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R/S-АНАЛІЗ ВАЛЮТНОГО РИНКУ

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Анотація. У статті обгрунтовано можливість застосування R\S аналізу для дослідження ринку валют. Робота спрямована на дослідження валютного ринку. Питання дослідження за допомогою R\S ринку валют є новим науковим напрямом. Вивчення валютного ринку, його регулювання, вплив на фінансові системи країн світу набуває актуальності в наші дні. Валютні операції часто ототожнюють процесом купівлі чи продажу цінних паперів. У роботі проведено аналіз поведінки валютних котирувань на валютному ринку за допомогою визначення динамічних змін у часі показника Херста, як одного з інструментів R/S аналізу, в рамках гіпотези фрактального ринку. Здійснено розрахунки показника Херста за скоригованими формулами R/S-аналізу що дозволяє порівняти значення показника на валютному ринку України у різних економічних умовах. Показник Херста при стабільній економічній ситуації має тенденцію до збереження свого середнього значення, при цьому він є індикатором подій, що прямо або опосередковано впливають на економіку держави та курс її національної валюти. Метою роботи є дослідження поведінки курсів валютних пар за допомогою моніторингу показника Херста, як одного з інструментів фрактального аналізу, у рамках гіпотези фрактального ринку. Передбачення майбутньої поведінки валютних курсів є дуже важливим, оскільки дозволяє зменшити валютні ризики та забезпечити підвищення ефективності різноманітних рішень у галузі міжнародного фінансового менеджменту. Показник Херста має широке застосування в аналізі часових рядів завдяки своїй стійкості. При його обчисленні необхідні мінімальні припущення щодо системи, яка вивчається, та на його основі можна класифікувати часові ряди за типом і глибиною пам’яті. Він може відрізнити випадковий ряд від невипадкового. У роботі проведено приклад розрахунку показника Херста за методикою Мандельброта. Цей показник використовується як показник довготривалої пам’яті часових рядів. Показник Херста як інструмент фрактального аналізу систем, дозволяє визначити ступінь персистентності фінансових рядів, наявності на валютному ринку довготривалої пам'яті. Щоденні дані про курс гривні до долар та євро взято з офіційного сайту НБУ. Виявилося, що в різні роки спостерігаються періоди стабільності курсу гривні відносно інших валют. Відповідно, змінюється і фрактальна розмірність ряду. Для більшості періодів курсу гривні виявлено антиперсистентні ряди, тобто коли спад імовірніше за все змінюється зростанням. Методики R\S аналізу аналізу є ключовим інструментом для ринкової аналітики, що дозволяє зрозуміти, коли і які активи варто купувати, а коли продавати.

Ключові слова: Ринок валют, валютний курс, фінансовий сектор, R\S аналіз, ціноутворення, показник Херста, мультифрактальний аналіз.

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R/S-ANALYSIS OF THE CURRENCY MARKET

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Abstract. The article substantiates the possibility of using R\S analysis for currency market research. The work is aimed at researching the currency market. The issue of research using R\S of the currency market is a new scientific direction. The study of the foreign exchange market, its regulation, influence on the financial systems of the countries of the world is gaining relevance these days. Foreign exchange transactions are often equated with the process of buying or selling securities. The paper analyzes the behavior of currency quotes on the foreign exchange market by determining the dynamic changes over time of the Hurst indicator, as one of the tools of R/S analysis, within the framework of the fractal market hypothesis. Calculations of the Hearst index were carried out according to the adjusted formulas of R/S-analysis, which allows to compare the value of the indicator on the foreign exchange market of Ukraine in different economic conditions. In a stable economic situation, the Hearst indicator tends to maintain its average value, while it is an indicator of events that directly or indirectly affect the state's economy and the rate of its national currency. The purpose of the work is to study the behavior of exchange rates of currency pairs by monitoring the Hurst indicator, as one of the tools of fractal analysis, within the framework of the fractal market hypothesis. Forecasting the future behavior of exchange rates is very important, as it allows to reduce currency risks and ensure the improvement of the effectiveness of various decisions in the field of international financial management. The Hurst indicator is widely used in time series analysis due to its stability. Its calculation requires minimal assumptions about the system being studied, and based on it, time series can be classified by memory type and depth. It can distinguish a random series from a non-random one. The paper provides an example of calculating the Hurst index using Mandelbrot's method. This indicator is used as an indicator of the long-term memory of time series. Hurst's indicator as a tool for fractal analysis of systems allows you to determine the degree of persistence of financial series, the presence of long-term memory in the currency market. Daily data on the exchange rate of the hryvnia to the dollar and the euro are taken from the official website of the NBU. It turned out that periods of stability of the hryvnia exchange rate relative to other currencies are observed in different years. Accordingly, the fractal dimension of the series also changes. For most periods of the hryvnia exchange rate, anti-persistent series were found, that is, when the decline is most likely replaced by growth. R\S analysis techniques analysis is a key tool for market analysis, which allows you to understand when and which assets should be bought and when to sell.

Key words: Currency market, exchange rate, financial sector, R\S analysis, pricing, Hurst indicator, multifractal analysis.

Introduction. The currency and stock markets are a dynamic system that is constantly evolving. Financial indicators reflect the development of these systems. It is also an important tool that helps identify trends in financial markets. Their use contributes to the formation and improvement of decision-making measures in economic policy. Understanding the concept of an indicator is a necessary and key point that allows you to identify the main components that form

it. Such factors often cause crisis situations, moments of bifurcations, when the market changes its direction of development [1].

For many decades, phenomena in the currency market have been studied and researched. Scientists and scientists from different countries of the world tried to describe the dynamics of phenomena and processes in the foreign exchange market using various models. Many methods of forecasting future quotation values are described and highlighted in separate directions. However, forecasting requires stability both in the economy and in the country's politics, then the forecast values will be the most accurate and close to the real ones. It is not possible to include all influencing factors in the model. The policy of the government and the National Bank also plays a significant role. Statistics also play a significant role. It is difficult for analytics to process data that is either unavailable, incomplete, or heterogeneous, and bringing data to a unified view takes a lot of time. There are some drawbacks to such forecasting and modeling. For example, it is difficult to predict such indicators as the money supply or the interest rate, the correlation coefficients in the model can be variable, which will lead to a significant error in the forecast [2].

A complex of economic and mathematical models allows you to capture the change in properties at the stage of multifractal analysis. In the case of unfavorable conditions, the use of econometric tools for modeling is impractical [3]. If the stock market is characterized by stable dynamics and favorable conditions for market activity, then with the help of econometric models it is possible to predict the dynamics of the financial indicator for the short term.

At the current stage of research, nonlinear methods and tools are increasingly used in the forecasting and analysis of financial and economic systems. Such systems are complex and have the following properties: synergy, emergence, chaos. The use of non-linear research methods will allow to interpret the dynamics of such a complex system as the financial market at a qualitatively different level. This is due to the fact that most linear methods do not take into account the random component, which is perhaps the most important in the study of financial time series.

Statistical analysis begins with the assumption that the system under study is primarily random; that is, the causal process that created the time series has many components or degrees of freedom, and the interaction of these components is so complex that a deterministic explanation is impossible. Therefore, probability can help us understand the process and use it to our advantage. To study the statistics of these systems and create a more general analytical structure, we need the application of probability theory, which is non-parametric. That is, we need a statistic that makes no prior assumptions about the shape of the distribution we are studying. The Central Limit Theorem (or Law of Large Numbers) states that as more and more trials are performed, the marginal distribution of a random system will be the normal distribution [4]. The events being investigated must be independent and normally distributed . That is, events should not affect each other, and they should have the same probability of occurrence. If the system under study is not independent and normally distributed, then we need a non-parametric method. Such a non-parametric methodology was discovered by X. E. Hearst, who included many natural systems in his research and gave us a new statistical methodology for distinguishing between random and non-random systems, the constancy of trends and the duration of cycles, called the method of normalized swing, or R/S analysis, which is used to study random time series and fractal time series.

Using the work [5] on Brownian motion, we can state that the distance traveled by a random particle increases in proportion to the square root of the time used to measure it, which we use in financial economics to calculate the annual volatility, or standard deviation.

Time series can be divided into three groups: deterministic, random, and chaotic. It can be argued that the development of the dynamics of economic processes and phenomena has a non-linear, that is, chaotic character. Therefore, it is impossible to apply the usual linear methods, as a result, there is a need to use alternative methods, to conduct a study of economic processes, this

issue can be studied with the help of the fractal theory of markets. [6]. Fractal analysis should be used when market processes cannot be presented using classical models.

Task Statement. The R/S analysis method examines the fractality of time series. This technique was proposed by B. Mandelbrot and is based on the research conducted by Hurst. Today, many methods of calculating the Hurst index are known. This indicator reflects the maximum range of currency quotes or share prices for a certain period.

Work [7] gives an example of calculating the Hurst index using Mandelbrot's method. This indicator is used as an indicator of the long-term memory of time series, and its value is in the range from 0.5 to 1.56. It is worth calculating the Hurst index on the basis of at least 128 observations.

Based on the value of the Hurst indicator H, it is possible to conclude about the randomness or persistence of the considered data [4]. If x is white noise (zero mean, zero persistence), then the range of the perturbation population forming the random walk, scaled by the standard deviation, grows as the square root of the series size, giving an expected value of the Hurst exponent of 0.5. If the obtained value exceeds 0.5, then it can be concluded about persistence, that is, the series is a generalized Brownian motion and is characterized by long-term memory. This means that what happens today affects the future. If the Hurst value is between 0 and 0.5, then antipersistence can be concluded. Such a time series is much more variable than a random series, because it constantly fluctuates. If we observe a decline in the previous period, then in the next period we should expect growth and vice versa. At H=0.5, it corresponds to ordinary white Gaussian noise, a random Brownian walk, i.e., a memoryless process [8]. Fractal dynamics is a branch of fractal theory that studies the dynamics of whole structures and systems that exhibit self-similarity properties when their state changes over time, provided that the structure and shape of the system is preserved. The concept of fractal dimension is introduced to study irregular fractal objects. The fractal dimension of a time series gives an idea of how jagged the time series is. If a line scales according to a straight line scale, then its fractal dimension is one. However, random wanders have a fifty-fifty chance of increasing or decreasing dynamics. Then the fractal dimension of the random time series is 1.5. If the fractal dimension is between 1 and 1.5, then the time series is more than a line and less than a random walk. It is more smooth compared to a random walk, but is more jagged than a line [9]. This technique can be used to determine the fractal dimension of price dynamics of a certain asset, including exchange rates.

The fractal dimension of the time series is important because it recognizes that the process can be deterministic (line with fractal dimension) or random (fractal dimension 1.5). The Hurst indicator (H) reflects the maximum range of prices for a certain period. The value of the indicator always ranges from 0 to 1. Hurst's empirical discovery showed that this indicator is always greater than 0.5, while if its value ranges from 0.5 to 1, this indicates that the time series is characterized by stable trends , i.e. is persistent. If the Hurst value is between 0 and 0.5, the series is anti-persistent. And when the indicator is equal to 0.5, the studied time series is a Brownian motion [10].

Despite the fact that the US and the EU have a free-floating exchange rate, in which there is no official establishment of the exchange rate, the participation of the state in regulating the functioning of the foreign exchange market is allowed. The level of the exchange rate is formed due to the demand and supply for the currency, which in turn are determined by the actions of the players in the foreign exchange market. In the case of currency depreciation, national goods also become cheaper, which causes an increase in the volume of exports of goods and services. If the currency becomes more expensive, then national goods and services increase in price, and as a result, exports decrease and the share of imported goods and services increases. Under such a regime, the exchange rate will a priori be volatile.

The dynamics of financial markets were analyzed and confirmed non-linear character, mono- and multi-fractal properties of the dynamics of exchange rates were investigated, which at the current stage of the development of dynamics are characterized by persistence (stock

financial indicator) and Brownian motion, that is, it is a random process (currency financial indicator).

Results. In a period of economic and political stability, the volatility of the national exchange rate will be characterized by low volatility, and vice versa, in a period of crisis, political or economic instability, the volatility of the exchange rate will increase. Efforts to ensure favorable conditions for doing business, replenishment of the state budget cause the government to implement regulatory measures. Therefore, the modern currency system in its pure form cannot be a flexible exchange rate system. Hence, the exchange rate is a lever of state influence on the market economy.

Having considered the foreign exchange market of Ukraine, we will use the data on the exchange rate of the hryvnia set by the NBU against the euro and the US dollar for the period from 01.01.2019 to 04.31.2024. We will calculate the Hurst index for the quotation of the dollar/hryvnia exchange rate.

We will get the following results of R/S-analysis regarding the exchange rate of the US dollar to the hryvnia.

Table 1

The results of the R/S analysis of the exchange rate of the US dollar against the hryvnia

Constant	$e^{3,029687493}$
Standard error	3,029687493
R^2	0.81315583
Hurst index	0,602019903

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The obtained value exceeds 0.5, then it can be concluded about persistence, that is, the series is a generalized Brownian motion and is characterized by long-term memory. This means that what happens today affects the future.

The results of the R/S analysis regarding the exchange rate of the euro against the hryvnia are as follows

Table 2

The results of the R/S analysis of the exchange rate of the euro against the hryvnia

Constant	$e^{2,629743959}$
Standard error	2,629743959
R^2	0,910637
Hurst index	0,610635094

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The Hurst index ranges from 0.5 to 1, this indicates that the time series is characterized by stable trends, that is, it is persistent.

Today, the study of fractal and multifractal properties of financial indicators is quite widely used. Fractal objects include lines, surfaces, and bodies that have a strongly cut shape and show some repeatability over long time intervals. Fractal time series are a whole class of curves that are used in the description and modeling of many phenomena and processes. The analysis of time series using fractal methods allows the evolution of complex systems to be consistently studied on the basis of a relatively small sample of data. One of the most important quantitative characteristics of fractal objects is the concept of fractal dimension, or scaling index, which describes the repeatability of geometry (for regular fractals) or statistical characteristics (for irregular fractals) when changing the scale. However, in various scientific fields there are many phenomena that require the spread of the concept of fractal to more complex structures, which are characterized by a spectrum of indicators of fractal dimension - multifractals [11]. The first

to propose multifractal analysis as a tool for studying non-stationary time series was proposed in [7]. Initially, this research method was used in physics. However, it is difficult to find a field of science where multifractals cannot be encountered. To describe a fractal, one quantity is sufficient – the fractal dimension. However, multifractals are complex and heterogeneous objects. In order to characterize them, a whole spectrum of fractal dimensions is needed. Most objects, either in nature or in the economy, are multifractals. Fractal time series often occur in the form of singular functions. For the analysis of the signal structure, the availability of a rigorous mathematical approach is most valuable [5]. Fractals are formed as a result of unpredictable movements of the chaotic world around us. The most important qualitative property of fractals is the property of self-similarity. This means that the object or process is statistically similar on different scales, each of which resembles scales, but is not identical.

Today, scientists, scientists, specialists, traders use a huge number of indicators that are linear, and also take into account analytical reports of countries and experts that can affect the dynamics of the financial time series. With this in mind, it is worth noting that linear methods are not able to fully cover all aspects of the development of a dynamic system and track the moment of the turning point that will prevent the development of a new stage of the financial market. Political and economic stability is a necessary condition for predicting future values. In addition, it is impossible to include all influencing factors in the models for forecasting the dynamics of the series, because this will deteriorate the quality of the model and such negative phenomena as heteroskedasticity, autocorrelation, and multicollinearity will occur. It should also not be excluded that the state of the country's economy and financial markets are largely influenced by the political measures of the government and the National Bank.

Conclusions. As a result of the conducted research, it can be noted that R\S analysis is widely used in the financial sphere of activity. The results of modeling and analysis of the dynamics of exchange rates and stock indices as financial indicators can be used by the state in the form of the government and state financial organizations for the purpose of assessing the current state of the financial market and economy, as well as for forecasting the dynamics of indicators in order to strengthen the economic security of the state and, if necessary, implement regulation of the functioning of the financial market and its constituent elements.

The methodology discussed in the article is promising for use in the study of the dynamics of financial series. The Hurst indicator can serve as an indicator that can signal the emergence of negative trends in the financial market. This is confirmed by the approbation of the method on the data of the National Bank of Ukraine regarding currency quotations. Multifractal analysis should be used because economic processes are complex and it is difficult to describe them with one indicator. We can only speak about the general picture and predict with a certain probability whether there will be a decline or growth in the following periods. With the help of multifractal analysis of detrend fluctuations, it is possible to more fully describe the behavior of the object under study.

Prospects for further research in this direction are the use of "Data Mining", as well as neural networks, which will allow us to understand the possibility of using analytical technologies for a quick and thorough study of large data sets, in order to obtain valuable information. For all time, various cryptocurrencies have left a lot of information. For example, trading volume, currency price in different time periods and others. All this information can be analyzed and based on the results you can clearly see what affects the growth and volume and predict the growth of this currency in the market. In this regard, new algorithms can be created to predict the rise or fall of the price.

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