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Dynamics of World Indices as a Reflection of the Development World Financial Market

Vyacheslav Lyashenko[1], Mykhailo Bril[2], Olena Shapran[3]

[1]Department of Media Systems and Technology, Kharkiv National University of Radio Electronics, Kharkiv, Ukraine
e-mail: lyashenko.vyacheslav@gmail.com

[2]Department of Economic Theory and Economic policy, Simon Kuznets Kharkiv National University of Economics, Kharkiv, Ukraine

[3]Department of Economics and Marketing, National Technical University «Kharkiv Polytechnic Institute», Kharkiv, Ukraine

Abstract: *Economic dynamics are closely interconnected with various segments of economic relations. A special role among such relationships is formed in the financial markets. This is due to the ability to attract the necessary financial resources or redistribute financial resources between various business entities. This can be achieved with the help of various groups of securities. Each such group of securities is also characterized by some stock index. This index reflects the dynamics of securities prices. Consequently, the dynamics of stock indices is a reflection of the dynamics of the development of the financial market. To study the dynamics of stock indices, we use the ideology of wavelets. We have chosen wavelet coherence among the tools of the wavelet ideology. Wavelet coherence allows you to study the mutual dynamics of stock indices and draw the necessary conclusions. The paper examines the dynamics of the main world stock indices. The estimates of the wavelet coherence for the mutual dynamics of stock indices are shown. All results are based on real data. The conclusion is made about the expediency of using wavelet coherence for assessing the mutual dynamics of stock indices and assessing the development of the financial market.*

Keywords—dynamics; time series; financial market; securities; stock indices; wavelet analysis; wavelet coherence.

1. INTRODUCTION

The development of economic relations and interaction between various business entities is impossible without the functioning of the financial market. Financial markets allow you to redistribute free financial resources between different business entities, between sectors of the economy, between different countries [1], [2]. Financial markets also make it possible to regulate relationships between various business entities, to develop such ties in the required context.

The financial market is well structured. The financial market consists of several components that are closely interconnected. One of such parts of the financial market is the securities market [3]. Such securities can be grouped according to certain criteria. Moreover, each group of securities is characterized by a certain stock index. The stock index is an indicator of the change in prices of a certain group of securities.

The dynamics of stock indices characterizes the processes under the influence of which the price of a certain group of securities is formed. Since different components of the financial market are closely interrelated, stock indices are indicators of the development of the entire financial market. The stock index is also an indicator of the development of economic relations, an indicator of economic dynamics [4], [5].

Thus, the dynamics of stock indices reflects the development of the financial market. Therefore, the analysis of the dynamics of stock indices is an important and urgent task. This analysis also allows you to explore the economic dynamics of relationships between individual market segments, market participants, to outline the ways of their development. Based on this, the paper considers various aspects of the dynamics of world indices as a reflection of the development of the world financial market.

2. MATERIALS AND METHODS

2.1 Related Work

Analysis of the dynamics of the values of stock indices is one of the areas of research. Therefore, there are many works where the authors consider various methods and approaches to the analysis of the dynamics of the values of stock indices.

For example, J. Cao and J. Wang use the classical approach based on principal component analysis to study the dynamics of stock indices [6]. This approach and methods of neural networks are used by the authors of [6] to predict changes in the values of stock indices. J. Cao and J. Wang show that the highest prediction accuracy is achieved when using the Bayesian algorithm for neural network regulation. At the same time, the authors emphasize the need to analyze the mutual dynamics of stock indices. This allows you to better understand the economic dynamics and build a high-quality forecast model.

A. A. Cecen, R. Jain and L. Xiao use methods of nonlinear dynamics to study the return on stock indices [7]. The authors investigate the dynamics of the profitability of the world's major stock indices. Among the analysis tools, A. A. Cecen, R. Jain and L. Xiao use data taking into account the high-frequency component of stock index trading and the

probabilistic properties of stock returns in various markets. This approach allows one to take into account the mutual influence of the dynamics of the values of various stock indices.

In their earlier work, J. Cao and J. Wang construct a stock price forecasting model based on time series analysis and a modified convolutional neural network [8]. The authors use both classical statistical analysis tools to study the dynamics of stock prices, and the apparatus of neural networks to build a predictive model. At the same time, J. Cao and J. Wang also pay attention to the optimization of the forecast model. This allows for real-time data manipulation and quick predictions.

In the work of M. Osoolian, S. A. Hoseyni Esfidavajani and M. Bagheri, an approach to the analysis of the stock market, which is based on the theory of entropy, is considered [9]. In their study, the authors proceed from the assumption that changes in stock prices should correspond to some volatility. This volatility is subject to a certain change in entropy as a parameter that characterizes the change in stock prices. The authors have shown that some entropies are a linear cause of stock indices [9].

M. Pepi conducts a general analysis of the price index for various stocks in the stock market [10]. The author examines the time series of prices for each stock and tries to determine the trends of chaos in these time series. The author also uses the theory of nonlinear dynamics and chaos theory to study the dynamics of prices for various stocks. This allows you to expand your understanding of the mutual dynamics of various stock indices.

K. H. Al-Yahyaee, W. Mensi and S. M. Yoon consider the efficiency, multifractality and long memory of the time series in the study of the stock market [11]. This allows for a comprehensive analysis of the dynamics of changes in the values of stock indices. The authors also consider the comparative aspects of the dynamics of prices for bitcoin, gold, currencies and stock indices. This allows us to analyze the mutual dynamics of the values of stock indices in a comparative aspect.

A. Dutta analyzes stock market data from the oil and gas sector [12]. This analysis allows you to reveal the dynamics of the values of the stock index of one of the groups of shares. Nevertheless, the author compares the dynamics of prices for shares of companies in the oil and gas market, taking into account different market segments. This allows us to say that the author takes into account the mutual dynamics of various factors of influence on stock indices. As a tool for analyzing the dynamics of stock indices, A. Dutta uses statistical tools for studying time series, which are based on the concept of data volatility.

D. Shah, H. Isah and F. Zulkernine provide an overview of various models and methods for predicting the dynamics of stock index values [13]. These models and methods are different: from the use of general provisions of the theory of statistics to the approaches of chaos theory, nonlinear dynamics, and neural networks. At the same time, the authors provide a critical analysis of the possibility of using various models and methods.

We see that various methods and approaches are used to analyze the dynamics of the values of stock indices. At the same time, the researchers note that for such an analysis it is also important to study the mutual dynamics of various stock indices. Therefore, we will pay attention to the ideology of wavelets, which makes it possible to explore data in the form of a time series. Wavelet coherence should be singled out among the tools for such analysis [14]-[16].

2.2 Wavelet Coherence as an Analysis Tool

The dynamics of the stock index values can be represented as a certain time series ($z(t)$). Then if we have two time series $z_1(t)$ and $z_2(t)$ we can calculate their mutual wavelet coherence. In this case, the wavelet coherence can be considered as multiple correlations. The following expression is used to calculate the wavelet coherence [17], [18]:

$$R^2(a,b) = \frac{\left|\Omega(a^{-1}W_{z1z2}(a,b))\right|^2}{\Omega(a^{-1}\left|W_{z1}(a,b)\right|^2)\Omega(a^{-1}\left|W_{z2}(a,b)\right|^2)}, \quad (1)$$

where:

$W(a,b)$ – values of cross wavelet spectra;

Ω – is a smoothing operator;

$R^2(a,b)$ – the squared wavelet coherency coefficient. $0 \le R^2(a,b) \le 1$. If these values tend to zero, then we have a weak correlation. Otherwise, we have a strong correlation [16]-[18].

The wavelet coherence values are treated in the same way as the cross-reference values between the data we are examining. This allows you to take into account the relationship between data in separate time intervals. Then we can analyze the mutual dynamics of different time series for different time intervals. This is important when analyzing the dynamics of the values of stock indices, when choosing a model to predict such dynamics.

The following expression can be used to describe the wavelet transform [19], [20]:

$$W(z(t)) = \frac{1}{\sqrt{a}}\int_{-\infty}^{+\infty} z(t)\phi(\frac{t-b}{a})dt, \quad (2)$$

where

$\phi(\frac{t-b}{a})$ – is a mother wavelet satisfying condition: $\int_{-\infty}^{+\infty}\phi(t)dt = 0$ [17], [20];

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a , b – scale and center of time localization, that determine the scale and φ(t) function offset in accordance with the scaling conditions: $\int_{-\infty}^{+\infty} \varphi(t)dt = 0$ [17], [20];

z(t) – is time series that is being explored, t – determines the order of the function data z(t) .

2.3 Data for Analysis

In this paper, to study the mutual dynamics of the values of stock indices as a characteristic of the development of the financial market, we use data on world stock indices. Among these indices, we chose: Dow Jones Industrial Average (DJI), S&P 500 (SPX), Nasdaq 100 (NDX), DAX (GDAXI), FTSE 100 (FTSE) and Nikkei 225 (N225). These are the most famous and significant stock indices. These indices reflect global economic development and reveal the main trends in the development of the world financial market. All data from the site – investing.com. We are considering the period from January 5, 2020 to August 29, 2021. Data are presented as weekly averages.

Fig. 1 shows the dynamics of the DJI and SPX indices.

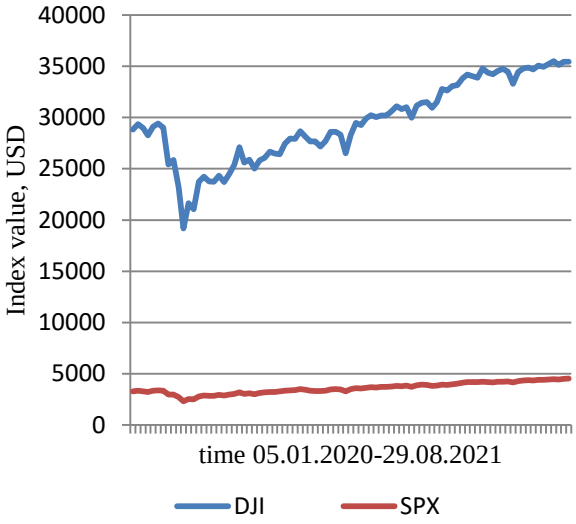

Figure 1. Dynamics of the DJI and SPX indices

Fig. 2 shows the dynamics of the NDX and GDAXI indices.

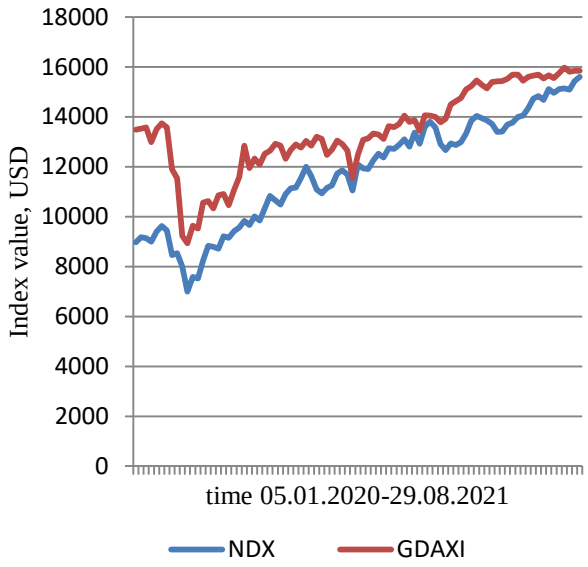

Figure 2. Dynamics of the NDX and GDAXI indices

Fig. 3 shows the dynamics of the FTSE and N225 indices.

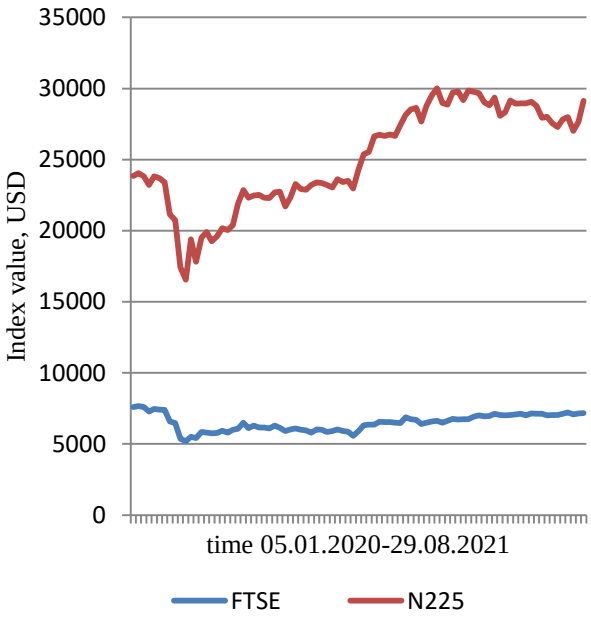

Figure 3. Dynamics of the FTSE and N225 indices

We see that the dynamics of the indices that we are examining are not identical. This can be explained by the fact that the selected indices reflect different trends. These trends are different for different sectors of the economy. It can also be argued that the dynamics of stock indices as a whole is increasing. Consequently, we can talk about the influence of

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the same factors on the dynamics of the stock indices that are being studied.

The difference in dynamics between the investigated values of stock indices is confirmed by the statistical data presented in table. 1.

Table 1: Some statistical data on the values of stock indices that are being investigated

Statistical characteristics	Stock indices					
	DJI	**SPX**	**NDX**	**GDAXI**	**FTSE**	**N225**
Mean	29552,5	3592,1	11765,7	13400,6	6506,1	25100,9
Median	29348,1	3509,4	11937,8	13432,8	6502,1	24325,2
Standard Deviation	3958,9	540,4	2207,2	1738,2	582,4	3548,9
Kurtosis	-0,67	-0,81	-0,99	-0,22	-0,87	-0,96
Skewness	-0,23	-0,07	-0,21	-0,47	-0,05	-0,33
Minimum	19173,9	2304,9	6994,29	8928,95	5190,78	16552,83
Maximum	35515,9	4536,9	15604,25	15977,44	7674,56	30017,82

Consequently, the use of wavelet coherence for analyzing the mutual dynamics of stock indices is of interest and is justified in the statistical aspect.

3. Results and Discussion

First of all, let us consider the values of the wavelet coherence for the mutual dynamics of stock indices in accordance with the data in fig. 1 - fig. 3.

Fig. 4 shows the variation of the wavelet coherence values between DJI and SPX indices.

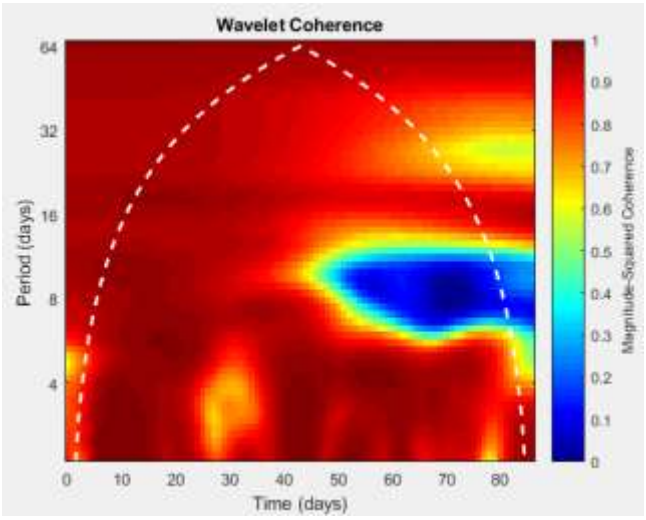

Figure 4. Variation of the wavelet coherence values between DJI and SPX indices

In fig. 4 is also shown (for all figures below):

– the abscissa is the time period that we are analyzing. The ordinal values of the data that we are examining from the interval 05.01.2020-29.08.2021 are shown;

– the ordinate is the depth of cross-references between the time series that we are examining;

– white dashed line – values of the wavelet coherence with the most reliable level of significance;

– the column on the right – the values of the wavelet coherence from 0 to 1, which also have a color characteristic.

Fig. 4 suggests that there is generally a high level of consistency between the time series of the DJI and SPX stock indices. This is typical for both short-term periods of time and long-term periods of time of their interval, which we are examining. However, in the medium term, we see that the level of consistency between the series of these values of the DJI and SPX stock indices is significantly reduced. Thus, in the context of the mutual dynamics of the DJI and SPX stock indices, we can say that the dynamics of the development of the global financial market is transforming. Similar conclusions can also be found in [21], [22].

At the same time, the data obtained must be taken into account when developing predictive models. It is important to note here that such forecast models must take into account the forecast horizon.

Fig. 5 shows the variation of the wavelet coherence values between NDX and GDAXI indices.

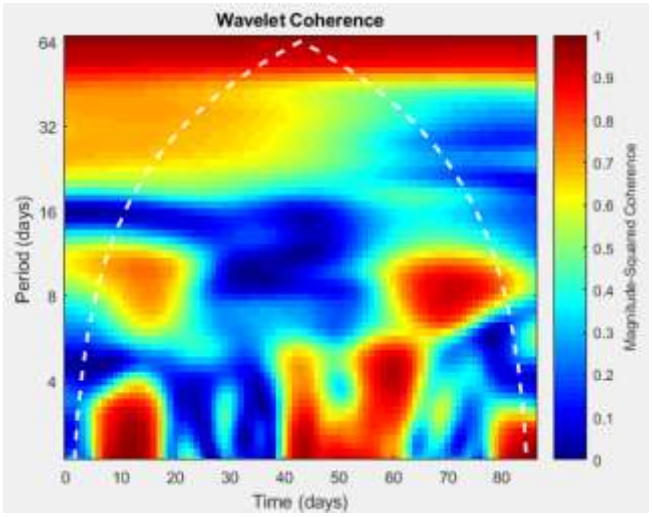

Figure 5. Variation of the wavelet coherence values between NDX and GDAXI indices

From the data in fig. 5 shows that the consistency between the values of the NDX and GDAXI stock indices is negligible and much less than between the values of the DJI and SPX stock indices. The agreement between NDX and GDAXI was

significant only in the middle of the time frame under study (and only in the short term).

At the same time, from the data in fig. 2 shows that there is a certain time lag in the dynamics of the values of the NDX and GDAXI stock indices. Moreover, such a time lag is different over the time interval that is being investigated. It is this fact that is decisive in considering the consistency between the NDX and GDAXI. This is important to consider when developing forecast models. We can also talk about the presence of volatile trends in the development of the global financial market.

Fig. 6 shows the variation of the wavelet coherence values between FTSE and N225 indices.

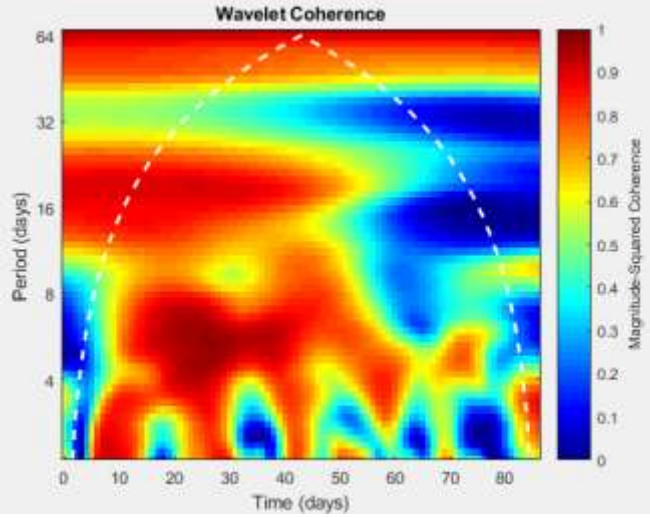

Figure 6. Variation of the wavelet coherence values between FTSE and N225 indices

Fig. 6 shows that the wavelet coherence between FTSE and N225 are quite significant. This consistency is observed at all-time horizons. However, it should be noted that this consistency is characteristic only for the first half of the time interval that we are studying. These data correlate with the data presented in fig. 4. Consequently, the dynamics of the development of the world financial market is transforming and is more volatile in the second half of the time interval that we are studying.

For the analysis, we will also consider wavelet coherence between data series for the DJI and N225 stock indices, as well as the SPX and FTSE.

Fig. 7 shows the variation of the wavelet coherence values between DJI and N225 indices.

Fig. 8 shows the variation of the wavelet coherence values between SPX and FTSE indices.

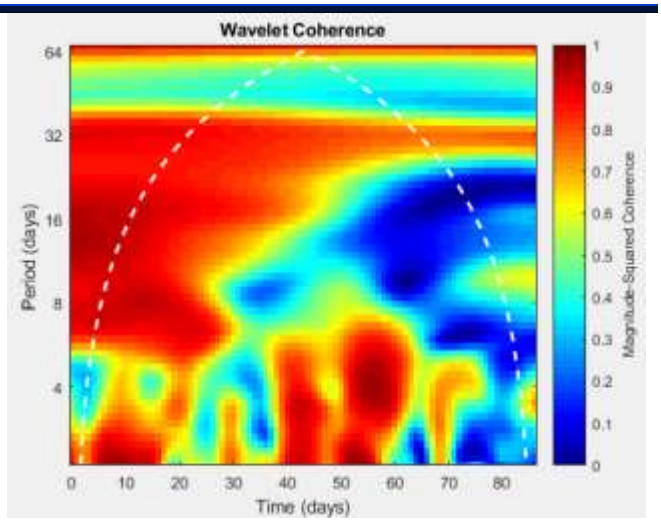

Figure 7. Variation of the wavelet coherence values between DJI and N225 indices

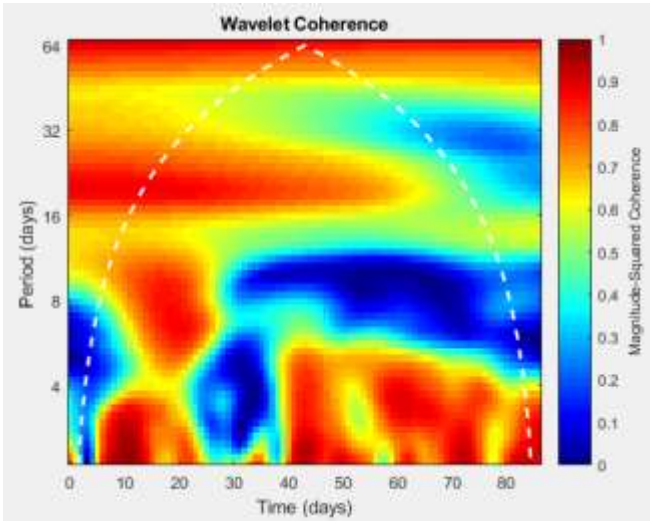

Figure 8. Variation of the wavelet coherence values between SPX and FTSE indices

Fig. 7 and fig. 8 confirms the earlier conclusions and shows:

– the presence of various trends in the development of the world financial market in the studied time interval;

– such variability is more characteristic of the second half of the time interval that we are examining;

– there is no clear consistency between stock indices for certain time horizons. This must be taken into account when developing predictive models.

4. CONCLUSION

The development of the world financial market is largely determined by the development of its constituent parts. One of the key such parts of the financial market is the stock market. Various stock indices can be considered as a generalized characteristic of the stock market. Stock indices are a generalization of the stock price of a particular group of commodities. Then the analysis of mutual changes in the values of stock indices can be the basis for understanding the trends in the development of the financial market as a whole.

For this analysis, we use wavelet coherence.

As a result of the study of the real values of world stock indices, it was concluded that the development of the world financial market in the studied time interval has different trends. These trends are variable over different time horizons, which must be taken into account when choosing forecasting models.

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