

## 1. Introduction

Globalization, unrestrained growth of financial markets, total computerization and development of information technologies (IT) resulted in a huge number of additional institutes, financial instruments and new forms of interaction between people in our society. One of such institutes in the modern world is electronic money or cryptocurrency.

Cryptocurrency is a technology, allowing resource exchange in the electronic form [1]. The idea of this technology is that it excludes any participation of a regulating side that would support the infrastructure (for example, bank) and at that allows to exchange resources safely. The role of accounting operations is transferred from centralized institutes on the network of autonomous computers, forming a decentralized structure, working beyond an influence of any managerial institution. Most often cryptocurrencies are floating relative to national currencies and between each other.

A rate of any assets, including cryptocurrency [2], is often moving. It is influenced by the demand and supply of average consumers, investors, traders, economic-political situation, information field and other events, typical for not only the cryptosphere, but economy in whole.

The aforesaid may influence cryptocurrency both positively and negatively. Positive and negative factors often coincide with a little difference in time, in which result rate fluctuations are observed [3]. They are intensified by trade games, when players purposefully try to raise or lower it.

Thus, the analysis and elaboration of methods for forecasting prices of e-currencies is an urgent task and needs detail research.

The aim of this article is the comparative analysis of a part of existing methods for forecasting prices of e-currencies at the markets, namely trend indicators that allows a trader to choose the most appropriate method or several ones for forecasting of a concrete problem.

## 2. Methods

A great number of mathematic models and methods for analyzing and forecasting financial markets are presented in scientific literature [4–6]. The process of making forecasts includes determination of specificity, aims, variants of using and choice of a forecasting method. Thus, conventional approaches to forecasting the price dynamics at the financial markets are technical and fundamental analysis. Study of the dynamics of parameters of the market itself is just in the base of technical analysis. Construction of different graphs, study of changes of

## METHODS OF FORECASTING THE PRICES OF CRYPTOCURRENCY ON THE FINANCIAL MARKETS

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**Abstract:** The article describes the problem of forecasting prices of cryptocurrencies at the financial markets. Methods for analyzing and forecasting prices of cryptocurrencies at the financial markets are considered in detail. A trend indicator – moving averages – is considered as an auxiliary tool for technical analysis that helps to analyze and forecast prices of cryptocurrencies at the financial markets. During the study there were analyzed several methods of different categories, namely: SMA (Simple Moving Average), EMA (Exponential Moving Average), WMA (Weighted Moving Average). For analyzing moving averages, there were conducted the analysis, based on mean-square deviation together with the standard graphic analysis. The whole process was divided in several stages: a moving average was calculated, based on basic values; based on values of the calculated moving average, there was calculated a mean square deviation; deviation with the least numerical value was chosen among the massive of deviations. It has been revealed, that SMA has the least value of mean-square deviation, but EMA is the better choice, because EMA is most sensitive among considered moving averages, although an error extent is rater more.

**Keywords:** cryptocurrency, forecast, electronic currency, simple moving average, exponential moving average, weighted moving average, trend indicator.

a market price in the dynamics allows an investor to make a correct decision.

Traditional technical analysis [5] is in constructing diagrams, studying just concluded contracts and so on. In the first turn, it is directed on studying the dynamics of prices for a concrete financial instrument for forecasting a price movement for the nearest period of time. For this aim, analysts search for repeating typical outlines, figures on graphs of price behavior and give recommendations for suggesting a further movement of a price along this figure.

An auxiliary mechanism for technical analysis is a trend indicator that helps to determine the distinct direction of a trend: ascending or descending movement of a price for a trade instrument. Indicators of a trend type smooth price fluctuations at forming a signal by data averaging. It gives a trader a possibility to determine visually what trend will be present at one or another time interval.

Trend indicators include methods, following a trend. One of bases of most trend indicators is a moving average [7] that has a lot of variations. A moving average demonstrates an average value of a price of paper for a certain period of time. At calculating a moving average, there is conducted

the mathematic averaging of a price of paper for a certain period. An average value of a price rises or falls at its changing.

There are five spread types of moving averages: simple, exponential, variable and weighted [8]. During the study there were analyzed several methods of different categories, namely: SMA (Simple Moving Average), EMA (Exponential Moving Average), WMA (Weighted Moving Average).

From the mathematic point of view, SMA is an average arithmetic value, and it is calculated by formula (1).

$$SMA_t = \frac{1}{n} \sum_{i=0}^{n-1} p_{t-i} = \frac{p_t + p_{t-1} + \dots + p_{t-1} + \dots + p_{t-n+2} + p_{t-n+1}}{n}, \quad (1)$$

where  $SMA_t$  – value of the simple moving average in the point  $t$ ;  $n$  – number of values of the initial function for calculating the moving average;  $p_{t-i}$  – value of the initial function in the point  $t-i$ .

The obtained value of the simple moving average belongs to the middle of the chosen interval, but it is traditionally related to the last point of the interval.

The exponential moving average is determined by adding a certain share of the today close price to the yesterday's value of the moving average. EMA is applied in the technical analysis as both an independent method and a component of other indicators.

In general view the formula for calculating the EMA value in t time period may be signed as following:

$$EMA_t = \alpha \times P_t + (1 - \alpha) \times EMA_{t-1}, \quad (2)$$

where  $\alpha$  – weight coefficient in the interval from 0 to 1, that reflects the speed of data aging: the higher its value, the more specific weight is inherent to new observations of the random variable, the less one – to old ones;  $P_t$  – value of the random value in the time period t;  $EMA_{t-1}$  – value of the exponential moving average in the time period t-1.

For calculating  $\alpha$  coefficient, the following formula is used:

$$\alpha = \frac{2}{N + 1}, \quad (3)$$

where N – smoothing interval.

For calculating the EMA value in t time period, it is necessary to know its value in the previous time period t-1. At that the simple moving average that is SMA with the same smoothing interval is used as the first value.

The weighted moving average represents the arithmetic weighted of price fluctuations for the certain time period. WMA is calculated as following:

$$WMA = \frac{\sum_{i=1}^n P_i \times W_i}{\sum_{i=1}^n W_i}, \quad (4)$$

where  $P_i$  – price value of the previous periods (i of the present day is equal 1);  $W_i$  – weight value for the price i of the previous periods. The weight coefficient is determined by the number of days in the period at calculating the moving average.

### 3. Results

Let's consider advantages and disadvantages of the methods, described in the previous section, scenarios of their use and their possible combination for raising the forecasting distinctness.

Fig. 1 presents the graph with the moving averages, where the considered methods are presented by the following symbols: SMA – line of pluses; EMA – simple line; WMA – line of small points [9].

Let's analyze the moving averages from the mathematical point of view. Let's take the following data set (Table 1). The graph of the chosen data set is presented on Fig. 2.

For analyzing the moving averages, let's conduct the analysis, based on mean-square deviation, together with the standard graphic one. A selection criterion is minimization of mean-square deviation. The whole process was divided in several stages: a moving average was calculated, based on basic values; based on values of the calculated moving average, there was calculated a mean-square deviation; deviation with the least numerical value was chosen among the massive of deviations.

Table 1  
Data set for testing the moving averages

No.	Price
1	7,35
2	7,08
3	8,07
4	9,4
5	11,25
6	11,88
7	11,35
8	11,38
9	10,21
10	9,17
11	7,35
12	7,08
13	8,07
14	9,4
15	11,25

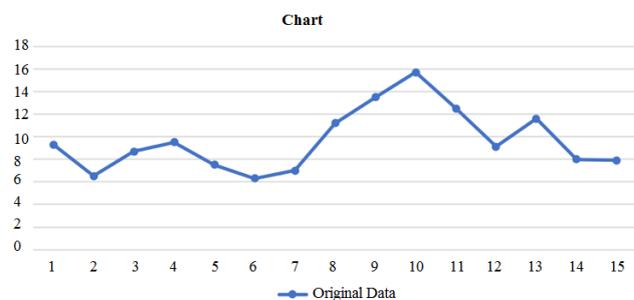


Fig. 2. Data set for the analysis

Let's take the period, equal 5 for all moving averages. SMA with the period 5 is demonstrated in Table 2.



Fig. 1. Graph of the price of shares of Apple with the different moving averages [9]

**Table 2**  
SMA value

No.	Price
1	8,3
2	7,7
3	7,8
4	8,3
5	9,1
6	10,74
7	11,98
8	12,4
9	12,48
10	11,38

**Table 4**  
WMA values

No.	price
1	7,35
2	7,08
3	8,07
4	9,4
5	11,25
6	11,88
7	11,35
8	11,38
9	10,21
10	9,17

$$\mu = \frac{8.3+7.7+7.8+8.3+9.1+10.74+11.98+12.4+12.48+11.38}{10} = 10.018. \quad (5)$$

Let's calculate the average value of the sample:

$$\sigma = \sqrt{\frac{2.951524+5.373124+4.919524+2.951524+0.842724+0.521284+3.849444+5.673924+6.061444+1.855044}{10}} = \sqrt{\frac{34.99956}{10}} \approx 1.87081693386. \quad (6)$$

The mean-square deviation is calculated as following:

The list of EMA values with period 5 and smoothing 0.3 will look as following (Table 3).

**Table 3**  
EMA value

No.	Price
1	8,06
2	7,28
3	7,56
4	9,17
5	10,42
6	12,228
7	12,136
8	11,41
9	12,216
10	10,366

The mean-square deviation for EMA results is:

$$\sigma \approx 1.856569966. \quad (7)$$

The list of WMA values with period 5 is presented in Table 4. The mean-square deviation for WMA results is:

$$\sigma \approx 1.68335213. \quad (8)$$

Table 5 presents the data sets for the considered moving values and their mean-square deviation.

**Table 5**  
Comparative analysis of the data sets for the moving averages

No.	SMA	WMA	EMA
1	10.74	11.88	12.22
2	11.98	11.35	12.13
3	12.4	11.38	11.41
4	12.48	10.21	12.21
5	11.38	9.17	10.36
Mean-square deviation	0.46	0.69	0.50

#### 4. Discussion

Having analyzed the graph on fig. 1, we can see the lowest dynamics is inherent to SMA. All moving averages on the expressed ascending trend (middle of the graph) were more or less at the equal level, but EMA manifested itself closer to the price. On the periods of short-term takeoffs and falls (beginning of the graph), EMA was also closer to the price.

The results of Table 5 testify that the least value of mean-square deviation belongs to SMA (0.46), but among all moving averages, only EMA reacts to the change of the values faster that is an undoubted advantage. Moreover the difference between mean-square deviations of SMA and EMA is 8 %.

Thus, it is better to use exponential moving average on short intervals, and simple one – on long ones. Each of existing analytic methods has its advantages and shortcomings. Technical analysis allows to make a short-term prognosis of the rate of cryptocurrency. Nevertheless, authors [5] and [10] note, that the distinct analysis of the cryptocurrency market for the nearest future needs the correct use of the aforesaid methods in complex, especially at an expressed tendency.

The obtained results are useful for further use in the sphere of finances and financial forecast. In further it is planned to create a mobile app as a dialogue system for supporting decisions making by traders for comparing the described methods and to integrate it with services that present financial data of assets of great exchanges in real time.

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