Wavelet Analysis Methodology as a Tool for Predicting Cryptocurrency Price Dynamics

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Abstract: The stock market allows you to attract free investment resources, redistribute free financial resources between various spheres of the economy, business entities. For this, various tools and mechanisms for raising funds are used. Cryptocurrency is one of the tools of the modern stock market. The attractiveness of cryptocurrency, sharp and rapid changes in cryptocurrency prices necessitate various studies. At the same time, it is important to consider not only the dynamics of prices for cryptocurrencies, but also the mutual dynamics of prices between different types of cryptocurrencies. This is important in the aspect when choosing and building various forecasting models, assessing the mutual dynamics of cryptocurrency prices. To solve such a problem, it is necessary to carry out a complex and comprehensive analysis of the data. At the same time, it is important to obtain additional information that will be useful in the corresponding analysis. For this, it is proposed to use the wavelet ideology. We consider wavelet coherence as a data analysis tool. This choice is justified, and also the feasibility of its use on various datasets is confirmed. The paper deals with the mutual dynamics of prices for various types of cryptocurrencies. For this purpose, the corresponding estimates of the wavelet coherence are considered in the work. These estimates are based on real data. These estimates allow a number of conclusions to be drawn about cryptocurrency price prediction. In the work, information is presented in the form of various graphs and diagrams. This allows us to repeat and check the obtained estimates of the wavelet coherence, to evaluate the results that have been obtained.

Keywords—cryptocurrency; bitcoin; analysis; dynamics; stock market; wavelet analysis; wavelet coherence.

1. INTRODUCTION

Analysis is one of the research tools that are used in various fields to obtain the necessary information. Various analysis procedures can also be viewed as a source of information. At the same time, it is important that additional information can be obtained during the analysis. The presence of the necessary amount of information allows you to make the right decisions, consider various strategies for achieving the goal that was previously defined. Analysis, as a research method, also helps to examine in detail the dynamics of a process or phenomenon [1]-[3]. This allows you to build predictive models, make generalizations that relate to the development of processes or phenomena in the future. We can also talk about the general ideology of building predictive models.

An important area for analysis is the dynamics of the processes that take place in the stock market [4]-[6]. This is due to the fact that the stock market plays an important role in the development of the economy, economic relations between various business entities. At the same time, among the various areas of functioning of the stock market, a segment should be distinguished that considers the dynamics of prices for cryptocurrency [7]-[9]. This segment of the stock market is characterized by its rapid development, discussion of the role of cryptocurrency as an investment tool and a tool for generating savings. This indicates the importance of considering the dynamics of prices for cryptocurrency, the need to analyze such a segment of the stock market. It is also necessary to take into account the mutual dynamics for different types of cryptocurrencies.

An important aspect of analyzing the dynamics of prices for cryptocurrency, the possibility of building predictive models is the choice and justification of the appropriate procedure for conducting such an analysis. This determines the main goal of this work, its practical and theoretical orientation. Thus, among the tasks of this work, the following should be distinguished:

– conducting a brief overview of related work related to the research topic;

– substantiation of the choice of procedure for analyzing the dynamics of prices for cryptocurrency. At the same time, it is important to take into account the possible aspects of building predictive models;

– selection of various cryptocurrencies for the appropriate analysis.

2. MATERIALS AND METHODS

2.1 Related Work

There are many works by various authors that analyze the dynamics of cryptocurrency prices. At the same time, the authors use various methods and approaches for such analysis.

For example, W. Yiying and Z. Yeze in their research emphasize that cryptocurrency plays an important role in the formation of a new financial system [10]. Therefore, the authors analyze the dynamic characteristics, uncertainty and predictability of the cryptocurrency. To do this, W. Yiying and Z. Yeze use advanced artificial intelligence structures with a fully connected artificial neural network and a recurrent neural network with long-term short-term memory to analyze the dynamics of Bitcoin prices [10]. Thus, the authors combine long-term and short-term memory data on cryptocurrency prices. This allows us to talk about the predictability of prices for cryptocurrency, the possibility of building predictive models.

C. Y. H. Chen and C. M. Hafner investigate the influence of investor sentiment on the dynamics of prices for cryptocurrency [11]. The authors construct a model that has the conditional heteroscedasticity and thick tails of the conditional distribution of the error term. At the same time, the volatility of a cryptocurrency may depend on the constructed index of investor sentiment [11]. This approach allows us to identify speculative bubbles in the dynamics of cryptocurrency prices. This is a good indicator for building predictive models.

S. Lahmiri and S. Bekiros use deep learning methods to predict cryptocurrency prices [12]. Such training and related research has been done for three cryptocurrencies: Bitcoin, Digital Cash, and Ripple. The authors also note the fractal dynamics of time series data for each of the cryptocurrencies that are being investigated. This conclusion allows us to expand the use of tools for analyzing the dynamics of cryptocurrency prices.

The authors M. Gidea, D. Goldsmith, Y. Katz, P. Roldan and Y. Shmalo consider the analysis of critical transitions in time series that describe the dynamics of prices for cryptocurrency [13]. For this, the authors use persistence homology and clustering of critical transitions [13]. The study also combines topological analysis with machine learning techniques and k-means based data clustering. The authors analyze the price dynamics of Bitcoin, Ethereum, Litecoin and Ripple. The work also noted that the corresponding series of data on the dynamics of prices for cryptocurrency have signs of chaos. It also allows you to identify the transition points in the time series that describe the price dynamics of the cryptocurrency.

K. Wu, S. Wheatley and D. Sornette are considering the possibility of classifying cryptocurrencies [14]. This classification is based on an analysis of the dynamics of the market capitalization of different types of cryptocurrency. This is important for building effective predictive models for assessing cryptocurrency price dynamics. For this analysis, the authors use a simple proportional growth model. At the same time, it is shown in the work that theoretical predictions are consistent with empirical estimates. This makes it possible to use this approach for forecasting.

G. M. Caporale, L. Gil-Alana and A. Plastun investigate the issues of sustainability in the cryptocurrency market [15]. This fact is an important point in predicting cryptocurrency price dynamics. For such an analysis, the authors use two methods of long time series memory that characterize the dynamics of cryptocurrency prices. The authors emphasizes that this approach speaks of the possibility of obtaining abnormal profits in the cryptocurrency market. At the same time, such predictability of the market may indicate its inefficiency.

S. Lahmiri and S. Bekiros in one of their most recent works also consider the impact of the COVID-19 pandemic on the dynamics of cryptocurrency prices [16]. The authors research various cryptocurrency exchanges before and during the pandemic. This allows you to assess the stability of cryptocurrency price dynamics, to assess the risks of sharp jumps in the dynamics of cryptocurrency prices. For this, the authors use various statistical methods that are based on the Lyapunov exponent, Rosenstein's method, and approximate entropy [16]. The paper shows the effectiveness of using various approaches to analyze the dynamics of cryptocurrency prices, the possibility of building predictive models.

C. X. Nie examines the correlation dynamics in the cryptocurrency market [17]. This is an important point when choosing and building an appropriate predictive model. This study is based on the multidimensional scaling method and gives good results when considering the dynamics of the profitability of various cryptocurrencies.

We see that various methods, approaches, procedures are used to analyze the dynamics of cryptocurrency prices. This expands the possibilities of conducting appropriate analysis, carrying out comparative analysis, obtaining various results for making management decisions. At the same time, many researchers emphasize the need to analyze the joint price dynamics for various types of cryptocurrencies. At the same time, the choice of types of cryptocurrencies for conducting an appropriate analysis is not limited.

2.2 Data for Analysis

Let's take a look at several cryptocurrencies that will be used for the relevant analysis. Earlier, we noted that the choice of types of cryptocurrencies for conducting the appropriate analysis is not limited. However, we will be looking at cryptocurrencies that are in the top five in terms of market capitalization. At the same time, the time series of data for such cryptocurrencies should be comparable.

Among such currencies, we single out (data from the site https://www.investing.com/):

Bitcoin – market capitalization 800.74 billion dollars (as of 18.12.2021),

Ethereum – market capitalization 464.51 billion dollars (as of 18.12.2021),

Binance Coin – market capitalization of 88.09 billion dollars (as of 18.12.2021),

Tether – market capitalization 76.29 billion dollars (as of 18.12.2021),

Cardano – market capitalization 42.53 billion dollars (as of 18.12.2021).

We will consider the dynamics of cryptocurrency prices in the period from 05.01.2020 to 12.12.2021 in their weekly averaged terms. All prices are in relation to the US dollar.

Fig. 1 shows the dynamics of prices for Bitcoin over the time period that we are researching.
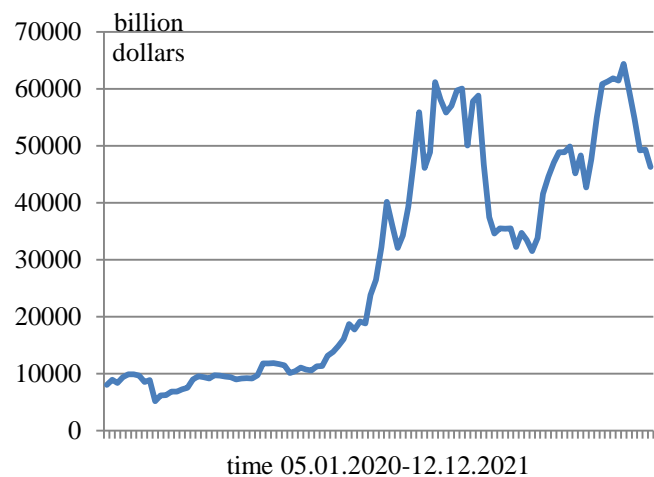
Figure 1: Dynamics of prices for Bitcoin over the time period that we are researching

We see that the price dynamics of the respective cryptocurrency is very volatile. However, such changes can be very drastic. This is especially true for the middle of the period that we are studying. In general, the dynamics of prices for Bitcoin is increasing. But the dynamics of this growth is not stable.

Fig. 2 shows the dynamics of prices for Ethereum over the time period that we are researching.

Fig. 3 shows the dynamics of prices for Binance Coin over the time period that we are researching.

We see that the dynamics of prices for Bitcoin and Ethereum are similar. This can be used for predictive estimates.
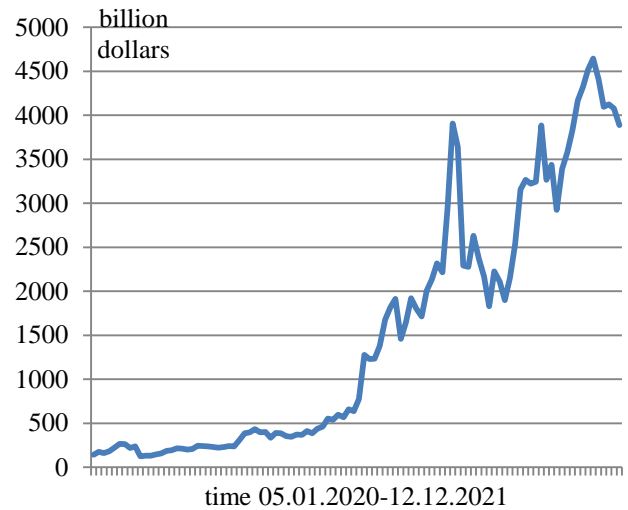

Figure 2: Dynamics of prices for Ethereum over the time period that we are researching
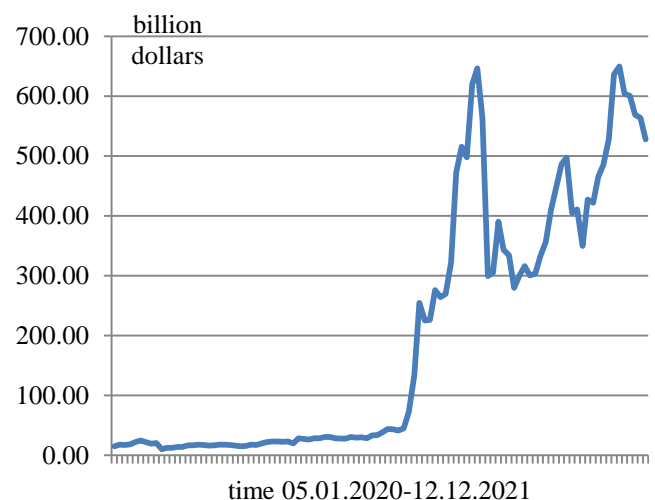

Figure 3: Dynamics of prices for Binance Coin over the time period that we are researching

Binance Coin price movements are also similar to Bitcoin and Ethereum price movements. At the same time, a number of characteristic features can be noted. These features include the depth of periods of sharp changes in the price dynamics of Binance Coin, Bitcoin and Ethereum. Therefore, it is important to investigate the mutual price dynamics of different types of cryptocurrencies.

Fig. 4 shows the dynamics of prices for Tether over the time period that we are researching.

We can see that the price dynamics for Tether is different from the price dynamics for Binance Coin, Bitcoin and Ethereum.
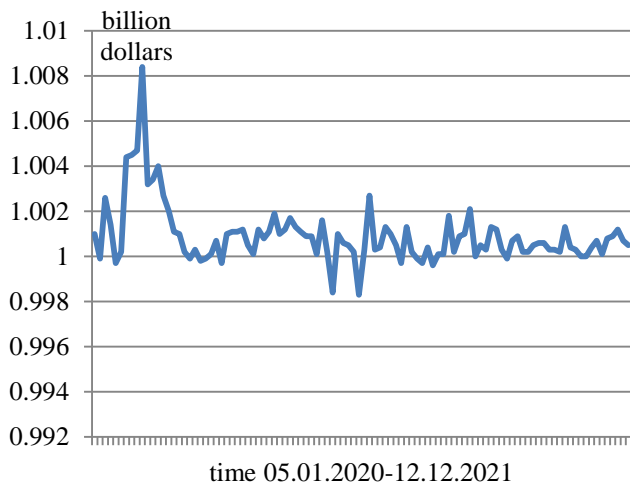
Figure 4: Dynamics of prices for Tether over the time period that we are researching

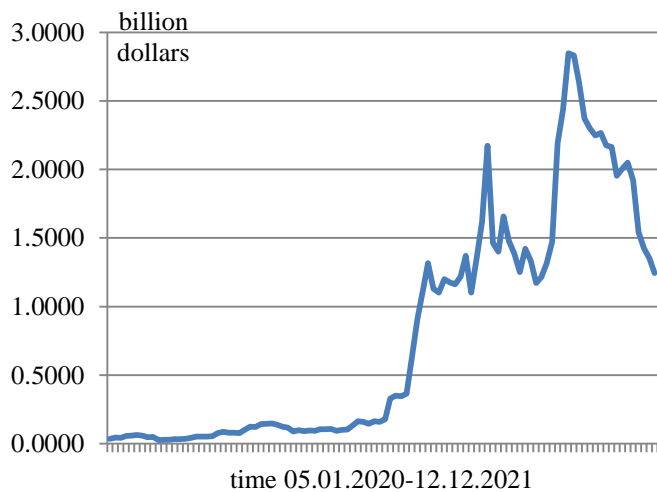Fig. 5 shows the dynamics of prices for Cardano over the time period that we are researching.

Figure 5: Dynamics of prices for Cardano over the time period that we are researching

Cardano price movements are more similar to Binance Coin, Bitcoin and Ethereum price movements than Tether price movements.

To compare the price dynamics of different types of cryptocurrencies, let us consider one of the methods of wavelet ideology [18]-[22].

2.3 Wavelet Coherence as an Element of Building a Predictive Model

As noted earlier, an important point in the study of cryptocurrency price dynamics is the analysis of mutual price dynamics between different types of cryptocurrencies. Such analysis, first of all, helps to find time intervals when the price dynamics for different types of cryptocurrencies is reciprocal or opposite. This, as mentioned above, helps to build adequate predictive models that will identify not only abrupt changes in the dynamics of the corresponding prices, but also identify periods for which the mutual dynamics of prices for cryptocurrency is characteristic.

To analyze the joint dynamics of prices for different types of cryptocurrencies, it is advisable to use the estimation methodology based on wavelet coherence. This is due to the fact that wavelet coherence helps to find abrupt changes in the dynamics of time series, to assess the mutual dynamics of the data series that are being investigated. Then wavelet coherence can be considered as a key element for constructing predictive estimates.
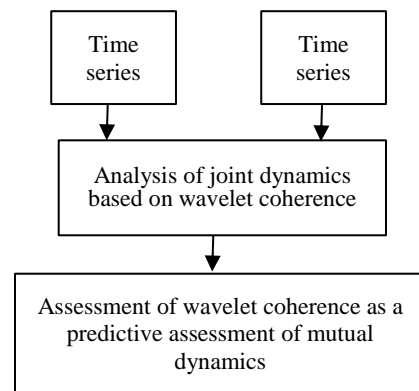

Figure 6: Wavelet coherence as an element of constructing a predictive estimate

At the same time, wavelet coherence, from the point of view of predictive estimates, makes it possible to reveal the time intervals of the mutual dynamics of the data that are being investigated. This is what helps to build an overall predictive estimate.

To implement wavelet coherence, you can use the following expression [23]-[25]:

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

where:

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

a, b – is a scale and center of time localization, that determine the scale of the wavelet transform;

z1,z2 – is a data series that we explore;

Θ – is a smoothing operator;

$Q^2(a,b)$ – is a squared wavelet coherency coefficient. $0 \leq Q^2(a,b) \leq 1$. If these values tend to zero, then we have a weak correlation. Otherwise, we have a strong correlation.

3. SOME PREDICTIVE ESTIMATES OF THE MUTUAL DYNAMICS OF CRYPTOCURRENCY PRICES

Fig. 7 shows the values of the wavelet coherence between the price dynamics of Bitcoin and Ethereum.
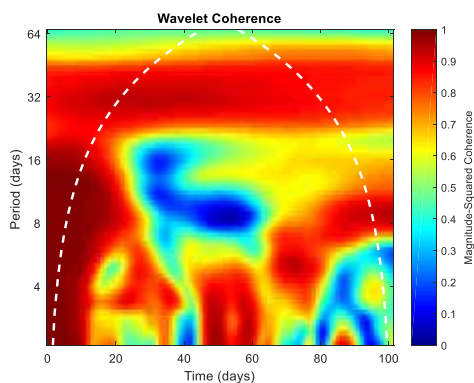
Figure 7: Assessment of wavelet coherence between Bitcoin and Ethereum price movements

Fig. 8 shows the values of the wavelet coherence between the price dynamics of Bitcoin and Binance Coin.
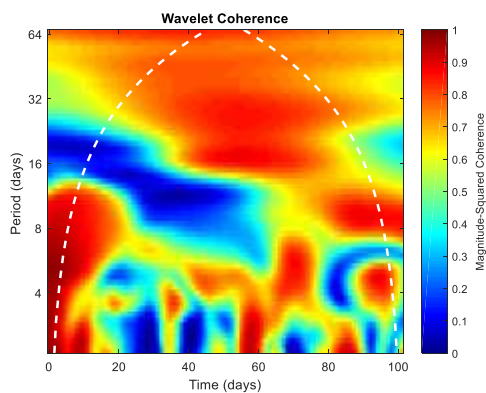

Figure 8: Assessment of wavelet coherence between Bitcoin and Binance Coin price movements

We can see roughly the same estimate of the wavelet coherence between the mutual price dynamics of Bitcoin and Ethereum, Bitcoin and Binance Coin. It also allows us to give approximately the same predictive value between the price dynamics of Bitcoin and Ethereum, Bitcoin and Binance Coin. However, it should be noted that the joint price dynamics between Bitcoin and Ethereum is deeper than the price

dynamics between Bitcoin and Binance Coin. This fact must be taken into account when building a generalized forecast model.

Fig. 9 shows the values of the wavelet coherence between the price dynamics of Bitcoin and Tether.
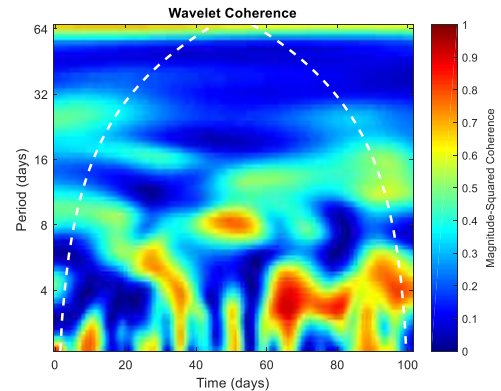

Figure 9: Assessment of wavelet coherence between Bitcoin and Tether price movements

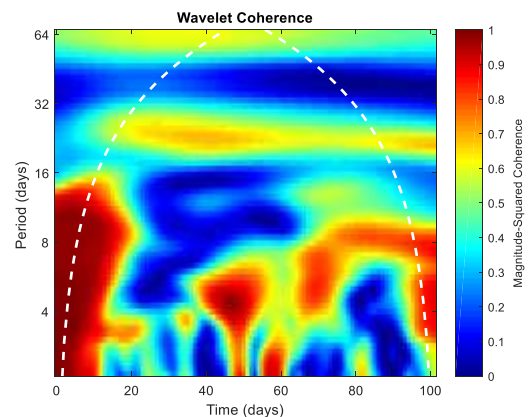Fig. 10 shows the values of the wavelet coherence between the price dynamics of Bitcoin and Cardano.

Figure 10: Assessment of wavelet coherence between Bitcoin and Cardano price movements

The wavelet coherence estimates between Bitcoin and Tether, Bitcoin and Cardano price movements differ from previous estimates. We can observe time intervals that are less consistent in depth, where the dynamics of cryptocurrency prices is mutual. Also, such assessments are more fragmented. Consequently, the corresponding predictive assessment of the mutual dynamics of cryptocurrency prices is the opposite in relation to the previously considered estimates. In this case, we have time intervals where the mutual dynamics of cryptocurrency prices is inconsistent.

Fig. 11 shows the values of the wavelet coherence between the price dynamics of Ethereum and Binance Coin.
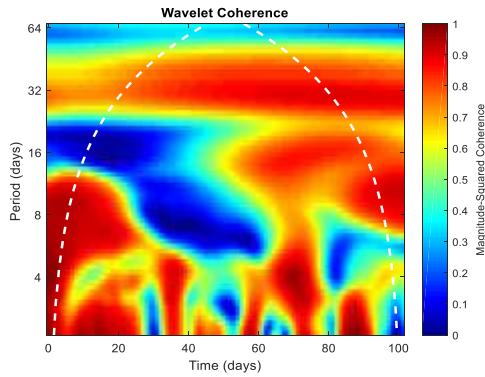
Figure 11: Assessment of wavelet coherence between Ethereum and Binance Coin price movements

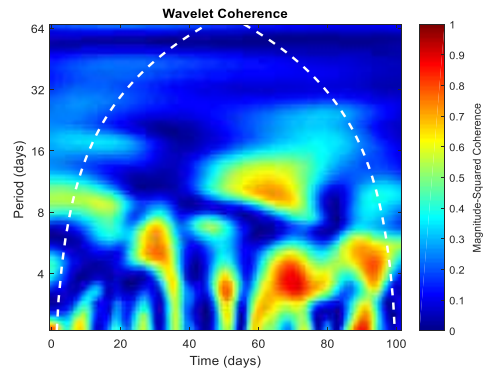Fig. 12 shows the values of the wavelet coherence between the price dynamics of Ethereum and Tether.

Figure 12: Assessment of wavelet coherence between Ethereum and Tether price movements

Fig. 13 shows the values of the wavelet coherence between the price dynamics of Ethereum and Cardano.
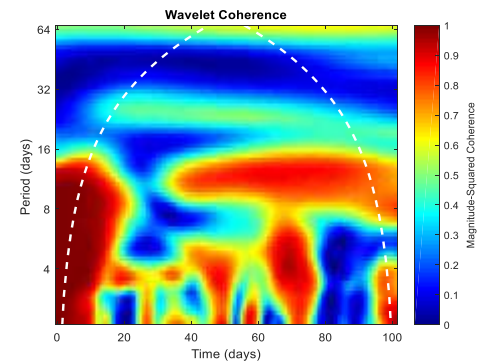

Figure 13: Assessment of wavelet coherence between Ethereum and Cardano price movements

We can see that the grade presented inherits the grade types that were presented earlier. The same can be seen in the figures below.

Fig. 14 shows the values of the wavelet coherence between the price dynamics of Binance Coin and Tether.
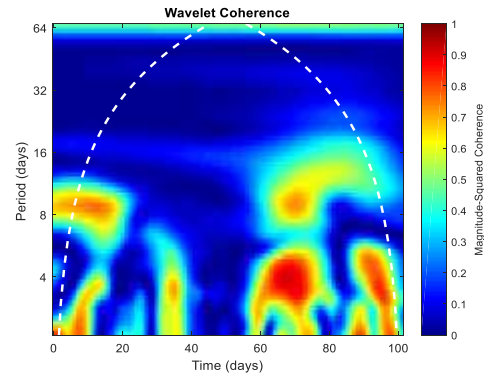

Figure 14: Assessment of wavelet coherence between Binance Coin and Tether price movements

Fig. 15 shows the values of the wavelet coherence between the price dynamics of Binance Coin and Cardano.
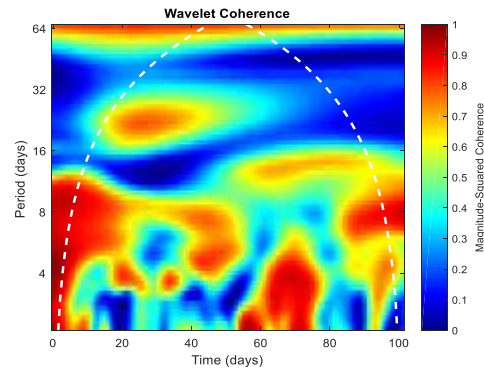

Figure 15: Assessment of wavelet coherence between Binance Coin and Cardano price movements

Fig. 16 shows the values of the wavelet coherence between the price dynamics of Tether and Cardano.
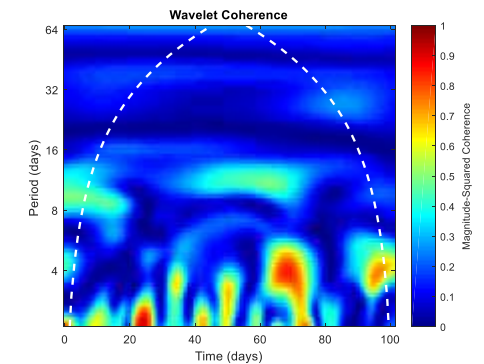

Figure 16: Assessment of wavelet coherence between Tether and Cardano price movements

Then the general methodology for constructing predictive estimates based on wavelet coherence is as follows:

We select pairs of cryptocurrencies to analyze the mutual dynamics of their prices. This choice is based on a preliminary analysis of the mutual dynamics of cryptocurrency prices.

Estimates of the wavelet coherence for the corresponding pairs of cryptocurrencies are constructed.

The intervals of mutual dynamics are analyzed for each pair of cryptocurrencies that we are researching.

Predictive estimates of the mutual price dynamics between the selected pairs of cryptocurrencies are built.

A predictive model is formed to identify mutual dynamics in cryptocurrency prices. The periods for investing in the respective cryptocurrencies are selected.

4. CONCLUSION

The paper deals with the analysis of mutual price dynamics between different types of cryptocurrencies. We also made a brief overview of the work related to the research topic. Before analyzing the mutual price dynamics between different types of cryptocurrencies, the choice of the relevant data was justified. We also substantiated the choice of tools for analyzing the mutual price dynamics between different types of cryptocurrencies.

To analyze price dynamics between different types of cryptocurrencies, we used the wavelet coherence method. The paper considers estimates of wavelet coherence between price dynamics for various types of cryptocurrencies. For this, real data were used. The work presents the research results in the form of graphs and diagrams. A generalized characteristic of the use of wavelet coherence for the construction of predictive estimates for the dynamics of prices for cryptocurrency is given.

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