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STOCK INDICES AS INDICATORS OF MARKET EFFICIENCY AND INTERACTION[5]

The efficient market hypothesis dominates in the studies on the effectiveness of stock market performance, one illustration of which is the presence of calendar anomalies of different nature. The advent of the Adaptive Market Hypothesis calls into question both the presence of such anomalies and the effectiveness of the stock market. To confirm the effective market hypothesis, the time series behaviour of the rates of return of the most significant global stock indices and a local Ukrainian PFTS Stock Index has been investigated in the work. According to the study results, the efficient market hypothesis has not been confirmed; the results partially confirm the adaptive market hypothesis. To confirm the hypothesis that global stock markets have an impact on local stock exchanges, a pre-selected sample of time series of stock index rates of return was used. The Granger causality test was used for this purpose. To determine whether the time series of the dynamics of the stock index rates of return are stationary, the advanced Dickie-Fuller test was used since it takes into account the possible autocorrelation in residuals. The Phillips-Perron test was used as well.
Keywords: S&P; NIKKEI; DAX; FTSE; PFTS; day-of-the-week; calendar; anomalies; effect
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Introduction

The modern stock market is an important component not only of the country’s financial market, but of the country’s economy as a whole. The highly liquid stock market, along with

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the country‘s efficient banking system, can stimulate economic development primarily by attracting funds from investors. At the same time, in most studies, the hypothesis of efficient markets assumes that the previous prices of a financial asset cannot be used for forecasting future prices, and therefore the price of financial assets changes accidentally, due to the appearance of new information, since the price contains all the existing information on the market. However, the studies conducted on the example of different stock markets with different development levels showed the presence of calendar anomalies of different nature, called as the day-of-the-week, January, turn-of-the-month, Halloween and Dekansho-bushi effects.

Despite the considerable amount of researches, this problem is still the focus of attention for scientists from all over the world. Gradually, additional factors of various nature were introduced, such as the market conditions – recovery or decline, the quality of financial assets – high-quality or purely speculative, the level of market development - developed, developing or frontier market, etc. For today, there is no general consensus as to the presence of such calendar anomalies, as well as the effect of investor sentiments on decision-making regarding the transactions in financial assets. Moreover, in the early 2000s, a new Adaptive Market Hypothesis emerged, which, in contrast to the efficient market hypothesis, casts doubt on the existence of an efficient market. According to this hypothesis, investors act rationally, but mistakes can be made, however, they learn to adapt to the dynamic market environment, that is, the periods of market efficiency alternate with the periods of its inefficiency, which manifests itself in the market conditions, profit-making conditions, number of market players and so on. In turn, the presence of calendar anomalies indicates that markets are not constantly efficient, so the efficiency changes over time. The adaptive market hypothesis confirms that such adaptation, as well as innovative tools, are the result of competition between investors and natural selection in favour of more powerful players. That is to say, the adaptive market hypothesis confirms that effective market and market anomalies can coexist.

For Ukraine, like for most countries, this problem is very pressing, despite the low development of the local stock market, but in such conditions, the problem of calendar anomalies can be further exacerbated. In addition, for the Ukrainian stock market, its integration into the world stock market is becoming increasingly important, as well as the justification of the presence or absence of influence from world stock exchanges. The reasonable existence of such influence will allow to make more exact forecasts concerning the functioning of national stock exchanges. All of the above-mentioned material has determined the relevance and purpose of the study.

1. Literature Review

The issue of the formation of effects and certain patterns that frequently occur in the stock markets is the focus of researchers from different countries, and such effects can occur, both in the well-developed global stock markets and emerging and developing ones.

Regarding the developed markets, the historical evolution of monthly anomalies – the January effect, the December effect and the Mark Twain effect in the stock markets of the

USA, UK, Japan, Canada, France, Switzerland, Germany and Italy has been systematically investigated by Plastun A. at al (2020) using different statistical methods (average analysis, Student's t-test, ANOVA, the Mann – Whitney test and a trading simulation approach). The January effect was recognized as the most widespread among the three monthly anomalies, but it was determined that it existed in the mid-twentieth century and was typical for the US stock market. Since then, it has no longer manifested itself. At the same time, other calendar anomalies still exist and appear in stock markets as the December effect in the Canadian stock market and the Mark Twain effect in the UK stock market. Moreover, the calendar effects can appear in emerging markets, too, and that is why these studies are interesting not only scientifically but also practically.

As regards the anomalies appearing in the middle of the month, the study by Rosenberg M. (2004), in view of the basic research by Ariel, R. A. (1987), found that the effect of the month has a direct relationship with the business cycle, which is important for the systematic study of the market sustainability issue.

Rounaghi M. M. and Zadeh F. N. (2016), using the ARMA model, compare the S&P 500 and the London Stock Exchange and note that both markets are efficient and have financial stability during periods of boom and bust.

Khan M. S. R. and Rabbani N. (2018), having analyzed bidding data on the Japanese market from 1979 to 2018, firstly concluded that calendar anomalies in the Japanese stock market were not detected. To do that, they used the least squares method or a generalized form of autoregressive conditional heteroscedasticity. After that, for more detailed analysis, the authors arranged the same data into relevant ranges which corresponded to the UP and DOWN market conditions. Applying the same methods – the least squares method and the generalized autoregressive conditional heteroscedasticity revealed the presence of different calendar anomalies (the day-of-the-week, January, turn-of-the-month, Halloween effects), but these anomalies were observed only when the market went up, but when the market went down these anomalies in the Japanese market were never observed.

Chiah, M. and Zhong, A. (2019) analyzed the day-of-the-week effect on the example of twenty-four countries from four regions of the world (Europe, North America, Global excluding the US and Pacific), taking into account the proposed by Asness, CS, Frazzini, A., Pedersen, LH (2019) a quality-minus-junk factor, at that profitability, growth and safety are the main attributes of quality. As a result, they concluded that investors made more optimistic market forecasts for speculative securities on Friday, as their mood was significantly improved and on Monday, the situation looked more pessimistic, as investors' mood was also pessimistic.

Wats S. (2019), having examined the situation on the stock market of India for the period from 1997 to 2016, which is considered to be one of the emerging markets, has concluded that despite the fact that the Indian economy is growing rapidly, India's stock market is inefficient and does not fully ensure the performance of its functions. The reason for this is the lack of sufficient highly liquid assets, as well as an adequate number of investors. Among all possible anomalies that may occur in the stock market, the study identified some calendar anomalies, such as the day-of-the-week effect.

Obalade, A. A. and Muzindutsi, P.-F. (2019), on the example of stock markets in Africa, prove the presence of calendar anomalies when the situation in the market changes, that is, bull and bear market situations. They state that some anomalies appear in one situation and disappear in another one, thereby confirming the adaptive market hypothesis.

Tevdovski D. at al. (2012) studied the day-of-the-week effect from 2006 to 2011 on the example of five countries from South Eastern Europe (SEE): Bosnia and Herzegovina, Bulgaria, Croatia, Macedonia and Serbia in the most recent period characterized by a bear market conditions. Applying a regression with dummy variables, the so-called Analysis of Variance (ANOVA) model, as well as the Wald test showed that this effect appeared only on the Croatian and Bulgarian stock markets, as the average daily profitability of leading national indices on Monday was lower than on other days, which was not confirmed for other countries in the sample.

In view of the active development of the Islamic financial market in recent years, the presence of calendar anomalies in the stock markets of Islamic countries is also becoming increasingly important to investors. Khurram MU at al. (2019) investigates the effectiveness of the financial markets, their integration and shock transmission channels in the example of eight stock markets of the Islamic developing countries of D-8 group, established in Turkey in 1997, comprising Pakistan, Bangladesh, Iran, Indonesia, Malaysia, Turkey, Egypt, and Nigeria. The study period covered 2011-2016. Unit Root Test, Serial Correlation Test, Runs Test, and Variance Ratio Test were used in this study to evaluate the market effectiveness as well as Johansen Cointegration Test, Granger Causality Test, Vector Error Correction Model and Impulse Response Test were used to prove the presence of financial integration between the stock markets and shock transmission. The study concluded that the markets were poorly performing and that there was only a short-term benefit for investors. A. Alotaibi and A. Mishra (2017) determined the degree of international integration of stock markets in the region of the Gulf Cooperation Council (Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, and United Arab Emirates) on the basis of data generated by 2002–2013 period. The presence of significant fluctuations in the indices of stock markets of these countries was substantiated, which is formed under the influence of local risks, according to the authors.

Taking into account the ambiguity of the research results of the functioning of stock markets and their compliance with the hypothesis of an efficient market in the early 2000s, there are works that indicate that investors in the stock market can act rationally. The works of A. Lo (2005, 2007, 2012) should be singled out among the works in which the hypothesis of an efficient market is questioned and the hypothesis of an adaptive market is substantiated. In particular, it is noted that markets may not always be efficient, but they are usually competitive and able to adapt depending on how the market environment and the number of investors change over time.

Regarding the Ukrainian stock market, rational and irrational investor behaviours were analyzed and a situational approach was used to avoid losses (Kushnir, 2016). In addition, Caporale GM at al. (2019) studied the effects of force majeure (economic force majeure, social, natural and man-made disasters, as well as the acts of terrorism) on pricing in the stock market of Ukraine and specified that the market absorbs all information and transforms it into prices except for the cases of natural and man-made disasters. Shkolnyk, I. et al. (2017)

studied the problems of ensuring the protection of investments of individual investors in the stock market of Ukraine, studying the experience of countries with developed stock markets. In another paperwork by Shkolnyk, I. (2021), studying the development trends of the stock market of Ukraine for the 2015-2020 period under the influence of global stock markets, we argued that the dynamics of trading on stock exchanges of Ukraine is 50% determined by the situation on stock exchanges of American region.

Regarding the studies of the mutual influence of world stock indices on the formation of Ukrainian stock indices, it should be noted that I. S. Blahun and I. I. Blahun (2020) conducted a study based on data for the 2010-2017 period and found a unilateral impact on the PFTS index by the global stock indices Standard & Poor's Global Ratings, NIKKEI 225, FTSE, DAX, WIG, as well as the presence of long-term balance between the PFTS index and the group formed from these indices. At the same time, starting from 2018, the results of the reform that implements the regulators of the financial market of Ukraine are becoming more tangible, so the results obtained in this work may not coincide with the results obtained earlier.

Given the limited number of studies on the appearance of anomalies in the Ukrainian stock market, there is a need for such studies. In addition, it is important to specify whether there is a relationship between the local Stock Exchange PFTS, which is one of the largest stock markets by the traded volume in Ukraine, and the global stock markets.

These three countries are relatively small and underdeveloped in terms of their geographical size and population, geopolitical importance, market size and aggregate demand, production, investment, export, and technological potential. According to many non-economic indicators (political stability, democratization, liberalization and institutionalization of society, law, infrastructure development, safety, security, investment, compliance with environmental and social standards, efficiency of the legal system, human rights respect, etc.), as well as economic indicators (purchasing power, rate of economic growth, foreign trade balance, current account deficit, public debt, inflation rate, unemployment rate, public expenditure, investments, etc.), they are characterized by a long-term transitional crisis of structural type.

2. Methodological Approach

This study was based on the data of the time series behaviour of the rates of return of the most significant global stock indices – Standard & Poor's Global Ratings 500, NIKKEI 225, FTSE 250 and DAX. A local PFTS Stock Exchange was selected to conduct this research. The choice was also guided by the fact that the PFTS index, taken into account when analyzing the stock market conditions in Ukraine, is formed in view of trading on this stock exchange. The study period covered 2014-2021. Data were processed using eViews and MatLab program.

The study was conducted as follows. Firstly, a data extract of daily rates of return for these indices over a specified time period was made. Then the determined rates of return for the stock indices were divided into five groups: the first group - the trading week of each month, between the 5^{th} and the 11^{th} day of the month; the second, third and fourth groups are, respectively, the second, third and fourth full weeks of the month. The fifth group includes the weeks, which cover the end of one month and the beginning of the following one. As for the fifth group, it covers the weeks that fall before the 5th day of the month. For each of the groups, the average rate of return for the week was calculated on the basis of values of the index during the fixing at the last session of the week.

Based on these data, the weekly rate of return for each stock index was individually determined, and their normalization was carried out by the formula:

$$R_w = \frac{I_2 - I_1}{I_1} \quad (1)$$

where:

R_w is the average rate of return per week;

I_1 is the index value during the fixing at the last session of the previous week;

I_2 is the index value during the fixing at the last session of the current week.

The obtained normalized indicators are used for all calculations in order to establish the presence/absence of the impact of the state of world stock markets on the situation developing in the Ukrainian stock market.

The Granger causality test was used for this purpose. To test the time series of the stock index rates of return for their stationarity development, the augmented Dickie-Fuller test was used, since it takes into account the possible autocorrelation in residue. The Phillips-Perron test was used as well. Both tests are the tests for unit roots; that is, the equations of the autoregressive time series model have roots that are equal to a unit modulo. The cointegration tests were also conducted.

For a more objective result as to the relationship between the figures analyzed, nonlinear dependencies are identified using fuzzy databases. The model of fuzzy logic inference is an approximation of the input-output dependence based on the linguistic rule “IF ... THEN”. An adaptive neuro-fuzzy inference system (ANFIS) based on Takagi-Sugeno fuzzy inference system is used for this purpose (Takagi, Sugeno, 1985). ANFIS model was proposed by Jang, J.-SR (1993), and is a multilayer neural network with direct signal propagation. The relationship between the input $X = x_1, x_2, \dots, x_n$ and the output y is defined by a fuzzy database, using the following rules:

$$IF\ x_1 IS\ X_{1,i}\ AND \dots AND\ x_{n_x}\ IS\ X_{n_x,i}\ THEN\ y = f_i\left(x_{1,} \dots, x_{n_x}\right), i = 1, \dots n_r \quad (2)$$

where:

$X_{1,i}, \dots, X_{n_x,i}$ – linguistic value in the antecedent of the ith rule;

$f_i\ (x_1, \dots, x_{n_x})$ – function in consequence of the ith rule.

The output in the model is defined as follows:

$$y = \sum_{i=1}^{n_R} \omega_i(x_1, \dots, x_{n_x}) \cdot f(x_1, \dots, x_{n_x}) / \sum_{i=1}^{n_R} \omega_i(x_1, \dots, x_{n_x}), \quad (3)$$

where:

$\omega_i(x_1, \ldots, x_{n_x})$ – degree of implementation of the ith rule.

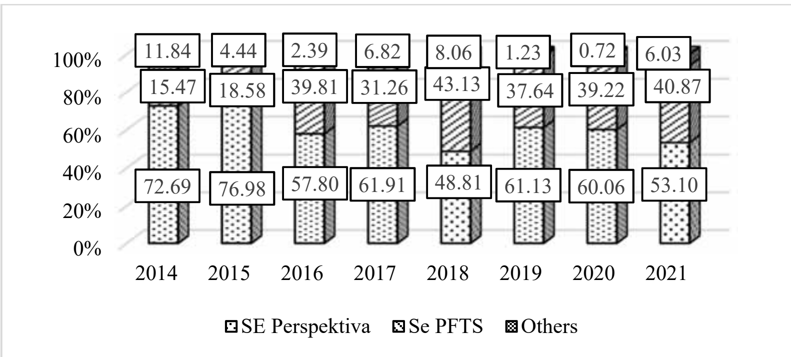
In this model, the database is hybrid; that is, its rules contain fuzzy sets and it is written as a clear linear function. In the model, several linear laws can be executed at the same time, but with different significance.

3. Conducting Research and Results

To assess the situation on the local Ukrainian market, the indicators characterizing the trading on the PFTS Stock Exchange, which was one of the first stock markets created in Ukraine, were used. Before the crisis of 2008, it was the stock exchange of the largest share of trading, and such situation had been observed since the early 2000s. Then, the share of trading on the PFTS Stock Exchange gradually decreased to 15% in 2014, which was a crisis for the Ukrainian economy, primarily due to some political factors. In general, since 2012-2014 stock market transactions were concentrated on two stock exchanges – SE PFTS and SE Perspektiva. After 2014, the situation was gradually balanced and as of 2021, the share of the trading on the SE PFTS was 41%, and on the SE Perspektiva – 53%. At the same time, the PFTS index has been calculated in Ukraine for a long time, it is taken into account by financial market regulators in Ukraine when building macroeconomic forecasts, it can form a sufficient sample, which can be compared with data from global stock markets.

Figure 1

Structure of trading on the stock exchanges of Ukraine



Source: compiled by the author according to the data of the National Securities and Stock Market Commission.

Based on the formed data extract of daily rates of return of world stock indices and the PFTS index, it can be stated that a clear trend in the behaviour of the rates of return on any stock exchange during the whole analyzed period was not observed.

In the context of individual indices, no patterns of anomaly manifestation at the beginning or at the end of the month were established, so it could be argued that the condition of the studied markets within the period from 2014 to 2021 cannot be considered rather effective. That may be due to the post-crisis period for markets, as well as due to changes in the Ukrainian market in the legislation governing the functioning of stock markets.

Table 1

Effect of the week for index rates of return by year

Indices	I group	II group	III group	IV group	V group
PFTS					
2014	0,0299	0,0099	0,0120	0,0129	0,0347
2015	0,0056	-0,0063	-0,0086	-0,0269	-0,0119
2016	0,0252	-0,0031	-0,0206	-0,0014	0,0101
2017	0,0139	-0,0031	-0,0011	0,0162	0,0082
2018	0,0053	0,0019	0,0188	0,0168	-0,0032
2019	0,0104	-0,0107	-0,0033	-0,0208	-0,0128
2020	0,0044	-0,0101	0,0058	0,0103	0,0029
2021	0,0052	0,0047	0,0062	0,0014	0,0015
FTSE					
2014	0,0154	0,0111	0,0136	0,0130	0,0166
2015	0,0034	-0,0046	-0,0013	0,0061	-0,0106
2016	0,0080	0,0058	0,0001	-0,0034	0,0173
2017	0,0109	0,0033	0,0066	0,0041	0,0111
2018	0,0054	0,0082	0,0036	-0,0036	-0,0048
2019	0,0020	-0,0009	-0,0028	0,0093	0,0007
2020	0,0041	0,0053	-0,0038	0,0161	0,0021
2021	0,0014	0,0013	0,0038	0,0023	0,0028
DAX					
2014	0,0163	0,0128	0,0062	0,0181	0,0073
2015	-0,0107	0,0130	-0,0045	0,0027	-0,0104
2016	0,0225	0,0032	0,0107	-0,0007	0,0084
2017	0,0121	0,0117	0,0091	0,0030	0,0071
2018	0,0105	0,0104	0,0082	-0,0100	-0,0094
2019	-0,0037	0,0055	0,0035	0,0139	0,0073
2020	0,0026	0,0083	-0,0150	0,0204	0,0009
2021	0,0061	0,0081	0,0070	-0,0009	-0,0027
S&P					
2014	0,0157	0,0084	0,0152	0,0092	0,0058
2015	0,0114	-0,0069	0,0054	-0,0007	-0,0098
2016	0,0060	0,0100	0,0032	-0,0023	0,0202
2017	0,0116	0,0066	0,0084	0,0085	0,0121
2018	0,0134	0,0078	0,0041	-0,0039	0,0010
2019	0,0070	-0,0029	0,0032	0,0018	0,0049
2020	0,0045	0,0037	0,0008	0,0075	0,0026
2021	0,0044	0,0039	0,0056	0,0001	0,0052
Nikkei					
2014	0,0125	0,0107	0,0116	0,0027	0,0052
2015	0,0076	-0,0034	0,0007	-0,0112	-0,0071
2016	0,0062	0,0075	-0,0036	-0,0021	0,0298
2017	0,0050	0,0054	0,0226	0,0271	0,0089
2018	0,0144	0,0095	-0,0037	-0,0047	0,0068
2019	-0,0010	0,0001	0,0123	0,0064	0,0104
2020	-0,0095	-0,0049	-0,0025	0,0137	0,0096
2021	0,0082	0,0040	0,0008	0,0010	0,0068

Source: compiled by the author.

Since 2015, Ukrainian financial market regulators such as the National Securities and Stock Market Commission and the National Bank of Ukraine have implemented a number of reforms aimed at clearing the financial market from illiquid and speculative financial assets, as well as creating economic and technological conditions for the entry of foreign financial assets into the Ukrainian stock market and the possibility of transactions by Ukrainian investors. Similar conclusions can be drawn from the results obtained as the effect of the week and the effect of the day (Appendix A and Appendix B).

The next step is to test the hypothesis about the essential impact of global stock markets, namely – the US market with the Standard & Poor's Global Ratings 500 impact index, the Japanese market with the NIKKEI 225 impact index, the UK market with the FTSE 250 impact index and the German market with the DAX impact index, on the dynamics of the formation of stock index rate of return on local markets on the example of the Ukrainian market using the PFTS index. The series of stock index rates of return with a time lag in calculations equal to 2 were made using the Granger causality test (Table 2).

Table 2

Causality test for the series of stock index rates of return

	Null Hypothesis:	F-Statistic	Prob.
S&P 500	S&P 500 does not Granger Cause PFTS	1,2982	0,3261
	PFTS does not Granger Cause S&P 500	0,8615	0,4944
FTSE 250	FTSE 250 does not Granger Cause PFTS	0,0394	0,9752
	PFTS does not Granger Cause FTSE 250	1,2193	0,3721
DAX	DAX does not Granger Cause PFTS	0,0134	0,8985
	PFTS does not Granger Cause DAX	0,8142	0,4754
NIKKEY_225	NIKKEY_225 does not Granger Cause PFTS	3,3505	0,0856
	PFTS does not Granger Cause NIKKEY_225	0,8962	0,5241

Source: compiled by the author.

The study was conducted in two ways: firstly, it was determined whether the PFTS index contributes to changes in the Standard & Poor's Global Ratings 500, NIKKEI 225, FTSE 250 and DAX indices, and secondly, whether the global indices are retroactive in effect. The time lag 2 was taken for these calculations. At that, the null hypothesis about the nexus between the rate of return of the PFTS index and the rate of return of world stock indices should be taken into account. There was no significant improvement in the quality of the model due to the inclusion of the PFTS index rate of return in the list of indices of powerful global stock markets. The obtained results showed that in the first case, the probability of the PFTS impact on the selected world indices is insignificant and ranges from 0.3721 – as for FTSE 250 index to 0.4944 – as for S&P 500 index.

At the same time, a different dynamic can be observed with an inverse effect. The situation here is ambiguous, as the NIKKEY 225 index (almost 92%) and the S&P 500 index (67.39%) are characterized by the highest probability of impact on the local stock index; in other words, the dynamics of the PFTS index rates of return is determined by the situation on the Japanese and US stock markets. However, the DAX and the FTSE 250 indices, with an impact probability of 10.1% and 2.5%, respectively, do not have any influence on the PFTS index. Thus, there is an impact of world stock indices on the local index, but this influence is selective. Despite the fact that geographically Ukraine is a part of Europe, nevertheless, ties with European stock markets are not confirmed. Also, Shkolnyk I. (2021) reached the same result in their work using other models and basing on trading volumes in regions that accumulate trading volumes on stock exchanges of the US and European regions.

In addition, the impact of the US market can intensify in the future, since, after changes in the legislation of Ukraine, in 2020, the stock exchanges have the opportunity to carry out transactions with foreign financial acts, which have mainly American origin.

To justify the linkages between global and local indexes, the cointegration tests, which determine the PFTS index rate of return as a dependent variable, were used (Table 3). The highest dependence between the PFTS index is manifested with the FTSE 250 (71%) index, unlike the previous stage, and S&P 500 (65.4%), which in the previous stage showed almost the same result.

Table 3

Equations and cointegration tests. Dependent Variable: PFTS

Variable	Coefficient	Std. Error	t-Statistic	Prob.
S&P 500	0,6537	0,3128	1,6781	0,0812
NIKKEY_225	0,3264	0,2025	1,1823	0,2126
FTSE 250	0,7108	0,3171	2,1051	0,0451
DAX	0,0294	0,2517	0,1043	0,9322
	S&P 500	NIKKEY_225	FTSE 250	DAX
R-squared	0,0745	0,0351	0,1052	0,0003
Adjusted R-squared	0,0745	0,0351	0,1052	0,0003
SE of regression	0,0115	0,0117	0,0113	0,0119
Sum squared resid	0,0052	0,0054	0,0051	0,0056
Log-likelihood	124,5261	122,4151	123,9813	120,7158
Durbin-Watson stat	1,9062	1,8934	1,8243	1,8485
Mean dependent var	-5,06E-06	-5,06E-06	-5,06E-06	-5,06E-06 (It is advisable in the Excel output file to choose a numeric format to get lack of E and replace these numbers in a line!)
SD dependent var	0,0235	0,0235	0,0235	0,0235
Akaike info criterion	-6,0632	-6,0132	-6,0761	-5,9851
Schwarz criterion	-6,0198	-5,9679	-6,0518	-5,9541
Hannan-Quinn criter.	-6,0532	-6,0073	-6,0771	-5,9843

Source: compiled by the author.

The augmented Dickey-Fuller and the Phillips-Perron tests, which are unit root tests and enable to evaluate the quality of the regression model, were used to test the time series for stationarity development. The obtained results are shown in Appendix C. Since the probability value according to the results obtained by the Dickey Fuller and the Phillips-Perron tests were 0.0000 for all stock index rates of return, the null hypothesis that says that time series are non-stationary, was discarded, and it could be argued that stock index rates of return are stationary series, which are of the first-order integration, and therefore the model is appropriate. In addition, McQinnon's t-Statistic value in all indices without exception was less than an absolute ultimate value for the significance level of 1%, 5%, and 10%.

The last step of the study is determining the integration of the PFTS index with the group of world indexes. The results are presented in Table 4.

Table 4
Equations and cointegration tests (PFTS index as a dependent variable, cumulative effect of world stock market indices). Dependent Variable: PFTS

Variable	Coefficient	Std. Error	t-Statistic	Prob.
S&P 500	0,0008	0,6568	0,0013	0,9895
NIKKEY_225	0,0985	0,2819	0,3481	0,7297
FTSE 250	0,9051	0,54391	1,6651	0,1044
DAX	-0,3083	0,2752	-1,2521	0,2173
R-squared	0,1451	Mean dependent var		-5.06E-06
Adjusted R-squared	0,0745	SD dependent var		0,0235
SE of regression	0,0127	Akaike info criterion		-6,0632
Sum squared resid	0,0052	Schwarz criterion		-6,0182
Log-likelihood	124,5261	Hannan-Quinn criteria.		-5,930783
Durbin-Watson stat	1,9062			

Source: compiled by the author.

As it was in the previous step, the formed time series were tested for stationarity. In this case, the probability value according to the results of the Dickey-Fuller test and the Phillips-Perron test was 0.0004 and 0.0000, respectively, which means that the time series nonstationarity was not confirmed, the McKinon t-Statistic value for the Dickie-Fuller test (-4.77) has less value than the absolute values of the ultimate value for the significance level of 1%, 5%, and 10%, the similarly expanded value of the adjusted t-Statistic value for the Phillips-Perron test (-6.6) has less value for the threshold (Table 5).

Table 5
Summary results of the Augmented Dickey_Fuller Unit Root Test and the Phillips_Perron Unit Root Test Cointegration tests (cumulative effect of world stock market indices)

Augmented Dickey_Fuller Unit Root Test				
		t-Statistic	Prob.	
		-4,7651	0,0004	
Test critical values:	1 % level	-3,6213		
	5 % level	-2,95442		
	10 % level	-2,6193		
Variable	Coefficient	Std. Error	t-Statistic	Prob.
BI(-1)	-1,1247	0,278286	-4,6912	0,0000
D(BI(-1))	0,3087	0,2212	1,3923	0,1737
D(BI(-2))	0,1672	0,1525	1,0104	0,3195
C	-0,0021	0,0018	-1,1246	0,2689
Phillips_Perron Unit Root Test				
		Adj. t-Stat	Prob.	
		-6,6014	0,0000	
Test critical values:	1 % level	-3,6101		
	5 % level	-2,9014		
	10 % level	-2,5932		
Residual variance (no correction)			0,0002	
HAC Corrected variance (Bartlett kernel)			7,25E-05	

Source: compiled by the author.

Thus, it can be argued that the time series are stationary and the model is adequate. Therefore, the impact of world stock market indices on local stock markets can be proved, in particular, it is the case of the Ukrainian stock market.

Based on the fuzzy approximation theorem by Kosko, B. (1994), it can be argued that any mathematical system can be approximated by a fuzzy logic system. It is quite obvious that the dependence of the PFTS indices on the dynamics of other indices, in particular, the FTSE and S&P indices should be considered nonlinear. Therefore, for better justification of the relationship between the studied indices, Takagi-Sugeno model is used, which provides several consistent steps in implementation. The entire set of profitability observations for each of the three stock exchanges is represented by a set of values with a length of 2994, which is further respectively divided into two samples – training one (2396) and test one (598).

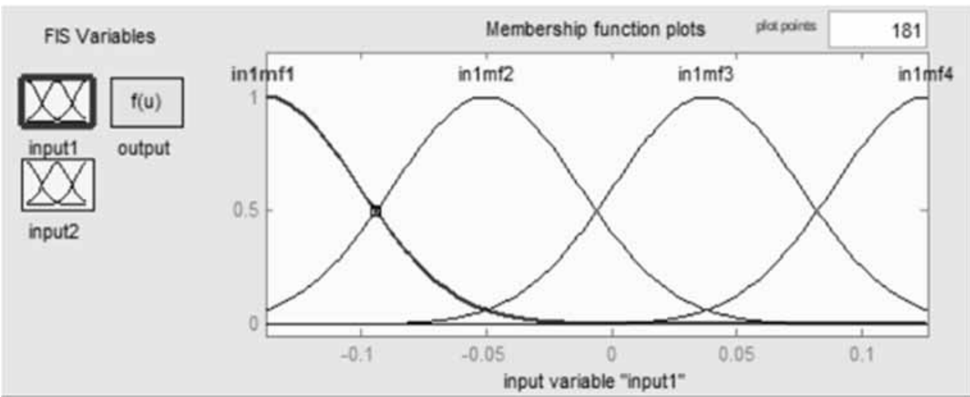
Takagi-Sugeno fuzzy inference system is generated based on the test sample. In particular, term sets are defined for both the input variables (FTSE and S&P) and the dependent variable (PFTS); the membership function is defined for each term. The task of constructing the membership function looks like this. There are two sets: a term set $L = \{l_1, l_2, \dots, l_m\}$ and a universal set $U = \{u_1, u_2, \dots, u_n\}$. The fuzzy set l for determining the linguistic term lj on the universal set U has the form:

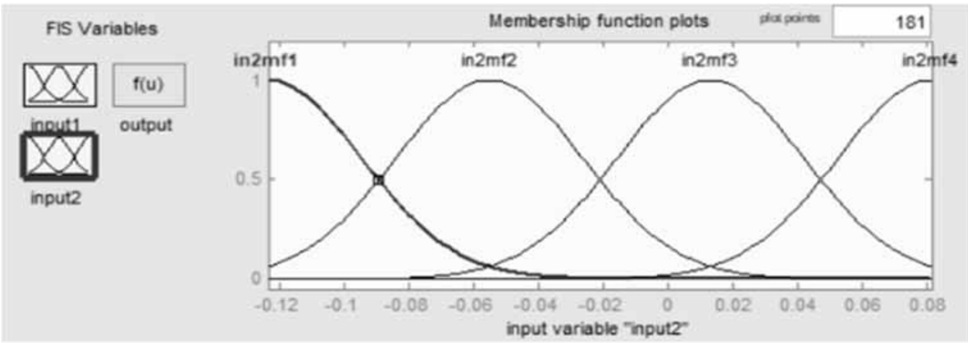
$$\widetilde{l_j} = \left(\frac{\mu_{l_j}(u_1)}{u_1}, \frac{\mu_{l_j}(u_2)}{u_2}, \dots, \frac{\mu_{l_j}(u_n)}{u_n}\right), j = \overline{1, m}. \quad (4)$$

The Grid partition method gives the initial fuzzy inference system (Figure 2-3). According to this method, the membership functions of the fuzzy terms are uniformly distributed within the range of changing input and output variables. The number of membership functions and their types are determined (in our case, for each of the terms of all input variables, the normal type of distribution was determined).

Figure 2

Takagi-Sugeno fuzzy inference model





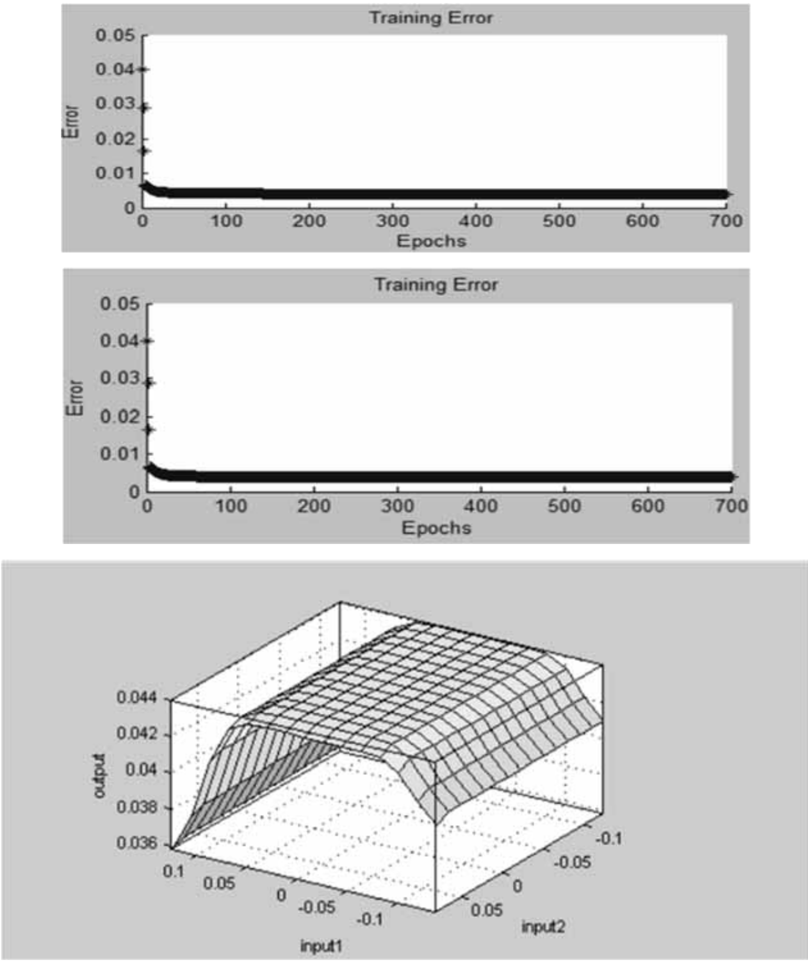
Source: compiled by the author

The rule system in Takagi-Sugeno fuzzy inference model looks like this:

1. if (input1 is in1mf1) and (input2 is in2mf1) then (output is out1mf1) (1)
2. if (input1 is in1mf1) and (input2 is in2mf2) then (output is out1mf2) (1)
3. if (input1 is in1mf1) and (input2 is in2mf3) then (output is out1mf3) (1)
4. if (input1 is in1mf1) and (input2 is in2mf4) then (output is out1mf4) (1)
5. if (input1 is in1mf2) and (input2 is in2mf1) then (output is out1mf5) (1)
6. if (input1 is in1mf2) and (input2 is in2mf2) then (output is out1mf6) (1)
7. if (input1 is in1mf2) and (input2 is in2mf3) then (output is out1mf7) (1)
8. if (input1 is in1mf2) and (input2 is in2mf4) then (output is out1mf8) (1)
9. if (input1 is in1mf3) and (input2 is in2mf1) then (output is out1mf9) (1)
10. if (input1 is in1mf3) and (input2 is in2mf2) then (output is out1mf10) (1)
11. if (input1 is in1mf3) and (input2 is in2mf3) then (output is out1mf11) (1)
12. if (input1 is in1mf3) and (input2 is in2mf4) then (output is out1mf12) (1)
13. if (input1 is in1mf4) and (input2 is in2mf1) then (output is out1mf13) (1)
14. if (input1 is in1mf4) and (input2 is in2mf2) then (output is out1mf14) (1)
15. if (input1 is in1mf4) and (input2 is in2mf3) then (output is out1mf15) (1)
16. if (input1 is in1mf4) and (input2 is in2mf4) then (output is out1mf16) (1)

Figure 3

Dynamics of fuzzy inference system training using ANFIS neural network

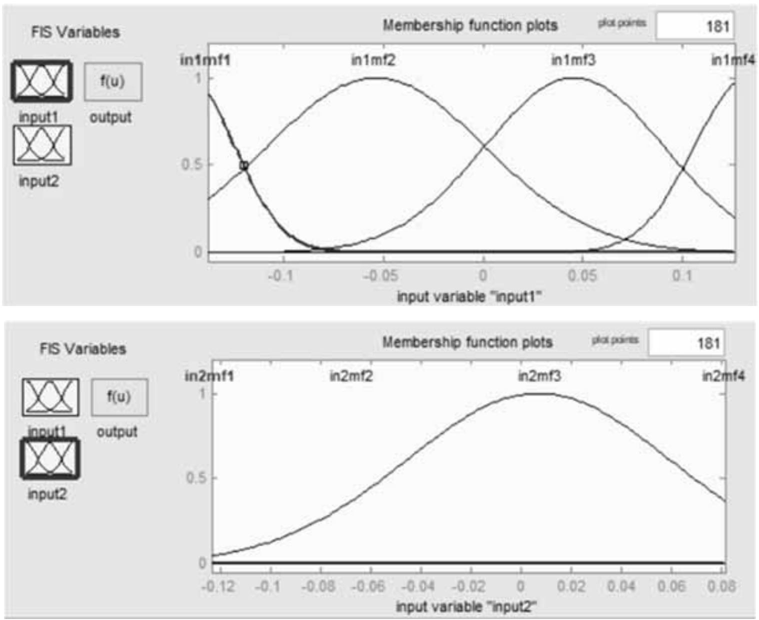


Source: compiled by the author.

According to the results of the training, average error of 0.0040298 and 0.0039193 was obtained. After determining the optimal parameters of the input variables, the following results were obtained (Figure 4). Thus the synthesized system of fuzzy inference as a neural network for the generated sample of PFTS, FTSE and S&P indices has the following form. To verify the results, the value of the final variable in the test sample was determined (Figure 6).

Figure 4

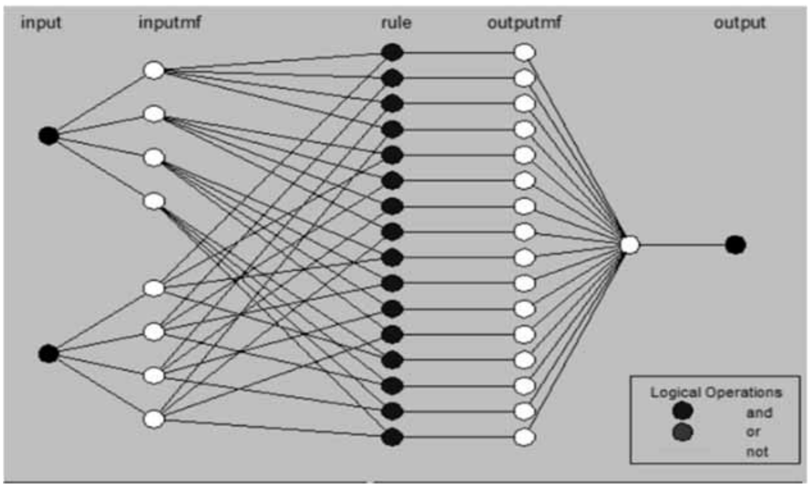
Membership functions of the fuzzy terms of one of the input variables after determining their optimal parameters



Source: compiled by the author

Figure 5

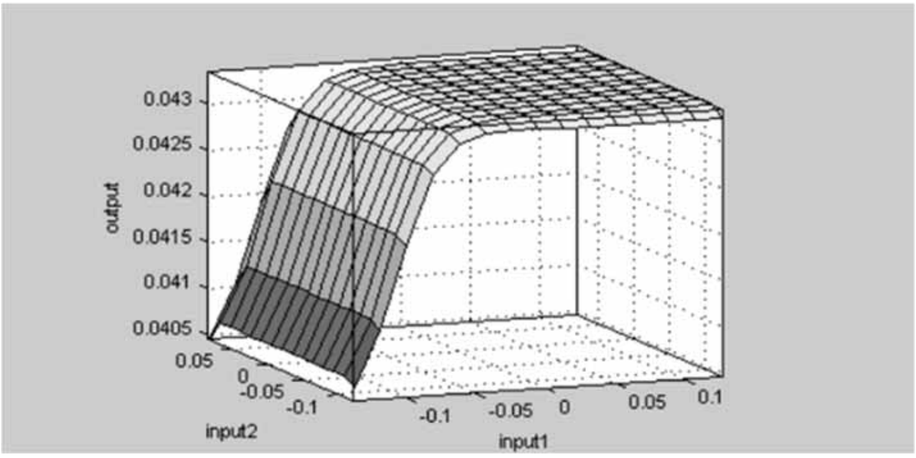
Synthesized fuzzy inference system of ANFIS network



Source: compiled by the author

Figure 6

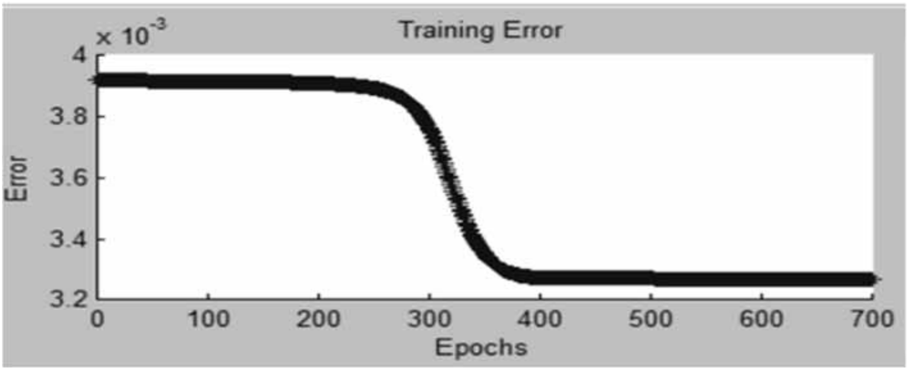
The value of the final variable in the test sample



Source: compiled by the author.

Figure 7

Dynamics of testing fuzzy inference system using ANFIS neural network based on the test sample data



Source: compiled by the author.

The analysis of errors in the studied and test sample makes it possible to claim that the constructed model of the dependence of index dynamics on the studied stock exchanges is adequate. The calculations of the theoretical values of the final variable by Takagi-Sugeno fuzzy inference model, as well as their comparison with the actual observational data, enabled to obtain an average error value of 0.0032685, which, in our opinion, is an acceptable result and also indicates sufficiently well-defined system parameters of the fuzzy inference system that models the dependence of the PTFS on the FTSE and S&P.

Conclusion

Thus, the behaviour of the daily rates of return of the world stock indices such as Standard & Poor's Global Ratings 500, NIKKEI 225, FTSE 250, DAX, as well as the local PFTS index, which were grouped in five trading weeks, showed that calendar anomalies, which are the evidence of the efficient market hypothesis, have not been revealed. In addition, there was no clear trend in the behaviour of the rates of return on any stock exchange during the whole analyzed period.

As a result of the test, the hypothesis about the impact of global stock indices on local stock indices in the example of the SE PFTS was confirmed only for the US S&P 500 (67.39%) and the Japanese NIKKEY 225 (almost 92%) indices. At the same time, the DAX and FTSE 250 indices, with a probability over 90%, unlikely have an impact on a local index. This has objective circumstances since, on the one hand, the stock market of Ukraine is small in size, and on the other side, it is as open as possible to Ukrainian and foreign investors and is gradually integrated into the world stock markets.

The cumulative effect of world stock market indices on the PFTS index as a dependent variable showed a close link between them. Therefore, it can be stated that the global stock markets determine the Ukrainian stock market. Testing the proposed hypothesis using Takagi-Sugeno fuzzy inference model revealed the impact of the FTSE 250 and S&P 500 indices on the PFTS index.

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APPENDIX A

Effect of the week for index rates from 2014 till 2021

Index	1-7	8-15	16-22	23+
PFTS	-0,0058	0,0297	-0,0283	0,0176
FTSE	-0,0172	0,0138	0,0289	0,0039
DAX	-0,0106	0,0179	0,0297	0,0327
S&P	0,0004	0,0276	0,0343	0,0071
Nikkei	0,0091	0,0045	0,0329	0,0261

APPENDIX B

Effect of the day for index rates from 2014 till 2021

Index	Monday	Tuesday	Wednesday	Thursday	Friday
PFTS	0,2874	0,2993	0,6153	0,7712	0,8481
FTSE	0,0104	0,0106	0,0098	0,0051	0,0235
DAX	0,0268	0,0304	0,0231	0,0239	0,0286
S&P	0,0319	0,0286	0,0262	0,0285	0,0386
Nikkei	-0,0813	-0,0924	-0,1088	-0,0935	-0,1491

APPENDIX C

Summary results of the Augmented Dickey_Fuller Unit Root Test та Phillips_Perron Unit Root Test

Index		Augmented Dickey_Fuller Unit Root Test				Phillips_Perron Unit Root Test			
S&P 500			t-Statistic	Prob.			Adj. t-Stat	Prob.	
			-5,9325	0,0000			-5,9113	0,0000	
	Test critical values:	1 % level	-3,6113			1 % level	-3,6113		
		5 % level	-2,9138			5 % level	-2,9138		
		10 % level	-2,6107			10 % level	-2,6017		
		Coefficient	Std. Error	t-Statistic	Prob.	Coefficient	Std. Error	t-Statistic	Prob.
	S&P 500(-1)	-0,9676	0,1661	-5,9325	0,0000	-0,9676	0,1661	-5,9325	0,0000
	C	0,0018	0,0009	2,0141	0,0513	0,0018	0,0009	2,0141	0,0513
NIKKEY_225			t-Statistic	Prob.			Adj. t-Stat	Prob.	
			-7,4924	0,0000			-7,4924	0,0000	
	Test critical values:	1 % level	-3,6103			1 % level	-3,6103		
		5 % level	-2,9237			5 % level	-2,9237		
		10 % level	-2,60142			10 % level	-2,6014		

Index		Augmented Dickey_Fuller Unit Root Test				Phillips_Perron Unit Root Test			
		Coefficient	Std. Error	t-Statistic	Prob.	Coefficient	Std. Error	t-Statistic	Prob.
	NIKKEY_225(-1)	-1,2005	0,1625	-7,4924	0,0000	-1,2005	0,1625	-7,4924	0,0000
	C	0,0024	0,0014	1,6851	0,0944	0,0024	0,0014	1,6851	0,0944
FTSE 250			t-Statistic	Prob.			Adj. t-Stat	Prob.	
			-6,9302	0,0000			-7,1032	0,0000	
	Test critical values:	1 % level	-3,5214			1 % level	-3,5214		
		5 % level	-2,8987			5 % level	-2,8987		
		10 % level	-2,6107			10 % level	-2,6107		
		Coefficient	Std. Error	t-Statistic	Prob.	Coefficient	Std. Error	t-Statistic	Prob.
	FTSE 250(-1)	-1,10127	0,1561	-6,9302	0,0000	-1,0112	0,1561	-6,9302	0,0000
	C	0,0021	0,0009	1,4341	0,1977	0,0021	0,0009	1,4341	0,1977
DAX			t-Statistic	Prob.			Adj. t-Stat	Prob.	
			-6,4401	0,0000			-6,5016	0,0000	
	Test critical values:	1 % level	-3,5961			1 % level	-3,5961		
		5 % level	-2,9752			5 % level	-2,9752		
		10 % level	-2,5962			10 % level	-2,5962		
		Coefficient	Std. Error	t-Statistic	Prob.	Coefficient	Std. Error	t-Statistic	Prob.
	FTSE 250(-1)	-1,1583	0,1643	-6,4401	0,0000	-1,1583	0,1643	-6,4401	0,0000
	C	0,0019	0,0015	1,4972	0,1634	0,0019	0,0015	1,4972	0,1634