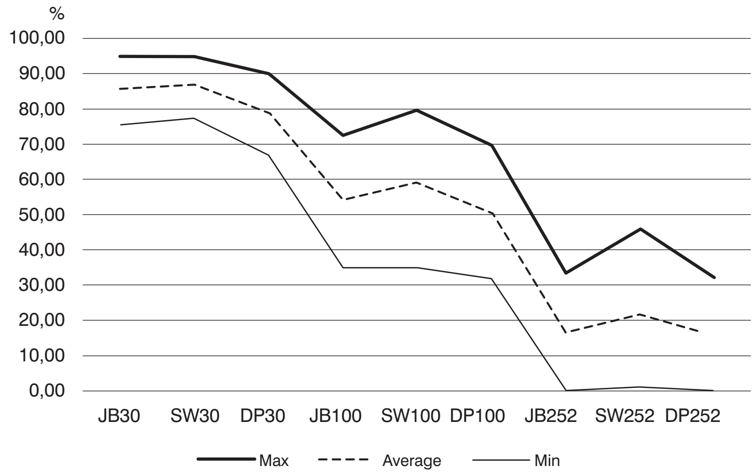

Fig. 9. Average, maximum and minimum values for all analyzed indexes, different test types, different parameters K and O-O rates of return

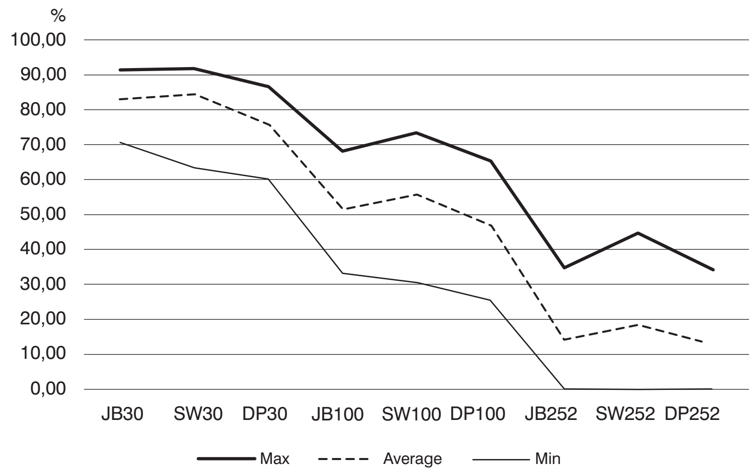

Fig. 10. Average, maximum and minimum values for all analyzed indexes, different test types, different parameters K and O-C rates of return

DOI 10.7172/1644-9584.74.1

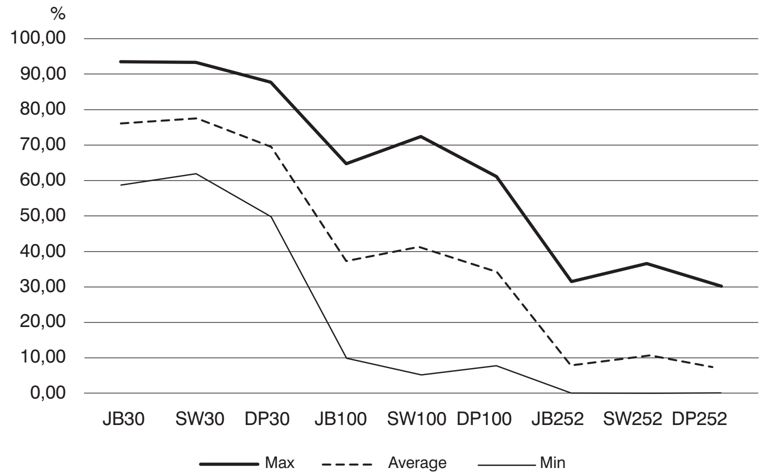

Fig. 11. Average, maximum and minimum values for all analyzed indexes, different test types, different parameters K and overnight rates of return

5. Conclusions

The conducted study is the first study concerning the distribution of return rates of Polish stock market indexes in a different system than C-C, i.e. O-C, overnight and O-O. Some of the calculations prove unequivocally that the distributions of index returns, published by the WSE, are not normal distributions, thus confirming the results obtained by other researchers such as Bołt and Miłobędzki, Osińska, Rokita Witkowska and Kompa (Bołt & Miłobędzki, 1994; Osińska, 2006; Rokita, 2000; Witkowska & Kompa, 2007). This remark applies mainly to C-C rates of return. The paper also proves that the distribution of the remaining returns, i.e. O-O, C-O and overnight, calculated for the analyzed WSE indexes does not follow a path of a normal distribution. Furthermore, it has been proved that the distribution of returns can be normal only at given time intervals. The obtained results are consistent with those of Piasecki and Tomasik, who proved the normal distribution of returns in certain upward and downward price movements (C-C regime) (Piasecki & Tomasik, 2013). Due to precise moments of possible transactions proceedings (Close or Opening), the obtained result can be implemented in investment strategies.

With the use of the parameter p, also a stock index ranking was created, due to the possibility of approximating the distribution of index returns with the normal distribution for the time horizon of $K = 30$, $K = 100$ and $K = 252$ sessions. As a result, it was found that the position of the index in the ranking is not dependent on the date of its first publication, and hence on the number of rates of return possible to calculate for the analyzed index, but on the distribution of these rates of return.

The analysis of the results obtained for $K = 30$ sessions concludes that, for such a short time interval, a sharp index change leads to a violent decrease in the value of the parameter p. This process is illustrated in Figure 12, which includes WIG20 index returns (C-C), the parameter p and the annualized standard deviation of returns. For example, with a strong increase in volatility on 21 August 2015, the value of p dropped below the trigger value of 0.05. Explaining the decrease in the value of the parameter p below 0.05 for $K = 100$ and $K = 252$ sessions becomes a more complex issue and requires further investigation.

Similar studies regarding a normal distribution of rates of return should also be conducted for commodities and FX market. Another direction of research may be an attempt to determine mathematical functions describing the observed rates of return in various segments of the financial market.

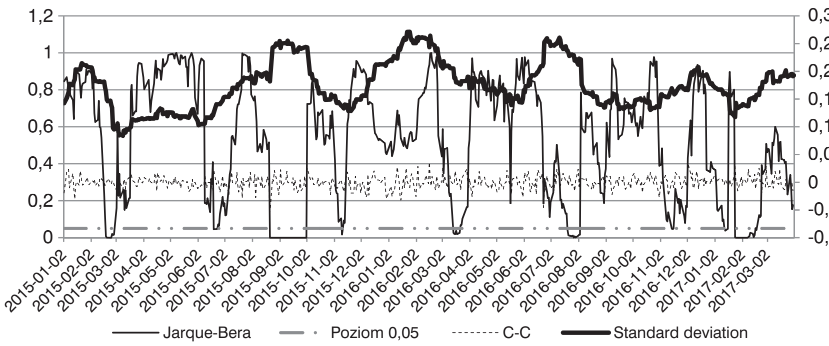

Fig. 12. The p parameter chart for the WIG20 index, K = 30, the Jarque-Bera test, the return rate (C-C) and the annualized standard deviation (p-value and level 0.05 – left scale, C-C return and standard deviation – right scale)

References

Affleck-Graves, J. & McDonald, B. (1989). Nonnormalities and test of asset pricing theories. *Journal of Finance*, *44*(4), 889–908. http://dx.doi.org/10.1111/j.1540-6261.1989.tb02629.x.

Bachelier, L. (1900). Theorie de la speculation. *Annales de l'Ecole Normal Superieure*, *17*(3), 21–86. http://dx.doi.org/10.24033/asens.476.

Barunik, J., Vacha, L., & Vosvrda, M. (2010). Tail behavior of the Central European stock markets during the financial crisis. *Czech Economic Review*, *4*, 281–294.

Bołt, T. & Miłobędzki, P. (1994). The Warsaw Stock Exchange in the period 1991–1993. *Quantitative Problems of Return, Economics of Planning*, *27*, 211–226.

Bookstaber, R. & McDonald, J. (1987). A general distribution for describing security price returns. *Journal of Business*, *60*(3), 401–424. http://dx.doi.org/10.1086/296404.

 DOI 10.7172/1644-9584.74.1

Clark, P. (1973). A subordinated stochastic process model with finite variance for speculative prices. *Econometrica*, *41*(1), 135–156. http://dx.doi.org/10.2307/1913889.
Fama, E. (1965). The behavior of stock market prices. *Journal of Business*, *38*(1), 34–105. http://dx.doi.org/10.1086/294743.
Fama, E. (1976). *Foundations of finance.* New York: Basic Books.
Fiszeder, P. (2000). Statystyczne i dynamiczne własności stóp zwrotu na przykładzie światowych indeksów giełdowych. *Nasz Rynek Kapitałowy*, (109), 187–197.
Ghahfarokhi, M. & Ghahfarokhi, P. (2003). Applications of stable distributions in time series analysis, computer sciences and financial markets. *International Scholarly and Scientific Research & Innovation*, *3*, 2009, 132–136.
Harris. L. (1986). Cross-security tests of the mixture of distributions hypothesis. *Journal of Financial and Quantitative Analysis*, *21*(1), 39–46. http://dx.doi.org/10.2307/2330989.
Kendall, M. (1953). The analysis of economic time series – Part I: Prices. *Journal of Royal Statistical Society. Series A*, *116*(1), 11–25. http://dx.doi.org/10.2307/2980947.
MacKinlay, C. & Richardson, M. (1991). Using generalized method of moments to test mean-variance efficiency. *Journal of Finance*, *46*(2), 511–527. http://dx.doi.org/10.1111/j.1540-6261.1991.tb02672.x.
Osborne, M. (1959). Brownian motion in the stock market. *Operations Research*, *7*(2), 145–173. http://dx.doi.org/10.1287/opre.7.2.145.
Osińska, M. (2006). *Ekonometria finansowa.* Warszawa: Państwowe Wydawnictwo Ekonomiczne.
Piasecki, K. & Tomasik, E. (2013). *Rozkłady stóp zwrotu z instrumentów polskiego rynku kapitałowego.* Kraków-Warszawa: edu-Libri.
Richardson, M. & Smith, T. (1993). Multivariate normality in stock returns. *Journal of Business*, *66*(2), 295–321. http://dx.doi.org/10.1086/296605.
Rokita, P. (2007). Próba estymacji VaR na rynku polskim. In W. Tarczyński (Ed.), *Rynek kapitałowy, Skuteczne inwestowanie* (conference proceedings, part I). Szczecin: Wydawnictwo Naukowe Uniwersytetu w Szczecinie.
Scalas, E. & Kim, K. (2007). The art of fitting financial time series with Levy stable distributions. *Korean Journal of Physics*, *50*, 105–111.
Witkowska, D. & Kompa, K. (2007). Analiza własności stop zwrotu akcji wybranych spółek. In W. Tarczyński W. (Ed.), *Rynek kapitałowy, Skuteczne inwestowanie* (conference proceedings, part I). Szczecin: Wydawnictwo Naukowe Uniwersytetu w Szczecinie.