

Assessment of Various Factors Impact on Cryptocurrency Functioning using Economic and Mathematical Modeling

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Abstract: This article has developed an economic and mathematical model that reflects the dependence of the cryptocurrency rate on factors of an exploratory nature. At present, an interesting and promising area of research is exploratory analysis, the economic meaning of which is to study the influence of sudden factors on the final result. Against the backdrop of the development of modern technologies in the world, taking into account the depreciation of the US dollar and the withdrawal of investors from the stock markets, the cryptocurrency market is considered one of the most promising and most influenced by exploratory factors. The cryptocurrency rate is based on economic expectation, and not on the availability of real assets. The article discusses the main indicators that affect the cryptocurrency rate, using the example of Bitcoin. An economic-mathematical model of the dependence of the price of bitcoin on a number of the most significant indicators is built. The economic and mathematical model proposed in the study allows you to take into account the degree of influence of exploratory factors on the formed cryptocurrency rate. The developed model will allow the most accurate prediction of the cryptocurrency rate in modern financial and economic conditions, since it takes into account exploratory factors.


1 INTRODUCTION


Today, the cryptocurrency market is actively developing. At the beginning of 2017, due to the rapid growth of the cryptocurrency market capitalization, many saw it as signs of a financial pyramid, but gradually the opinion began to change. "Financial institutions introduced Bitcoin futures, large investors began to come to the cryptocurrency market, pessimistic forecasts began to be replaced by more optimistic ones" (Kornilov et al., 2017).


The collapse of bitcoin in March 2020, according to analysts at JPMorgan Chase, was a stress test for the cryptocurrency market. "The industry managed to cope with it in a matter of months. Now Bitcoin is periodically subject to correction, but it has every chance to become the main competitor for stock markets. Many investors transfer their savings from the stock market to the currency. According to Dan Tapeiro, an investor and founder of Gold Bullion International, "the dollar will weaken even more, and

digital assets will become its full-fledged competitors".

The iTrustCapital cryptocurrency trading platform conducted its own research to find out which asset people of different generations are willing to invest in during pandemics and epidemics. "Respondents aged 33 to 44 are twice as likely as the others to call bitcoin and cryptocurrencies the most protected asset in general. They tend to invest in modern assets such as cryptocurrencies, stocks and bonds, but they do not exclude gold. It is worth noting that 44% of respondents admitted that they consider gold to be the most profitable investment tool, which is valuable at any time and under any conditions".

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2 THEORETICAL, EMPIRICAL AND METHODOLOGICAL GROUNDS OF THE RESEARCH

Cryptocurrency is an encrypted unregulated digital asset that is used as an analogue of currency in exchange transactions. Cryptocurrency does not have a physical form, it exists only in the electronic network in the form of data. At the moment, there is no single approach to determining the nature of virtual currencies and their classification. According to the opinion of a group of scientists, cryptocurrencies can be classified according to their functions and liquidity level (Jeskindarov et al., 2018):

- the first group: cryptocurrencies that are used as a means of payment, means of accumulation (savings), exchange, and as an investment tool (Bitcoin, Bitcoin-cash, Ripple, etc.);
- second group: cryptocurrencies tokens. Cryptocurrencies of this group are used as a means of payment, means of accumulation (savings), exchange, and as an investment tool (STRAT, Waves, etc.);
- the third group: tokens and cryptocurrencies that have not received distribution as a means of payment, means of accumulation (savings) and exchange, and are not used as an investment tool (TRUMP-COIN etc.).

According to statistics of the Coinmarketcap service, the list of cryptocurrencies is approaching one and a half thousand, and according to the A. Treschev calculations, the founder of the Russian Association of Cryptocurrencies and Blockchain, there are more than 900 of them.

The attractiveness of cryptocurrencies is due to the following factors:

- the release of cryptocurrency into circulation is decentralized, there are no non-issuing nature of crypto assets and state registration;
- independence of emissions from political preferences and economic views of the subjects of the system. Cryptocurrency is not a debt obligation of the issuer, it does not belong to central banks, which distinguishes it from electronic money and non-cash payments;
- indisputable right of ownership (the presence of an individual key, the operation with cryptocurrency cannot be performed by the counterparty without the private key of the contract holder; the holder can choose to execute the algorithm regardless of citizenship, place of residence, nation, religion, gender);

- An advanced technology of the register of blocks of information of the blockchain, on the basis of which the majority of cryptocurrencies are created and transmitted. Blockchain technology ensures the transparency of the cryptocurrency circulation mechanism, all of whose elements are controlled by a large number of independent entities;
- uninterrupted operation due to the low probability of a simultaneous failure in the work of all entities;
- use of cryptocurrency as a means of payment;
- current anonymity of payments (privacy of personal data of the parties);
- the transfer of a digital asset occurs without intermediaries;
- the cost of transfers is low or transaction is free of charge;
- The transaction speed is higher compared to the international interbank system SWIFT;
- with respect to cryptocurrency, there is no problem of limiting liquidity even when the entire amount of cryptocurrency is developed, since a unit of currency is divisible into smaller parts. "The total volume of the currency is known in advance, and the creation of each new block is accompanied by the solution of more complex mathematical problems, which leads to an artificial limitation of the growth rate of the currency supply" (Shaidullina, 2018).
- cryptocurrencies are used by an unlimited number of people to complete transactions for the sale of goods, payment for work and services, as well as for investment purposes;
- cryptocurrencies are considered by market entities as a source of revenue generation in connection with their use, mining, participation and raising capital through ICOs, operations on the exchange.

Despite all its advantages, cryptocurrencies have the following disadvantages:

- cryptocurrency, as a subject of exchange, settlement operations, a means of creating or acquiring capital, as well as an object of investment activity, is risky in nature, since it is not provided with real assets and is highly volatile, which creates a risk of losses (Jeskindarov et al., 2018);
- legal vulnerability of investors. The use of cryptocurrency in many countries is not legally regulated by legal documents or is prohibited, due to the lack of the ability to centrally regulate cryptocurrency and to prevent its use in the process of combating money laundering and terrorist financing;

- the danger of cyberattacks entails the possibility of a risk of insecure cryptographic code, it is almost impossible to deal with this risk, since the existing financial infrastructure is built on key principles of encryption;
- the risk of losing access to the crypto asset due to the loss of keys or because of their theft. This risk can be reduced through the use of password managers or specialized equipment.

Cryptocurrency does not act as a commitment to anyone. It is not provided with anything, and its value is based on the expectations of market players. Cryptocurrency quotes are formed solely by the balance of supply and demand, not initially tied to any currency or other asset; however, there are factors that affect its rate.

The most popular virtual and widespread currency in the world is Bitcoin. Bitcoin's market capitalization currently stands at about 172.6 billion US dollars. Bitcoin, despite its high volatility, is considered one of the most profitable investment tools in the cryptocurrency market (Figures 1, 2).

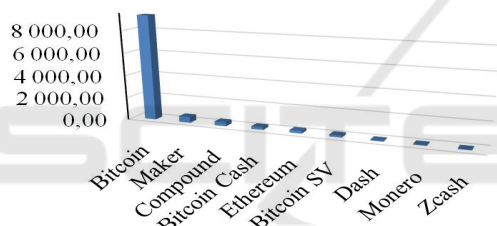


Figure 1: Price of the TOP 10 cryptocurrencies as of 06/20/2020 (USD).

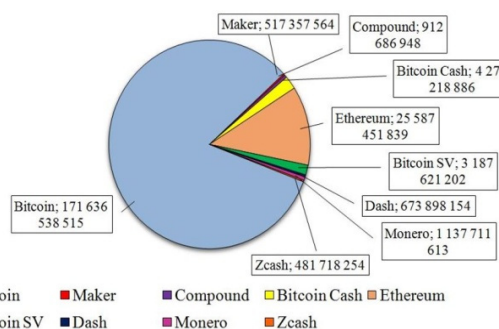


Figure 2: TOP 10 cryptocurrencies in terms of market capitalization as of June 20, 2020 (USD).

An exploratory factor analysis is used to study Bitcoin price formation that is, such an analysis system, according to which it is not initially determined which factors can most accurately describe the relationships and interdependencies.

Explosiveness (from French explosion - explosion) is a clinical violation. Readiness for a sudden, sometimes inadequate, explosive nature, manifestation of the effect.

We will build economic and mathematical models of the impact on the price of Bitcoin of a number of the most significant indicators indicated below (Table 1).

Table 1: Initial data.

Index	2014			
	I qr.	II qr.	III qr.	IV qr.
X ₁ – Total Gold Offer (tn)	1 104.1	1 104.1	1 104.1	1 104.1
X ₂ – Total gold demand (tn)	1 093.9	1 093.9	1 093.9	1 093.9
X ₃ – Gold price (London PM fix) (US\$/troy ounce)	1 293.1	1 293.1	1 293.1	1 293.1
X ₄ – Silver (US\$/troy ounce)	19.97	20.87	17.11	15.79
X ₅ – Platinum (US\$/troy ounce)	1 418.0	1 480.0	1 300.0	1 206.0
X ₆ – Palladium (US\$/troy ounce)	778.0	844.0	775.0	811.0
X ₇ – Brent Oil (dollars/barrel)	107.70	112.40	94.80	57.54
X ₈ – Euro/dollar, €/€	1.3771	1.3771	1.3771	1.3771
X ₉ – British pound/dollar, £/€	1.6663	1.6663	1.6663	1.6663
X ₁₀ – S&P 500	1	1	1	1
	872.34	872.34	872.34	872.34
X ₁₁ – U.S. Treasury current liabilities (12 months) (Treasury Bills), %	0.13	0.13	0.13	0.13
X ₁₂ – US Federal Reserve Rate, %	0.25	0.25	0.25	0.25
Y – Bitcoin, Bitcoin / €	702.55	702.55	702.55	702.55

Table 1: Initial data (cont.).

Index	2015				2016			
	I qr.	II qr.	III qr.	IV qr.	I qr.	II qr.	III qr.	IV qr.
X ₁	1 086.2	1 044.1	1 128.8	1 092.1	1 182.8	1 167.2	1 174.3	1 086.1
X ₂	1 110.1	958.3	1 162.7	1 112.2	1 284.0	1 055.1	1 027.7	972.0
X ₃	1 218.5	1 192.4	1 124.3	1 106.5	1 182.6	1 259.6	1 334.8	1 221.6
X ₄	16.60	15.70	14.65	13.82	15.38	18.36	19.35	16.24
X ₅	1 129.0	1 078.0	908.0	868.0	976.0	999.0	1 034.0	898.0
X ₆	729.0	677.0	661.0	555.0	569.0	589.0	722.0	670.0
X ₇	55.10	62.05	47.92	36.56	39.61	50.73	49.41	56.75
X ₈	1.0731	1.1138	1.1177	1.0861	1.1380	1.1105	1.1241	1.0516
X ₉	1.4818	1.5709	1.5129	1.4739	1.4362	1.3311	1.2976	1.2338
X ₁₀	2 067.89	2 063.11	1 920.03	2 043.94	2 059.74	2 098.86	2 168.27	2 238.83
X ₁₁	0.26	0.28	0.33	0.65	0.59	0.45	0.59	0.85
X ₁₂	0.25	0.25	0.25	0.50	0.50	0.50	0.50	0.75
Y	248.54	236.67	257.43	341.04	411.58	515.61	616.76	718.09

Table 1: Initial data (cont.).

Index	2017				2018		
	I qr.	II qr.	III qr.	IV qr.	I qr.	II qr.	III qr.
X ₁	1 037.2	1 092.1	1 185.7	1 138.0	1 107.1	1 079.0	1 161.6
X ₂	1 107.5	1 031.9	988.8	1 073.6	998.3	992.8	1 013.0
X ₃	1 219.5	1 256.6	1 277.9	1 275.4	1 329.3	1 306.0	1 213.2
X ₄	18.06	16.47	16.86	16.74	16.52	16.03	14.31
X ₅	940.0	922.0	920.0	917.0	936.0	851.0	815.0
X ₆	798.0	841.0	935.0	1 033.0	970.0	953.0	1 094.0
X ₇	53.62	48.94	56.53	66.87	69.35	79.12	82.98
X ₈	1.0652	1.1426	1.1814	1.1998	1.2323	1.1685	1.1609
X ₉	1.2550	1.3027	1.3397	1.3515	1.4018	1.3209	1.3039
X ₁₀	2 362.72	2 423.41	2 519.36	2 673.61	2 640.87	2 718.37	2 913.89
X ₁₁	1.03	1.24	1.31	1.76	2.09	2.33	2.59
X ₁₂	1.00	1.25	1.25	1.50	1.75	2.00	2.25
Y	934.49	1864.46	3397.77	9398.57	10672.55	7829.15	6799.21

3 RESULTS

Quarterly values are considered for calculation: indicators of supply and demand for gold, prices for precious metals (gold, silver, platinum, palladium), oil prices, exchange rates of major currencies, stock indices, discount rate of the Fed, securities with a

guaranteed level of yield (short-term US Treasury Obligations) for the period from 2014 to 2018 inclusive. The number of members of the time series of indicators (20) is quite sufficient for reliable statistical analysis. First, we compose a matrix of pair correlations between the variables (Table 2). Since this matrix is symmetric, its lower part is presented.

Table 2: Correlation matrix.

Index									
X ₁	1.00								
X ₂	0.20	1.00							
X ₃	0.09	-0.43	1.00						
X ₄	-0.06	-0.09	0.68	1.00					
X ₅	-0.16	0.17	0.28	0.68	1.00				
X ₆	0.06	-0.45	0.52	0.04	-0.12	1.00			
X ₇	-0.23	-0.19	0.52	0.53	0.67	0.47	1.00		
X ₈	0.06	0.02	0.50	0.55	0.73	0.38	0.84	1.00	
X ₉	-0.18	0.30	-0.10	0.24	0.83	-0.19	0.54	0.67	1.00

Table 2: Correlation matrix (cont.).

Index													
X ₁₀	0.12	-0.48	0.32	-0.28	-0.65	0.80	0.00	-0.14	-0.67	1.00			
X ₁₁	0.11	-0.40	0.27	-0.35	-0.68	0.74	0.01	-0.11	-0.63	0.97	1.00		
X ₁₂	0.10	-0.42	0.32	-0.28	-0.64	0.77	0.06	-0.07	-0.63	0.98	0.99	1.00	
Y	0.10	-0.36	0.44	-0.18	-0.43	0.80	0.19	0.17	-0.35	0.86	0.88	0.87	1.00

Y – the price of Bitcoin – is the resulting indicator, and if we examine its functional dependence on other indicators, then at the initial stage, the most obvious is the idea of using linear regression.

$$y = X \cdot b + e; \quad (1)$$

where y is the vector (column matrix) of the bitcoin exchange rate (Y) in the period from 2014 to 2018; X - a matrix of supply values (X₁) and demand (X₂) of gold, prices for banking metals and other indicators; b - vector of regression coefficients; e - vector of random deviations.

However, the classical linear regression model does not fit in this case, since the regressors are random variables and, at the same time, are interdependent, as shown by the correlation matrix.

We will use the model of exploratory factor analysis in order to circumvent this problem. She has the form

$$X = F \cdot A^T + U; \quad (2)$$

where X is the matrix of values of indicators (the same as in (1)); F - matrix of values of exploratory factors; A - matrix of factor loads; ...^T - sign of the transpose of the matrix; U - matrix of random deviations of the model of exploratory factor analysis.

We substitute expression (2) in (1), we obtain a regression-factor model

$$Y = F \cdot c + u. \quad (3)$$

Expression (3) is an equation of regression of a dependent variable on independent exploratory factors, in it

$$c = A^T b; \quad (4)$$

$$u = U \cdot b + e. \quad (5)$$

Expression (4) denotes the vector of regression coefficients for factors, and in (5) the vector of random deviations of the regression factor model.

It should be noted that in order to solve the issue of joint consideration of indicators having different units of measurement, they are all reduced to the so-called standard form, i.e. centered and normalized:

$$z_t = (\tilde{z}_t - \bar{z})/\sigma_z; \quad (6)$$

where z_t is the indicator in standard form; \tilde{z}_t - the real value of the indicator; \bar{z} - the average value of the indicator; σ_z - standard deviation of the indicator.

A variable in standard form has zero expectation and unit variance. In this case, the values of exploratory factors are also normalized and centered. Moreover, the factors are interdependent and orthogonal, i.e. satisfy the condition

$$F^T F = I, \quad (7)$$

where I is the identity matrix.

After factor loads and factor values are found, to obtain an estimate of the regression coefficients of equation (3), you can use the usual least-squares method:

$$\hat{c} = (F^T F)^{-1} F^T y; \quad (8)$$

and taking into account (7), expression (8) takes the form

$$\hat{c} = F^T y. \quad (9)$$

Let us find an estimate of the regression coefficients of model (1). To do this, we use expression (4), on the basis of which we need to find the vector of regression coefficients. If the matrix is chosen so that

$$W \cdot A^T = I, \quad (10)$$

then

$$b = W \cdot c. \quad (11)$$

Multiply (10) by $A(A^T A)^{-1}$ the right, we get

$$W \cdot (A^T A) (A^T A)^{-1} = A \cdot (A^T A)^{-1},$$

then

$$W = A \cdot (A^T A)^{-1}, \quad (12)$$

Substituting (12) in (11), we obtain an estimate of the regression coefficients

$$\hat{b} = A \cdot (A^T A)^{-1} \cdot c. \quad (13)$$

In the course of calculations, 4 exploratory factors for regressors were identified. The final results of the calculations are summarized in Table 3.

We check the adequacy of the regression equations according to the Fisher criterion, calculated on the basis of the coefficient of determination

$$R^2 = 1 - \frac{\sum_{t=1}^N (\hat{y}_t - y_t)^2}{(N-1)\sigma^2},$$

where N is the number of observations; \hat{y}_t - the value of the resulting indicator restored by the regression equation; y_t - the observed value of the resulting indicator; σ^2 - the variance of the index Y .

Table 3: Calculation results.

Index	Exploratory factor loads				Regress. coeff.
	F1	F2	F3	F4	
X ₁	-0.120	0.139	-0.026	-0.094	0.073
X ₂	0.180	-0.220	-0.288	0.438	0.275
X ₃	-0.130	0.616	0.770	-0.113	0.479
X ₄	-0.207	0.219	0.732	0.381	-0.448
X ₅	0.119	-0.280	0.699	0.627	-0.848
X ₆	0.275	0.111	0.518	-0.765	0.111
X ₇	0.508	-0.009	0.772	0.075	0.389
X ₈	0.524	0.015	0.762	0.233	0.551
X ₉	0.421	-0.439	0.385	0.617	-0.296
X ₁₀	0.102	0.336	0.032	-0.935	0.676
X ₁₁	0.261	0.420	-0.069	-0.865	1.345
X ₁₂	0.251	0.415	-0.007	-0.871	1.252
Exploratory factor regression coeff.					
Y	1.097	1.844	-0.048	-3.638	

The criterion itself has the form

$$F = \frac{R_2}{1 - R_2} \cdot \frac{N - k - 1}{k},$$

where k is the number of parameters of the regression equation. In the regression equation of exploratory factors, this is the number of factors (m), and in the

usual regression equation, this is the number of variables (indicators) - n .

For the equation of regression of factors, the calculated value of the criterion is $F = 392.546$; and the critical value: $qF(0.95; m; N - m - 1) = 3.112$. The calculated value of the criterion is more than critical, therefore, the equation is adequate.

For the equation of regression of variables, the calculated value of the criterion is $F = 56.078$; and the critical value: $qF(0.95; n; N - n - 1) = 4,000$. The calculated value of the criterion is more than critical, therefore, the equation is adequate. To interpret the factor solution in each row of the matrix of factor loads, we select the largest absolute value (shaded cells in Table 3).

The second factor accounted for one selected cell, and this factor can be unambiguously interpreted as the presence of gold on the market - the "gold factor".

The third factor is loading the prices of banking metals, except for palladium, as well as the price of oil and the euro-dollar pair the most. It can be interpreted as a "price factor".

The fourth factor has the largest load with a minus sign on the S&P 500 index, as well as financial obligations and the Fed discount rate, i.e. it determines negative trends in the financial sector, so it can be called a "crisis factor". Note that the crisis factor, in comparison with others, most determines the decrease in the stock index (S&P 500), the reduction in the rate of the Fed and securities with a guaranteed level of profitability (short-term obligations of the US Treasury) and increases the demand for gold.

The first factor does not have allocated cells, however, the loads are greater than 0.5 for the brand oil price and the euro-dollar pair. These indicators were under the dominant price factor. But the first factor can be called European.

The Bitcoin exchange rate regression equation for exploratory factors has the form

$$Y = 1.097 F_1 + 1.844 F_2 - 0.048 F_3 - 3.638 F_4 + U. \quad (14)$$

If we consider the coefficients of regression of factors, it becomes obvious the dominant negative impact of the "crisis factor" in the formation of the Bitcoin exchange rate. The growth of the "crisis factor" leads to a decrease in the price of Bitcoin, while the formation of the above factor is significantly affected by the following indicators: a decrease in the stock index, the rate of short-term liabilities of the US Treasury, the discount rate of the Fed, as well as an increase in demand for gold.

The second most important factor influencing Bitcoin is the “golden” factor - the larger the gold supply, the higher the Bitcoin exchange rate.

The factor determined by the price of oil and the euro exchange rate is in third place. And the price factor turned out to be in last place among the exploratory factors, and its influence is negative and insignificant.

Regression coefficients of variables allow you to determine the sensitivity of the change in each indicator to the cryptocurrency rate. So, an increase in the supply of gold per unit leads to an increase in the exchange rate of Bitcoin by 0.073 units.

In April 2020, Quantum Economics founder Mati Greenspan noted that the entire financial industry depends on the correlation of Bitcoin with the S&P 500 index.

Gold is also gradually increasing its correlation with Bitcoin, while it remains an alternative financial instrument and remains attractive to potential investors. The influence of gold supply and demand on the price of Bitcoin is increasing. The price of Bitcoin with an increase in the supply (production) of gold rises and with the emergence of factors that reduce the demand for gold (the absence of global financial turmoil), the price of cryptocurrency decreases. The impact of the rising cost of other precious metals, such as silver and platinum, is negligible, but still reduces the cost of Bitcoin.

On the world market, the value of Bitcoin falls during periods of political and economic instability (along with US assets) and increases in times of relative calm and prosperity. The price of Bitcoin has a strong correlation with stocks and other American traditional assets. With tight monetary policy in the United States, Bitcoin will not be an attractive tool for hedging the risks of global instability. The exchange rate of Bitcoin with an increase in demand for precious metals behaves similarly to the US currency. Perhaps in the future, “Bitcoin will equal the US dollar in terms of its payment properties and eclipse gold as a means of savings” (interview with Bloomberg CEO of Bitcoin exchange Kraken Jess Powell).

The growth of investor interest in Bitcoin from asset hedge funds, retail investors and day traders will increase, but this will be associated with Bitcoin as an alternative means of investment (in this quality, Bitcoin competes with other financial assets in different ways, yielding in terms of reliability, but surpasses them in profitability), especially with the improvement of technological characteristics of cryptocurrencies.

The head of Kraken expects improved payment functions of the first cryptocurrency thanks to second-level solutions like the Lightning Network. They will provide the same affordable and easy to understand features, such as the popular payment systems PayPal and Venmo, eliminating the need to transfer coins on the blockchain. “Soon the technology underlying Bitcoin will dissolve. It will become like an American dollar: no one understands how it works, but everyone uses it.”

Cryptocurrencies, including Bitcoin, cannot be considered as an alternative way of investing in conditions of falling profitability of traditional financial instruments. However, according to the analytical center of the international audit and consulting network FinExpertiza, which presented the results of the study of the most profitable investment investments, Bitcoin has become one of the most profitable financial instruments for 2019.

4 CONCLUSIONS

Based on the methods of correlation and regression analysis, methods of exploratory factor analysis, economic and mathematical models made it possible to more deeply analyze and confirm the degree of influence of indicators on changes in Bitcoin prices, as well as to identify the most significant of these indicators and use these results in the future to forecast the rate of Bitcoin in the world market.

The financial analysis carried out in the study using the exploratory principle made it possible to formulate a factor analysis scheme, in which it was not initially determined which system of factors made it possible to describe the correlation matrix.

It should be noted that it is precisely when constructing a model for assessing the level of influence of explorer factors on the cryptocurrency exchange rate that the introduction of an analysis based on the exploratory principle is of particular importance, since the cryptocurrency exchange rate, the price of Bitcoin are indicators whose values are most dependent not on constant, but on variables that suddenly appear parameters.

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