DEVELOPMENT OF THE STOCHASTIC MODEL FOR THE MEDIUM-TERM FORECASTING OF CRYPTO-CURRENCY RATE (BY THE EXAMPLE OF BITCOIN)

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Abstract: "Overflowing" the national economic systems, active growth of the global crypto-currency market forms a new type of economic relations. Despite the fact that at the current time a single (unified) approach to the legal regulation of the crypto-currency market has not yet been worked out in the world community, the crypto-currency is considered by many world regulators as a promising tool in the monetary policy of national economies. In this regard, it seems extremely urgent to solve the problem that reveals the features of the development of the market under study, as well as the possibility of its forecasting for the medium and long periods of time. The aim of the work is to find and scientifically substantiate the tools and mechanisms for developing predictive assessments of the development of the crypto-currency market. The process of economic and mathematical modeling of time series characterizing the volatility of the bitcoin exchange rate, based on the use of the ARMA class of autoregressive moving average models is the subject of the study. Based on the evaluations and calculations, it is proved that the use of the ARIMA model class in the process of modeling the parameters of the development of the global crypto-currency market allows us to predict with a high level of accuracy not only current but also future digital currency rate adjustments.

Keywords: crypto-currency market, forecasting, time series modeling, stochastic analysis, bitcoin

1 Introduction

Today there is observed a profound transformation of the traditional world of money and finance. Innovations in the financial sector, new technologies, tools and systems entail serious and profound changes in habitual financial institutions. One of the most important stages of these transformation processes was the emergence of crypto-currencies accompanied by the rapid development of related technologies and the lack of a clear figure for the future landscape of ecosystems (Lo & Wang, 2014).

For today, about 1500 types of crypto-currencies operate in the world. A number of them have a high capitalization, and another number can be compared with a "soap bubble".

Crypto-currency like money is an intermediary tool in the process of market exchange. So, the main function of crypto-currencies for today is the payment of goods and services or the transfer of funds (that is, as a means of payment or exchange) (Elshin & Abdukaeva, 2017; Nikolaev, 2018). Moreover, in spite of the fact that a large number of market players use crypto-currency as a means of payment or exchange for the purchase and sale of goods and services, few of them recognize crypto-currencies as the unit of account (Nakamoto, 2008; Villalobos Antúnez & Ganga, 2016).

At the same time, a number of market players use crypto-currency for speculative purposes, making short-term and long-term investments in them and earning on its purchase / sale transactions. During their existence, crypto-currencies (in particular, bitcoin) have proved themselves as a whole as an advantageous object for investment and the level of people's trust in them is getting higher and higher. Thus, we can assume that this category of players in some sense uses crypto-currency as a means of saving in order to continue to receive additional income (Elshin & Abdukaeva, 2017).

Despite the existing skeptical views on the crypto-currency market, the demand for the financial instruments based on crypto-transactions is not weakening; it is only rapidly gaining momentum. In this regard, attention to this tool by the international community, and state regulators is increasing day by day, as evidenced by the dynamics of the legalization of this market in the world (Luther, 2016).

2 Methodology

In order to identify trends that demonstrate the attitude of countries to the crypto-currency, and also to obtain a more detailed information of their legal status in different countries, an analysis was made reflecting the status of the crypto-currency for each quarter from 2013 to 2017 in 29 countries.

The following system of assessments of the legal status of crypto-currencies is adopted as a basis:

-1- negative attitude to crypto-currency / complete ban;

0- the crypto-currency status is not defined;

0.5- the question of legalization is being considered;

1- recognized as partial money, commodity, asset;

2- legally recognized, taxed.

The results are shown in Fig1.

The analysis implemented shows that in most states the legal status of the crypto-currency is debatable and unsettled. At the same time, despite the heterogeneity of the attitude from national governments to the crypto-currency market, the latter, judging from the data in Figure 1, shows a progressive positive trend, due to the growing trends in its legalization in various countries of the world (the average of the estimates for each quarter form a time series with a pronounced linear trend). This allows us to conclude that with each analyzed period the level of confidence of the world community in crypto-currencies is growing.

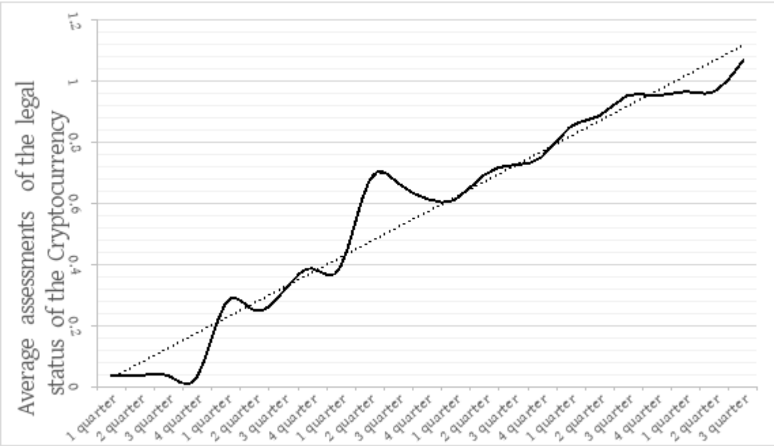

Fig 1. Average assessments of the legal status of the crypto-currency

Despite the impressive dynamics of the legalization and development of the crypto-currency market in the world, it should be noted that the market of "digital money" is still far from its final "maturity". At the same time, taking into account the emerging approaches to the attitude to the crypto-currency in the Russian Federation expressed in the activation of various structures of public authorities to the issues of its legalization and giving it a legal status, the relevance of their functions as a means of saving and accumulating can acquire a new "color" prospects. Suffice it to say that the Ministry of Finance of Russia proposed to include crypto-currency in the country's financial literacy strategy for 2017-2023 (Vranken, 2017).

At the same time, it should be noted that at the current time many economists and statesmen do not consider the factor of the influence from the global crypto-currency market on macroeconomic and financial stability as significant, even despite its exponential growth in recent years, as well as a very serious level of activation on the part of state regulators in the sphere of searching for mechanisms on regulating the crypto-currency turnover. The basis of this approach is the extremely low volume of the crypto-currency market in the overall balance of the payment system. For example, the weekly turnover of Bitcoin in the Russian Federation is only 0.006% of cash and 0.001% of the money supply (Wilson & Yelowitz, 2015).

However, in the foreseeable future, it is very likely that the scenario envisaging further activation of the market under study and its multifaceted integration into national economic systems makes it necessary to pay special attention to this issue today from the scientific and expert community (White, 2015; Perron, 1997).

In connection with the above, at the current time it is extremely urgent to search for and develop a special toolkit that allows anticipating and forecasting adjustments to the exchange rates of modern "digital money".

In all fairness, we should note that at the current moment there are extremely rare works devoted to this topic in the scientific publishing space. Questions of a research nature are mostly aimed either at an expert assessment of current and forthcoming prospects for the development of the market under consideration, or at the use of special methods of technical analysis based on currency exchange data that reveals the features and trends of exchange rate fluctuations for "digital money".

"Dipping" into the analysis of existing approaches in the current practice, aimed at modeling and forecasting exchange rates of crypto-currencies, it can be noted that forecasting the change in exchange rate is a very non-trivial task: using a fundamental analysis to predict the volatility of exchange quotations is ineffective, because the rate does not depend on the economy of a particular country. The use of technical analysis is also ineffective, since it is impossible to determine the state of the market by virtue of the formation of demand and supply due to data from individuals willing to buy or sell certain goods or services around the world (Boxing & Jenkins, 1994).

Nevertheless, the solution for the question raised in terms of developing tools that allow foreseeing future adjustments in the medium term, is also necessary and, in our view, possible based on the use of autoregressive moving average models ARMA, ARIMA. This approach is particularly relevant in the absence of effective tools for forecasting exchange rate fluctuations for this kind of "financial assets" characterized by uneven fluctuations of rates over time, the absence of a "binding" to underlying assets, high level of speculative demand, and so on.

The purpose of this paper is to identify the autoregression model and the integrated moving average with the minimum necessary order of parameters, on the basis of which it is possible to make reliable short-term forecasts of the crypto-currency’s volatility (Kantorovich, 2002).

The empirical and expert analysis demonstrated the expediency of using bitcoin as the object of research. This is due to a number of reasons, the main ones of which are presented below:

- The dominant share in the total world capitalization of crypto-currencies (about 45%)
- The most popular crypto-currency, the fluctuations in the rate of which completely determine the volatility of the absolute majority of other types of crypto-currency in the global market.

The modeling process applied to the object of research considered in this paper, is presented below with a detailed description of the sequence of solved iterations.

The calculations were made for data reflecting the monthly fluctuations of the crypto-currency Bitcoin in the period from 01/01/2014 to 18/03/2018. The source of the data was the virtual bitcoin wallet service "Blockchain.info". The calculations were carried out using the predictive analytical software Eviews, IBM SPSS.

Modeling of stationary time series, or series which can be reduced to stationary ones, can be performed using the autoregressive moving average (ARMA) models class, which is a combination of two models: an autoregression of order p and a moving average of order q. In the generalized form, the ARMA (p, q) model looks like this:

$$Y_t = a_0 + a_1 X_{t-1} + a_2 X_2 \dots + a_n X_{t-n} + \varepsilon_t - \beta_1 \varepsilon_{e-1} - \beta_2 \varepsilon_{e-2} - \dots - \beta_n \varepsilon_{t-n}$$

For non-stationary data, Box and Jenkins proposed the ARIMA model (p, d, q), which after taking d consecutive differences can be reduced to a stationary form (Granger, et al, 1995) , where p, d, q are the structural parameters characterizing the order for the corresponding parts of autoregressive, integrated and moving average models.

The methodology of model selection consists of several stages.

3 Model Identification

At the initial stage of the study, it is necessary to find out whether the series under study has the property of stationarity.

The stationary series is a series which behavior and properties in the present and future coincide with the behavior in the past.

The stationarity of the series can be estimated using various methods. The basic methods for checking the stationarity of a time series are Dickey-Fuller extensions, and also the construction of an autocorrelation function (ACF) and a partial autocorrelation function (PACF). The calculation of the autocorrelation function is performed using the following formula:

$$\rho_k = \frac{\gamma_k}{\gamma_0} = \frac{\mathrm{cov}(k)}{\mathrm{var}} = \frac{\mathrm{cov}(y_t; y_{t-k})}{\mathrm{var}(y_t)}; \ |\rho_k| \leq 1$$

A particular autocorrelation function (PACF) is defined as a particular correlation between the values y_t and y_{t-k} "purified" from the influence of intermediate variables on them.

For the original series, an autocorrelation function and a partial autocorrelation function were constructed (Fig 2).

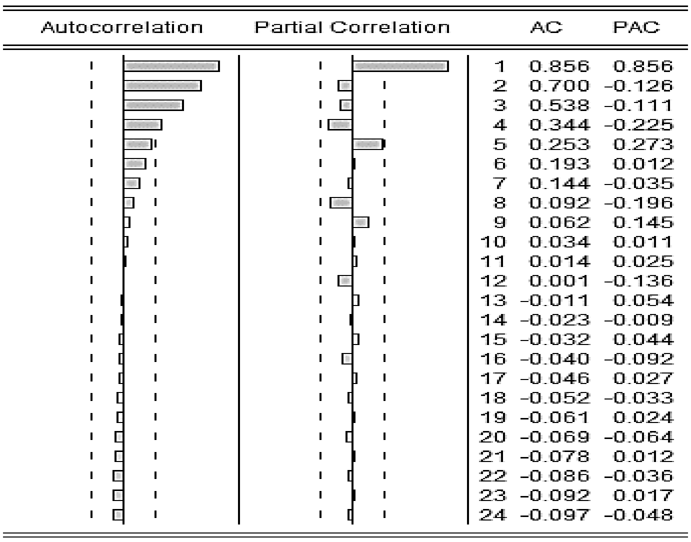

Fig 2. Autocorrelation function and Partial autocorrelation function (Partial Correlation)

The constructed autocorrelation function is characterized by a slow decrease in the coefficients of the autocorrelation function over the decaying exponential from the value of the coefficient close to 1. A particular autocorrelation function has a high value of the autocorrelation coefficient on the first lag, and close to 0 values on subsequent lags.

Thus, we can conclude that the initial time series is nonstationary.

In addition to visual analysis, an extended Dickey-Fuller test (ADF test) was performed to verify the stationarity of the time series. The test consists in testing the null hypothesis about the presence of a unit root in the equation:

$$y_t = \alpha y_{t-1} + \varepsilon_t$$

The decision on the stationarity of time series is adopted if the calculated estimates of the test are greater than the observed statistics t_{obs} ($t_{crit} > t_{obs}$). The test results are shown in Table 2.

Table 1. Results of the ADF test

		T-statistic	Prob.*
Augmented Dickey – Fuller Test Statistic		3.110313	1.0000
Test Critical Values:	1 % level	-3.588509	
	5 % level	-2.929734	
	10 % level	-2.603064	

For the test series under study t_{obs} = -3,11. Since the values obtained for different levels of importance (1, 5 and 10%) have values less than $t_{obs,}$ then the hypothesis of nonstationary time series is accepted.

Thus, the simulation of the bitcoin course was carried out on the basis of the autoregressive integrated moving average (ARIMA) model.

4 Criteria for selecting model parameters

After selecting a model, you need to choose the corresponding parameters. After taking the first difference, the original series was reduced to a stationary form, so the parameter d = 1.

To simulate the dynamics of the change in the crypto currency rate, the following models were tested: ARIMA (1,1,1), ARIMA (1,1,2), ARIMA (2,1,0) ARIMA (2,1,1), ARIMA (2,1, 2).

The basis for choosing the model was the functions constructed by autocorrelation function and partial autocorrelation function, as well as the calculated Akaike criterion (3) and the Bayesian information criterion (4).

These criteria allow choosing the best model from the group of candidate models. The advantage is given to the model, the values of AIC and BIC of which are minimal. The calculation is made by the following formulas:

$$\mathrm{AIC} = \ln\widehat{\delta^2} + \frac{2}{n}r,$$

$$\mathrm{BIC} = \ln\widehat{\delta^2} + \frac{\ln n}{n}r$$

Where $\widehat{\delta^2}$-a residual sum of squares divided by the number of observations,

r is the total number of terms of the ARIMA model.

The ARIMA model (2,1,1) has the minimum BIC and AIC criteria.

Thus, the final model took the following form:

$$\Delta X = 17{,}849 + 0{,}047\Delta X_{t-1} - 0{,}296\Delta X_{t-2} - 1{,}602\varepsilon_{t-1} - 0{,}845\varepsilon_{t-2} + \varepsilon_t$$

5 Results and Discussion

With the help of the received model, the bitcoin crypto currency rate was forecast for 4 points ahead. The results of the forecast are shown in Fig 4.

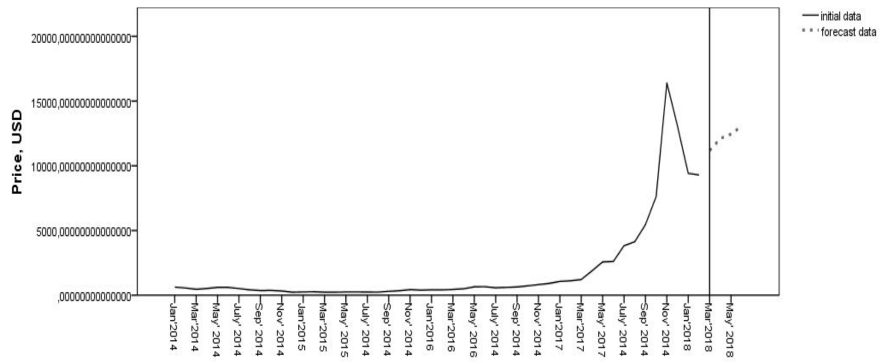

Fig 4.The predicted values of the bitcoin rate obtained with ARIMA (2,1,1)

Indicators which indicate the quality of the model obtained are given in Table 3

Table 3. Qualitative characteristics of the model

Statistics	Average value
Stationary R-Squared	0.771
R-Squared	0.892
RMSE	165.93
MAPE	4,182
MaxAPE	39.607
MAE	102,682
MaxAE	634,788

The reliability and adequacy of the results obtained were confirmed by comparing the actual and predictive parameters of the bitcoin course, and also on the basis of the high R-squared value (Fig 5).

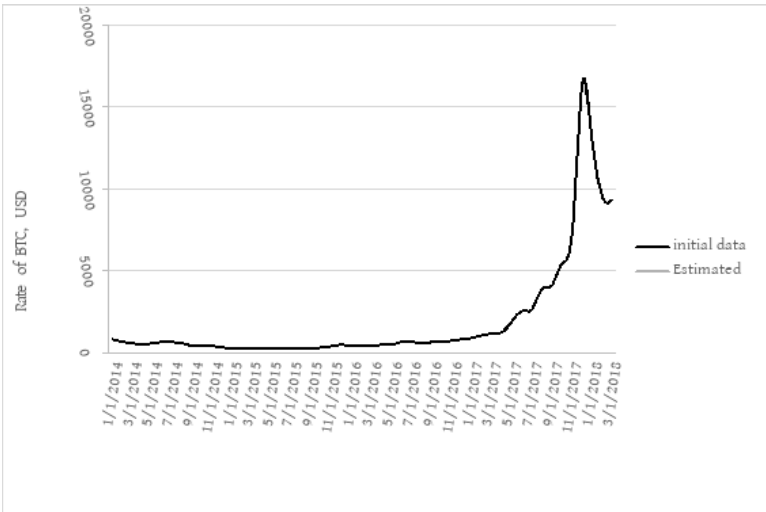

Fig 5. Convergence of prognostic and actual data estimating bitcoin / USD exchange rate

As can be seen from the presented graph, the predicted values describe the forthcoming corrections with high accuracy what is confirmed by the extremely high level of the predicted daily trend change. At the same time, undoubtedly, there are also minor discrepancies between the absolute values of the series, what is completely permissible and falls within the scope of the prognostic error.

So, in accordance with the obtained forecast estimates, the dynamics of the bitcoin course in the next 4 months will take a stable positive trend (Fig 6).

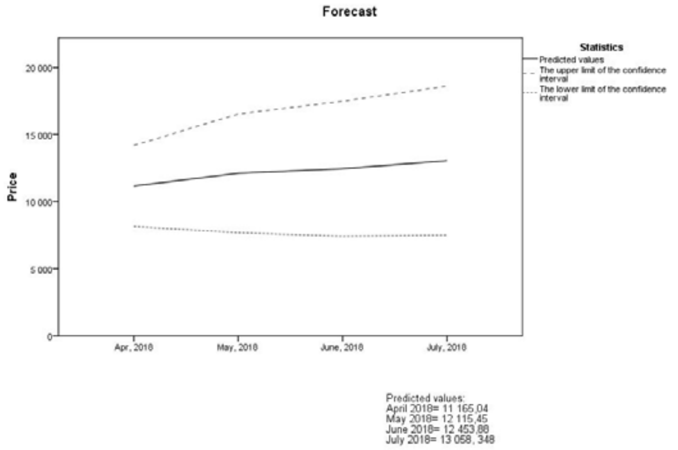

Fig 6. Predicted values

By the end of the third quarter of 2018, its stock price will be about $ 11,000. It is important to note here that the methodological modeling approaches used in this study allow us to determine not only possible future trends in the fairway of which corrections will occur, but also fluctuations in exchange rates throughout the forecast period of time. The expected slight adjustment in May 2018 will be insignificant and will not affect in any significant way the positive overall predicted trend within the analyzed period of time.

6 Summary

The obtained results in many respects testify to the prospects of the chosen forecasting tool based on the use of autoregressive algorithms and integrated moving average. However, it should be noted that the model constructed requires further improvement. So, for example, in connection with the high variability of the study series, it seems appropriate to apply stochastic volatility models.

Summing up the realized estimations and the developed methodical toolkit it is necessary to note a very high level of its perspective within the framework of business processes modeling based on the use of crypto-transactions. This is due, first of all, to the urgent need to understand and predict exchange rates of the crypto-currency, since its use in economic circulation forms very high risks of financial losses of economic entities caused by significant volatility.

7 Conclusions

In view of the above, the methodological approaches proposed in the study greatly expand the opportunities for predicting and forecasting the parameters of the digital money market development for a period of 3 to 4 months, which forms a firm basis for developing medium-term behavior patterns of economic agents involved in the process of crypto-transactions. In addition, the trends of recent months characterized by the activation of the legalization processes of the world's crypto-currency market, including Russia, actualize the need to predict the market under study for more "deep" time horizons than is accepted in most models of technical analysis, which is an integral part of the generation of analytical estimates on the exchanges. As calculations show, the presented methodical approach is able to solve issues that are so important for today's economy.

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