TESTING THE WEAK-FORM EFFICIENCY HYPOTHESIS IN THE UKRAINIAN STOCK MARKET VERSUS THOSE OF THE USA, RUSSIA, AND POLAND

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Abstract*.* *Objective****.*** *This empirical research was made to test a weak-form market efficiency of the stock market index in Ukraine as compared with other countries' stock indexes. Data. Daily data were investigated for the period from August 2008 to October 2011. Methods. We applied different statistical tests to verify the hypothesis that the Ukrainian stock market follows a random walk. Main results. The main research findings are: the daily returns are not normally distributed; I.I.D. tests and the Kendall test support the random walk hypothesis. Test results on autocorrelation and variance stability were ambiguous. The reported results may be considered as the first approach to the further research on the efficiency of the Ukrainian securities markets.*

Key words: *Ukraine, stock market, efficiency, test*

Introduction

The purpose of the paper is to describe investment markets in Ukraine and the information efficiency of the Ukrainian securities market. In Ukraine, the development of the market economy began in 1991 when the first stock exchange was established. In the next decades, several additional securities exchanges were organized and started operating in the country.

The security trade turnover in the market was small during the first years of market functioning in Ukraine, but the increase in turnover is obvious (see Table 1).

In the nineties and at the beginning of the 21st century, several new stock markets and exchanges emerged in Europe and all over the world. According to Smith and Ryoo (2003), the emerging markets have been developing fast. Their comparative changes are presented Table 2.

The data demonstrate an increasing turnover of securities markets in all the countries in 1991–1997 and in some of them also in 1997–2011. The Ukrainian market increased from zero to 4,2 billion dollars in six years of the first period and 62 times in the period

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1997–2011. A similar growth for the last period was noted for Turkey (5.8 times), Poland (about 10 times), Romania (9 times). Such data give the reasons for researchers to undertake investigations of different properties of emerging markets, including their efficiency.

TABLE 1. **Total turnover in Ukrainian security markets**

Year	Turnover in local currency (hryvna billions)	Turnover in USD billions	Percent change to previous period
1997	7.5	4.17	
1998	10.5	5.00	20.00%
1999	16.8	3.73	-25.33%
2000	39.2	7.40	98.11%
2001	68.5	12.92	74.74%
2002	108.6	20.49	58.54%
2003	203.0	38.30	86.92%
2004	321.3	60.62	58.28%
2005	403.1	79.04	30.38%
2006	551.8	110.36	39.63%
2007	754.3	150.86	36.70%
2008	883.4	114.73	-23.95%
2009	1067.3	136.83	19.27%
2010	1537.8	194.66	42.26%
2011	2147.5	265.12	36.20%

Source: National Bank of Ukraine, National Commission on Securities and Stock Market, Report 2011.

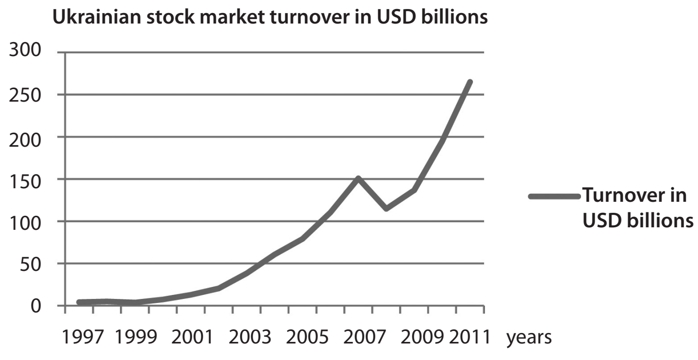

FIG 1. **Ukrainian market turnover growth from 1997 to 2011 in US Dollar Billions**

Source: Table 1 in Appendix.

TABLE 2. **Turnover of European emerging securities markets**

	Country	1991 turnover $ millions	1997 turnover $ millions	2011 turnover $ millions
1	Ukraine	n/a	4 170	265 120
2	Latvia	n/a	84	39(**)
3	Lithuania	n/a	239	261(**)
4	Romania	n/a	268	2 408(*)
5	Croatia	n/a	343	–
6	Estonia	n/a	1 484	187(**)
7	Slovakia	n/a	2 165	-
8	Check Republic	n/a	7 055	20 051(*)
9	Hungary	117	7 684	–
10	Poland	28	7 977	82 185(*)
11	Greece	2443	21 146	–
12	Turkey	8571	59 105	400 089(*)

Source: International Financial Organization (1998), taken from Smith G., Ryoo H. (2003), (*) European Exchange Report Federation of the European Securities Exchanges, Economics and Statistics Committee (September 2012): http://www.fese.be/en/?inc=art&id=4, (**) Market statistics from NASDAQ OMX. http://www.nasdaqomxbaltic.com/market/

Short overview of stock market efficiency

The idea of the efficiency of security markets concerned the issue of predictability prices or return behaviour. Predictability leads to the possibility of extracting additional profit when trading such securities. It is important to stress that such ability to have an additional advantage must be associated with the mechanism allowing to sell or to buy without substantial transactional costs. The predictability is inherently linked with relevant information extraction, information processing, and inference of reliable and relevant conclusions from it. In general, such possibility is available to all market agents. If they possess the same abilities and equal access to relevant information, they may infer the same conclusions. In some cases, agents understand that the stock prices are unusually low, i.e. the security under consideration is undervalued. To buy such security will be a bargain. In case this information is available to the other market participants and they made the same conclusion, the additional demand for security will drive the price up, and the opportunity to extract additional profit will be eliminated from the market.

If in markets all this information is reflected in prices, such markets are considered efficient. Taking into account different sources of information and their accessibility, Eugene Fama (1970) suggested to differentiate security into three degrees of markets efficiency: weak, semi-strong, and strong.

In the paper, we investigate the weak form efficiency of the Ukrainian stock market. The weak form of market efficiency exists when the information set is limited by historical prices and the current prices fully reflect all information from the previous ones.

Usually, it may be accepted that, to verify this efficiency market hypothesis (EMH), it is sufficient to find that prices or returns are statistically independent. We can express this idea as follows: prices are independent random variables. Together with the identical distribution of prices or returns, this is a random walk model usually used to describe the weak form of the efficiency market hypothesis. In other words, the market has a random walk property.

So far, statistical tests for the randomness of prices or returns have been applied to verify this statement. More formally, the conditional distribution of available information about prices or returns is equal to an unconditional distribution of prices or returns. Thus, testing the hypothesis on random walk allows defining the stability of price distribution over time when the changing economic conditions do not affect the equilibrium.

The relationship between randomness and the possibility to discover some regularities in data, in our case in a financial time series, is an important issue. Starting from the middle of the twentieth century, different efforts were undertaken to clarify this problem of randomness and regularity, especially in economics, mechanics, physics, theory of algorithms, dynamic theory, fractals, and cryptography. Researchers tried to understand the relation among deterministic, random, and pseudo-random phenomena.

Usually, the genuine stochastic properties are ascribed to such physical phenomena as movements of gas molecules, electron gas and the like. These objects and their movements have real stochastic or random properties. In the article by Kravtsov (1989), the randomness is interpreted as the unpredictability of a process and the absence of regularities (chaoticness). His approach is close to Kolmogorov's idea to describe the randomness of sequences of successes and fails in a series of the Bernoulli distributed outcomes. A. Kolmogorov (Kolmogorov, Uspensky, 1986) defined three properties of random series: they have to be typical in the sense of Martin–Löf, chaotic in the sense of Kolmogorov, and to show frequency stability in the sense of von Mises. The chaotic property means absence of a simple law that generates a series. When the outcomes are tested for randomness, they are usually tested for chaoticness.

Several approaches exist for testing the randomness. Traditionally, the problem is tailored to a statistical framework, and statistical tests for randomness are applied. These tests define whether the sequence under consideration is random or not.

In general, the complexity of a phenomenon (chaotic) may be considered as randomness. Sometimes, the results of relatively simple non-liner algorithms may have properties of a random process, especially in the situation when the viewer does not comprehend the internal mechanics of information generation. This approach to complexity may be plausible to explain the efforts of investment practitioners who do their best to find regularities in aprice series even when the academicians who have tested the financial data for randomness support the fact of randomness. Researchers usually accept the idea of a possible randomness of return and prices and use different statistical tests of the data to prove or reject the random properties. The application of statistical tests to securities' prices sometimes shows the random walk property in a financial time series. Here, we propose a short overview of recent works on the empirics of the problem.

There are many empirical works concerning testing for the efficiency of markets both in the USA and in Europe (see, for example, Levy (1999) and articles cited there). The general conclusion that can be drawn from this exposition holds that there is no definite empirical evidence related to the weak form of EMH (ibid., p. 423). As it follows from the cited research works, eight researches confirm the weak efficiency of the American securities markets, but seven do not support the efficiency market hypothesis about the randomness of price changes. Authors used different methods to verify the weak form of the EMH.

One way to test randomness is to compare returns to the "expected return" to identify abnormal returns. This approach depends on the model used to simulate this expected return. Some researchers use the linear CAPM model or the CAR (cumulative abnormal return) model. Another way is to test statistically the series of interest – prices, returns or others, directly using tests for the independency and identical distribution of observable samples.

According to Fama (1970), the oldest work on the possibility to get extra profit by a speculator in the stock markets is that of Bachelier. Bachelier arrived to the conclusion that the price movements of French bonds were random, and the profit for the speculator was zero. As mentioned in Fama's paper, assessing the serial correlation coefficients for one, four, nine, sixteen days' changes in logarithmic prices for 31 large American corporations during the period 1957 to 1962 give little support to the random walk hypothesis (Fama, 1970).

Later, researchers paid attention not only to the old well-established stock markets, but also to the emerging ones. Gilmore and McManus (2003) made a research concerning the existence of a weak-form efficiency in the equity markets of the Central European transition economies, namely the Czech Republic, Hungary, Poland. The authors used weekly data from July 1995 to September 2000 on the indexes developed by the International Finance Corporation. There is some proof that the tested stock prices exhibited a random behavior. This fact differs in some cases from studies using data for the starting period of these markets. The variance ratio test (VAR) demonstrates results somewhat in support of the random properties of indexes. The results of the model comparison approach reject the random walk hypothesis for all markets under research.

In the article of M. Omran and S. V. Farrar (2006), the efficiency of the stock markets emerging in the Middle Eastern countries was studied. Because of the recent establishment of these markets, the information on their efficiency is scanty. According to the authors' research, the Israel market seems to be more efficient than the other Middle East markets.

The purpose of the paper of Ntim et al. (2011) is to investigate and compare the weak-form efficiency of 24 African continent-wide stock price indices and eight individual African national stock price indices. The variance-ratio tests and tests based on ranks and signs were used to examine the weak-form efficiency of 32 stock price indices. The authors have found that, irrespective of the test employed, the returns of all the 24 African continent-wide stock price indices examined in the study are less non-normally distributed as compared with the eight individual national stock price indices examined. The authors have also reported the evidence of the African continent-wide stock price indices having a significantly better weak-form informational efficiency than their national counterparts.

The goal of this research is to test the Ukrainian stock market index for the weak-efficiency hypothesis, using a set of different statistical tests, and to compare the results with the indexes of other countries (USA, Poland, and Russia).

Methods

As mentioned above, the statistical methodology to test the weak form of market efficiency is a conventional methodological background of the research. Eugene Fama (1970) proposed some variation in the statistical approach, which he named the "fair game" model, to explain the efficiency of securities markets. In this approach, he used the linear dependence between the future and present prices of securities with the supposition that the future prices are equal to the present prices plus random variable conditioned by previous information.

We take into consideration this approach in a slightly more general form, i.e. we evaluate for randomness the following intertemporal equation: $I_{t+1} = I_t + x_t$, or $x_t = I_{t+1} - I_t$, here I_t is a price or an index value at a time point t, and x_t is a random variable or error that describes the change of I_t in time. These differences of prices x_t may be considered as the absolute daily return, and we shall test them for random properties. Other authors also explore for randomness the logarithmic differences of prices and relative returns. We use the significance level α equal to 5% for all statistical tests.

The applied statistical tests fall into three categories, because there are different forms of testing the random walk hypothesis. The first category concerns normality tests in which the null hypothesis asserts that observations are normally distributed independent random variables. The second category is the tests for correlation and variance, and the last category consists of tests on the independence and identical distribution of transformed observation.

As mentioned above, the randomness may be understood as x_t being identically and independently distributed random variables, for example, the Gaussian random variables.

Hence, the first step is to check the samples for normality. We used three closely related tests for normality (see Tsay, 2005): test for skewness is equal to 0 (*TS*), test for kurtosis is equal to 0 (*TK*), and the Jarque–Berra test (*JBT*). The null hypothesis for *TS* and *TK* tests is that the series are independent variables of a standard normal distribution N(0,1). Both statistics have an asymptotically standard normal distribution under H_0. The critical value to reject the null hypothesis H_0 is 1.96 when the significance level $\alpha = 0.05$.

The null hypothesis H_0 for the *JB* test asserts that the series are independent variables taken from a normal distribution. If H_0 is true then *the JB* test has an asymptotical chi-square distribution with two degrees of freedom. The critical value of this statistics is equal to 5.991 at the significance level $\alpha = 0.05$.

The random walk implies that there are no correlations among data in a series with different lags q. The Ljung and Box test (*LBT*) was used to verify whether the data are correlated (Tsay, 2005). The test null hypothesis is that data are not correlated. Let us denote the ρ_q autocorrelation function with a lag q, then the null hypothesis H_0 is $\rho_1 = \rho_2 = \cdots = \rho_m = 0$ against the alternative $\rho_i \neq 0$. When H_0 is true, this statistics is asymptotically distributed as a chi-square with the m degree of freedom. H_0 is rejected if $LBT(m) > \chi(m, 1-\alpha)$, where $\chi(m, 1-\alpha)$ is the $(1-\alpha)$ quantile of χ^2 distribution with the m degree of freedom. All values of the rejection region with a different degree of freedom and significance level 0.05 may be found in statistical tables for χ^2 distribution or in the Appendix (Table 2).

Another test is the test for the stability of variance, which means that if a series follows the random walk property, then the variance of q-difference equals to the variance of the first-order difference multiplied by q (the null hypothesis). The Lo and MacKinlay test (test statistics denoted as $Z(q)$ for homoscedastic data and as $Z^*(q)$ for heteroscedastic observations) was used to verify this property (Lo and MacKinlay (1987) or Liu C., He J. (1991)). When H_0 is true, both statistics have an asymptotically standard normal distribution $N(0, 1)$. When the significance level $\alpha = 0.05$, the rejection region is $|Z(q)| \geq 1.96$. In this study, we have chosen the following values of q: 2, 3, 4, 8, 16.

To verify whether the series are the independent and identically distributed variables, several additional tests where applied (I.I.D. tests). All of them convert the source data into other sequences, ordered or binary, and test them. These tests are the Bartel or rank test, the Kendall test for a pairwise correlation, the runs up and down test, the inversion test, the simple run test. All tests were adopted from Ying Wang (2003), except the inversion test which was taken from Medvedev (1984). The null hypothesis is that data are the independent and identically distributed random variables; when H_0 is true, all test statistics have an asymptotically standard normal distribution with the level of rejection 1.96.

Data description

The data to test were received from the Ukrainian Exchange, the New York Stock Exchange, the Moscow Exchange, and the Warsaw Exchange. The Index of the Ukrainian Exchange, denoted as UX, consists of 10 stocks from the following industries: banks, steel and coal production, electricity production and distribution, oil processing and distribution. We use daily data of the UX index, namely its closing daily value from 8 January 2008 to 14 October 2011, so the number of observations in the sample is 937. The source of data is the Ukrainian stock exchange (*http://www.ux.ua*).

The other indexes (Dow–Jones Index DJI USA, MICEX10 Russia, WIG20 Poland) we have chosen for the purposes of comparison.

The Dow–Jones Index (DJI) is the oldest stock index of the USA. It exists since 1896 and now consists of 30 best known companies from different sectors of the American economy. The data of the Dow–Jones Index are daily closing values. The total number of the index values used in this research is 952; the period of time series is from 3 January 2008 to 14 October 2011. The data are taken from the Yahoo finance service (*http://finance.yahoo.com*).

The Moscow MICEX10 Index started on 30 December 1997 and consists of 10 most liquid shares listed on the MICEX Moscow Exchange. Different companies are included in this index: natural gas producing company, banks, fertilizer producer and others. This list is reviewed every quarter. The number of observations is 940. The starting date of data used in the article is 9 January 2008 and the end date is 14 October 2011. The source of data is *http://www.micex.com/marketdata/indices/shares/composite#&index=MICEX10INDEX.*

The WIG20 Index was constructed by the Warsaw Stock Exchange in 1994 and includes 20 companies. These companies represent the most liquid companies listed on the WSE and belong to finance, mining, software, energy and other industries. The number of observations is 955. The starting date of data used in the article is 2 January 2008, and the end date is 14 October 2011. The data were supplied by the WSE site (*http: //www.gpwinfostrefa.pl/GPWIS2/en/quotes/archive/2*).

The study period includes the acute phase of the financial crisis as seen in Exhibit 2. Additional information concerning the index main statistical properties is shown in Table 3.

During the study period, the UX Index value changed from the maximum 2965 points to the minimum value of 445 points, so the minimum value was only 15% of the maximum value.

In contrast, the USA DJI Index falls only by 50% as compared with its maximum in May 2008. The Polish index WIG20 minimum was 39% of the maximum value, and the Russian MICEX10 minimal value reached 22% of the maximum. The relative standard deviation calculated as a relative standard deviation to the mean showed a similar picture: the Ukrainian index relative standard deviation was equal to 39%, for the USA index relative standard deviation was only 14%, for the Polish index 18%, and for the Russian index 30%. It supports the conclusion that the world financial crisis was most severe for the Ukrainian stock market of these four. The dynamics of the Indices is shown in Fig. 2.

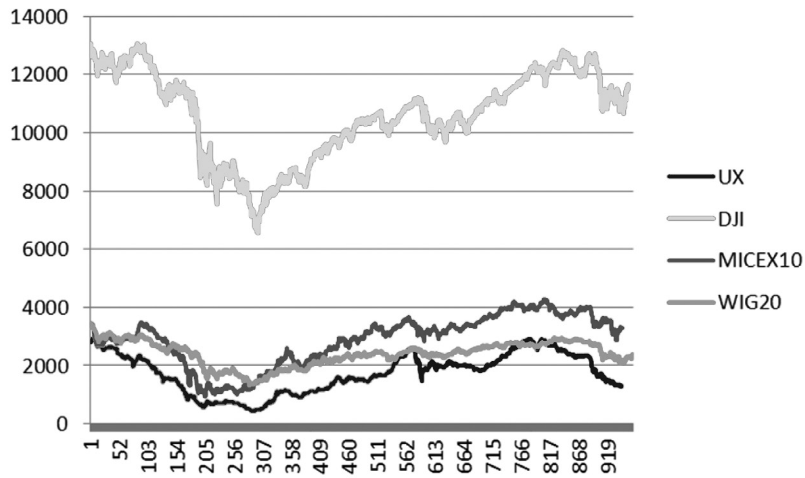

FIG. 2. **UX(Ukraine), DJI (USA), MICEX10 (Russia) and WIG20 (Poland) index values** (from August 2008 to October 2011)

TABLE 3. **The descriptive statistics of the UX, DJI, MISEX10, WIG20 indices**

	UX statistic	DJI statistic	MICEX10 statistic	WIG20 statistic
Mean	1734.0728 err(22.2240)	10619.3727 err(48.95573)	2887.1738 err(28.27011)	2402.8461 err(13.64625)
Median	1815.7000	10817.6500	3097,2850	2445,1100
Std. deviation	682.46133	1512.88246	868.58730	423.47375
Minimum	444.64	6547.05	937.01	1327.64
Maximum	2935.00	13058.20	4276.78	3431.72
Range	2490.36	6511.15	3339.77	2104.08

Source: compiled by the author, calculations made by SAS10.

Test results and findings

In this section, the test results for four indexes described above are presented. In Table 1 of Appendix, the calculated values of all tests reviewed in the previous section are shown. In this table, also the critical region values are enumerated: for all tests, the level of significance α is equal to 5%.

As mentioned above, different statistics were applied to verify the weak-form efficiency of the market. The final results on the rejection or non-rejection of the null hypothesis of the weak form of EMH are exposed in Table 4 (the level of significance $\alpha = 0.05$. The tests that support randomness, or a weak form of EMH, are marked with the sign (+), and the test results that do not support this hypothesis are marked with the sign (–). The source of the statistical test results used in Table 4 are presented in Table 1 in Appendix.

TABLE 4. **Test results for indexes with using data from Table 1 in Appendix. A minus (–) is assigned when the null hypothesis is rejected, and a plus (+) is used when the test results do not contradict the null hypothesis**

	UX	DJI	MICEX10	WIG20
Normality tests				
TS normality test (skewness)	–	–	+	–
TK normality test (kurtosis)	–	–	–	–
Jarque–Bera normality tTest	–	–	–	–
Ljung–Box correlation test with different lags				
Ljung–Box, lags = 3	–	–	+	–
Ljung–Box, lags = 6	+	–	+	–
Ljung–Box, lags = 10	–	–	+	+
Ljung–Box, lags = 15	–	–	+	+
Ljung–Box ,lags = 20	–	–	+	+
Lo–MacKinlay variance test for all *q* ($q = 2$, $q = 3$, $q = 4$, $q = 8$, q = 16)	–	–	–	–
I.I.D. tests				
Bartel test	–	–	+	+
Sample runs test	+	+	+	+
Runs up and down test	+	+	+	+
Mann–Kendall test	+	+	+	+
Inversions test	+	+	+	+

Source: compiled by the author.

Concluding remarks on the statistical test results

As mentioned above, the Ukrainian financial market was most vulnerable to the recent financial crisis. As to comparing the results on rejecting or accepting the null hypothesis of a weak form of market efficiency, statistical tests show that the Ukrainian market may be closer to the USA market than to the Polish or Russian ones.

The most controversial test results pertain to the Ljung–Box statistics. This test checks whether the autocorrelation with different lags in a sample equals to zero. If this holds, then we may conclude that the data are independent in this sense, and this does not contradict the weak-form EMH. As the test demonstrated, the data from Russia have a zero autocorrelation for all lags; on the other hand, Poland data do not reject the null hypothesis when the lag is 15 and 20 days. The Ukrainian market has the signs of interdependence of data that permit to decline the hypothesis of a zero autocorrelation with all lags, except the result with a lag of 6 days. The DJI test for all lags rejects the hypothesis of a zero autocorrelation. This phenomenon may be explained by the financial policy the US government has implemented in the market to tackle the crisis, e. g., bailouts and different measures of quantitative easing implemented by FRS. This information gives to investors the possibility to make a decision when the ongoing decisions have been done by using important previous financial data.

The normality of samples was partially confirmed only in Russia and only when the skewness was tested. The popular and more robust Jarque–Bera test rejected the normality hypothesis for all indices. The test on the variance stability of data in samples based on the variance relation (Lo–MacKinlay test) in all cases rejects the null random walk hypothesis. On the other hand, all tests which use the transformation of data in binary sequences (we called them I.I.D tests) do not reject the random walk hypothesis. Poland and Russia, when tested by the Bartel and Ljung–Box tests, demonstrate similar results: there is no autocorrelation in the test data.

Conclusions

1. The efficiency of stock markets attracts researchers' attention in the last several decades. When the emerging economies had organized stock markets to buy and sell investment resources with the purpose to facilitate the flow of capital to more efficient economic agents, the efficiency of markets became of practical use and importance. In general, there is no assurance of the market efficiency, even on the developed markets.
2. Some researchers have found a proof of a weak form of efficiency for developed and emerging markets, but some do not support the efficiency hypothesis by their investigations.
3. As demonstrated by this research, the tested markets exhibit a controversial picture. The Ukrainian market is not an exception. The tests that use the transformation of a source series into a binary series (Bartel test, simple runs test, up-and-down test, Mann–Kendall test, inversions test) do not reject the weak form of the efficiency market hypothesis, although the Lo–MacKinlay variance test rejects the null hypothesis of the variance ratio stability.

4. The research shows that other markets (USA, Poland, Russia) investigated by I.I.D. tests indicate that the weak-form market efficiency hypothesis does not contradict the test data.
5. The test of the Ukrainian index autocorrelation demonstrates the existence of a linear correlation in the UX index for short and long lags.
6. This paper is the first step on the way of efficiency investigation on the Ukrainian securities market, so further research is desirable in this direction to help financial authorities and private investors to understand the structure and efficiency of the Ukrainian market. The results of the article leave the room for investment practitioners to find the ways to ameliorate their portfolio decisions.

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Appendix

TABLE 1. **Statistical test results for differences**

Statistical test	Test statistical distribution and critical value	UX (Ukraine)	DJI (USA)	MICEX10 (Russia)	WIG20 (Poland)
Normality tests					
Normality test TS (skewness)	Std N; 1.96	-150.5179	-2.230554	-1.76225	-3.815593
Normality test TK (kurtosis)	Std N; 1.96	1656.797	27.346	29.76774	9.815506
Normality Jarque-Bera test (TJB)		2767631	752.779	889.2236	110.9029
Ljung–Box test with different lags (LBT)					
Ljung–Box, lags = 3		9.849924	18.94842	0.871039	9.848683
Ljung–Box, lags = 6		12.39657	22.42295	2.124184	13.39086
Ljung–Box, lags = 10	18.31	27.71077	25.8000	4.045597	15.36742
Ljung–Box, lags = 15	25,0	33.71326	32.1791	7.41855	15.90536
Ljung–Box, lags = 20	31.41	36.44562	52.56784	15.58628	26.72177
Lo–MacKinlay variance test					
z2 (q = 2)	Std N; 1.96	-14.9832	-16.3505	-14.6628	-13.6687
z2* (q = 2)	Std N; 1.96	-13.0137	-8.05553	-9.43669	-10.0416
z3 (q = 3)	Std N; 1.96	-12.8362	-14.7842	-13.5125	-13.9336
z3* (q = 3)	Std N; 1.96	-6.95635	-7.49696	-8.99423	-10.4765
z4 (q = 4)	Std N; 1.96	-12.0019	-12.7935	-12.0947	-12.4103
z4* (q = 4)	Std N; 1.96	-10.8204	-6.66096	-8.2581	-9.45231
z8 (q = 8)	Std N; 1.96	-8.96633	-9.31469	-8.98897	-9.06883
z8* (q = 8)	Std N; 1.96	-8.67179	-5.22011	-6.53062	-7.10874
z16 (q = 16)	Std N; 1.96	-6.45517	-6.6513	-6.53404	-6.58436
z16* (q = 16)	Std N; 1.96	-6.68147	-3.89328	-5.03522	-5.30483
I.I.D. tests					
Bartel test	Std N; 1,96	4.517421	2.256131	0.456305	0.255923
Simple runs test	Std N; 1.96	0.003291	0.012132	0.012214	0.010963
Up and down runs test	Std N; 1.96	1.598544	0.692103	0.335178	0.867895
Mann–Kendall test	Std N; 1.96	1.142614	1.507568	0.885065	1.170836
Inversions test	Std N; 1.96	1.340876	1.530335	0.997758	1.183309

Source: compiled by the author.

Note. In Table 1 of this Appendix, the values of statistical tests are given. In the first column, the critical value for the significance level 5% of the tests are shown. The note “Std N” stands for a standard normal distribution with the zero mean and the standard deviation equal to unit. The note” ” stands for the chi-square distribution with the degrees of freedom *df* and the significance level alpha. The corresponding critical values are presented. The absolute values of the variance and skewness tests must be used for comparison with the critical values.

TABLE 2. **Critical values of the chi-square distribution for some degrees of freedom used in the article, significance level 0.05**

Distribution	Critical values
Degree of freedom 3	
Degree of freedom 6	
Degree of freedom 10	18.31
Degree of freedom 15	25.00
Degree of freedom 20	31.41