Економіко-математичні методи та моделі фінансового розвитку

Economic and mathematical methods and models of financial development

DOI: 10.26565/2786-4995-2021-3-04
УДК 336.744

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ANALYSIS OF THE FACTORS INFLUENCING THE FORMATION OF THE TRANSACTION PRICE IN THE BLOCKCHAIN

Abstract. The blockchain as the tool was invented together with the Bitcoin and evolving. Despite the fact that new blockchains appeared, like Ethereum and other, the first one was not explored enough from the perspective of understanding dependencies between its elements. Mathematical and cryptographic dependencies are well described in the scientific literature, but dependencies exploration and description in relation to its economical usage of it is still missing.

The blockchain structure and mechanics provide that transaction registered within the blockchain are not free for the final user. The transaction price in the Blockchain exists. This transaction price can be decisive for the implementation of a project using blockchain. Understanding factors, which affect this price forming helps to understand frames, when usage of the blockchain is effective.

Taking into account all above mentioned, one of the targets of this article is to analyze the life cycle of transactions in the blockchain and determine the factors that have a significant impact on the formation of the transaction price in the Bitcoin Blockchain.

From the other hand blockchain assumed as the competitor or even “killer” of the traditional payment systems. There is the list of elements, which should be taken in account comparing both approaches for the transaction execution. This list includes comparing deficits and advantages of both systems, like security issues, transaction speed issues and so on. From this perspective based on the comparing the transactional price forming in both systems, author assess the prospects for using transactions in the Blockchain in comparing with the traditional payment systems.

Keywords: electronic money, crypto assets, distributed ledger, tokens, coins, crypto currencies, fiat money

GEL Classification: G3, M2

Formulas: 3; fig.: 5, tabl.: 4, bibl.: 10.

Introduction. The digitalization of the economy has become the most visible change in society and the economy in the past 10 years. The digitalization of production and distribution has gradually spread to all sectors of the global economy. Digital financial services an integral part of digitalization (Ali, 2020).

The is a lot of discussions exists currently regarding the resistance of the financial organization to Blockchain. (Walsh, O'Reilly, Gleasure, McAvoy, & O'Leary, 2021) There are some arguments used by these organizations and main of them are: Security of the blockchain, transparence of the blockchain, transaction speed in the blockchain and transaction price in the blockchain.

Despite the fact, that all above mentioned characteristics of the payment system based on the blockchain are significant. Author selected for the research the transaction price in the blockchain.

Without understanding factors, which influence the formation of this price within blockchain, it is impossible to take definitive decision about the usage of the Blockchain as the financial payment system.

Literature review and the problem statement. The research problem is obvious – the is no any research material, which factors or events influence the price of the transaction in blockchain. Now Central Banks all around the globe are interested in usage of the blockchain for their programs (Zhang & Huang, 2021) and therefore understanding of the transaction price forming principles within the blockchain is crucial, since it will allow to take appropriate decisions regarding how the blockchain should be used within this projects and which type of the blockchain is better for one or another project.

Research methodology, which was used by author within this research is econometrics methods based on the real Bitcoin blockchain data collected within the one calendar year daily. The theoretical framework for the research was developed to in this research by the author based on the Blockchain technical documentation and available blockchain data.

Bitcoin and other crypto assets have become the most visible signs of the digitalization of financial services.

What is Bitcoin? Simplifying a complex scientific and mathematical model, Bitcoin can be presented as a large crossword puzzle. Where in certain blocks the numbers are connected and form the same amount. Moreover, the size of this "matrix" is so large that only a special program that uses impressive computer resources can calculate such a "crossword puzzle". So, Bitcoin is one solved "crossword puzzle". At the same time, there is a condition that some blocks in each next Bitcoin cannot be repeated with any of the previously issued ones. Taking this condition into account, mathematically, it turned out that the number of Bitcoin that can be issued is limited to 21 million bitcoins. More than 21,000,000 bitcoins cannot be issued due to a mathematical limitation.(Casino, Dasaklis, & Patsakis, 2019)

The creation of just one Bitcoin would be a very interesting invention, but if it ended there, it would not have had such affect to changing the model of how financial services work, since it would remain an interesting hypothesis among cryptographers and mathematicians.

The author of Bitcoin decided not only solve the cryptographic task of creating Bitcoin, but also to provide the possibility of settlements, i.e. moving Bitcoin from a buyer to a seller of a product or service.

The author considers it necessary to formulate why the ability to move Bitcoin from buyer to seller was a task for which the creator of Bitcoin needed to find a solution.

In the early 21st century, finance and payments were dominated by technology from the late 20th century, when a financial transaction still required the use of a bank's payment promise system.

The author considers it necessary to note one important aspect of "traditional" payment systems - the formation of the payment price. The payment price was influenced by the costs associated with it, and since the demand for payments is not elastic, the cost of payments was usually formed by commercial banks at the expense of the sum of all payment costs + the Bank's margin. If

the payment went through a chain of banks, then each bank in the chain took its own commission for processing it. Thus, the payment price became quite impressive.

Let's highlight the following problems of payment systems that existed in 2007, which became prerequisites for the development of a new payment system based on bitcoin:

- The speed of payments was measured in days
- The passage of the payment was not a transparent procedure, and even the sender Bank itself did not understand at what stage and where the payment initiated by it is now, which has a direct impact:
  - The accuracy of the information about the payment (whether it was made or not)
  - On the reliability of information about the amount received, since the payment went through the chain by the bank and due to the commission charged, the amount that the client received could differ from the amount sent by the sender.
- High cost of payment, which did not depend in any way on the amount of the transfer
- In case it was necessary to make a transatlantic translation, there was always a problem with a time difference - which undoubtedly lengthened the speed of passage for such transfers.

Considering the above, the Bitcoin author (s) decided to create a decentralized automated payment system in order to be able to pay with Bitcoin. This system was called blockchain.

The name was formed from two English words - block - block and chain - chain (chain), that is, it meant - a chain of blocks. The invention consisted in the fact that each operation (with parameters, sender, recipient, links to a specific Bitcoin and an indication of its part (for example, cents are part of Euro)) as a block in a worldwide network, where this block was inextricably linked with other blocks in the network. This relationship is supported by complex mathematical tests. Accordingly, when, for example, one person sends some part of Bitcoin to another person, it simply adds a new block to the general list of other blocks.(Hashimy, Treiblmaier, & Jain, 2021)

The Blockchain system is built as a decentralized system. In the event that settlements are made through one center - as, for example, in the case of payments through the Central Bank - such a system was called centralized. Accordingly, if there is no such center, then the system is called decentralized. In practice, this means that there is not one, but several transaction processing centers - and anyone can become such a center. For the operation of the center - which is called - Node (Node), it is necessary that it keeps a complete copy of all blocks (transactions) that have ever passed through the blockchain system. Thus, distributed storage of this data is achieved - and even if several Nodes cease to exist for any reason, the blocks will not disappear from the network, since they are all in any other existing Node.

Accordingly, any user can see any operation in the Blockchain at any time, thereby achieving transparency. And decentralization avoids the influence of any Node owner on pricing or monopolization of the system.

Now, in order to understand how Bitcoin travels anonymously across the Blockchain network, it is necessary to consider how it is stored. As an author already considered earlier - Bitcoin is essentially a solved mathematical problem (crossword puzzle) that exists in electronic form. Accordingly, Bitcoin must be stored electronically. To store it, you need a special program - which is called a wallet (Wallet). These wallets can be located, for example, on removable media - and then such a wallet is called cold. I mean, not that it does not heat up, but that such bitcoin cannot be quickly used for payment or other operation. If the wallet is online or installed on a mobile phone or computer, which wallet is called hot. Wallets are distinguished by their unique numbers - also called - addresses.

Now, it is necessary to describe one more postulate that the Bitcoin author (s) defined for himself - about anonymity. The anonymity of operations is determined by the list of data located in

the block. For this, the author (s) of the Blockchain offered to identify the sender and it turns out that only their wallet numbers are indicated in the block.

Thus, by analyzing the information in the Blockchain, it is possible to accurately trace the path of bitcoin from its origin and further along the entire chain of its use, while all we will know is from which wallet the bitcoin was transferred.

There is another aspect that the author not yet touched upon, but it is important for further description. The accuracy of bitcoin is 10-8, which means that the amounts in bitcoin are 8 characters after the decimal point. If several well-established names for parts of bitcoin - 1/1000 bitcoin - are usually called - millibitcoin. The smallest part - 1 / 100,000,000 - is called satoshi in honor of the creator. Although, it should be noted that the author (s) in his document, published in 2007, called them - cents.(G. Wang, Zhang, Yu, & Ning, 2021).

To send Bitcoin, you need to have a wallet (Wallet) with some amount of Bitcoin placed on it.

Next, you need to ask the recipient for his address for transferring bitcoin. If the recipient is not far away and his Wallet supports the formation of a QR code, then it can be read and thus further it will be necessary to indicate the transfer amount. If the QR code is not available, then you must enter the full address (a long string of characters).

It should be noted here that the transaction is subject to a fee for transferring Bitcoin in the Blockchain system, which is paid by the sender. The amount of commission varies and depends on many factors. The sender must agree to the calculated commission before submitting the payment.

After confirmation of the payment, it enters the blockchain system and cannot be canceled or modified further. This is a significant difference from existing payment systems, where the sender has the opportunity to request a cancellation or change in the payment.

Blockchain Payment Fee

The author in this manuscript sets himself the goal of identifying the factors that affect the price of a transaction to transfer Bitcoin within Blockchain. In order to start analyzing the factors affecting the transaction price, it is necessary to understand how the transaction proceeds and determine the factors potentially affecting the pricing of the transaction fee, which will be then checked for their influence to the transaction fee.

Above, the author has already mentioned that Blockchain consists of blocks. A block is a software structure that contains a number of transactions. These blocks are combined into chains - which, in fact, is the blockchain. In order to avoid possible falsification of blocks, an electronic signature is calculated for each block - a hash (J. Wang et al., 2019), using cryptographic signature methods. To calculate the electronic signature of a block, information from transactions contained in it, electronic signatures of the previous block is used. Since the calculation of electronic signatures of blocks occurs in parallel by various participants in the system, the system can branch, i.e. the same block can be specified as the previous one in the calculation of electronic signatures (hash).

The process of calculating electronic signatures of blocks is carried out on computer facilities - miners. Which can be represented by individuals, legal entities or groups, including both individuals and legal entities.

Usually, it is the miners who keep the entire copy of the blockchain at their facilities, which form the processing node - Node. The mining process also allows new bitcoins to be calculated within a new block (receiving them for each verified block). But for this work, that part of their work, which is associated with the inclusion of transactions in a block and the formation of a block signature - a hash, is subject to research.

Since miners process all transactions for moving bitcoins on the blockchain, they are provided with a reward for this work - which forms the transaction fee. Thus, the miners are the recipients of the transaction fee on the blockchain, collecting payment for the transactions that they confirm.

In accordance with the protocol developed by the creators of the blockchain - transaction fees are calculated in the smallest parts of bitcoin - satoshi.

The commission is calculated as the number of satoshi per 1 byte of the transaction. In this case, the transaction must be translated into bytes. (Kochergin & Yangirova, 2019)

According to the official protocol description (Piotr Narewski, 2016), a Bitcoin transaction consists of:

- Version (4 Bytes)
- TxIn Count (1 ~ 9B)
- For each TxIn:
    - Outpoint (36B)
    - Script Length (1 ~ 9B)
    - ScriptSig (?)
    - Sequence (4B)
- TxOut Count (1 ~ 9B)
- For each TxOut:
    - Value (8B)
    - Script Length (1 ~ 9B) *
    - Script (?) *
- LockTime (4B)

Assuming a standard P2SH / P2PKH transaction is generated, the Script Length marked with an asterisk will be 1 byte since it is encoded as a variable integer; while the size of the Script marked with an asterisk will be 24 bytes since it will only contain the hash of the Script (s).

Thus, the author believes that the maximum size of each output (TxOut) is 34 bytes if the payment is made to the P2SH / P2PKH address, since there are 4 opcodes in each output script.

Assuming P2PKH outputs are used as inputs (TxIn), the ScriptSig (consisting of a 72-byte DER-encoded transaction signature + a 33-byte public key) will be 146 bytes in size, and the script will only be 1 byte in length, since ScriptSig size is less than 0xFD.

Considering the above, the following formula is used to translate a transaction into bytes:

$$Bytes = 146 * \text{количество входов} + 33 * \text{количество выходов} + 10$$

Since the blockchain system does not store the current balance for each user's wallet, but stores all transactions on it, then if the wallet user transfers 1.5 bitcoins, which he received by 5 transactions, for example: 0.2 + 0.3 + 0.1 + 0.1 + 1.4, then the number of entries for this transaction will be 5. Moreover, since these transactions can be sent in the same way as they were received, then to send 1.5 bitcoins, you will need to send all 5 and get back the "change" as the difference between these 5 transactions and the amount sent. For this example, change is = 0.2 + 0.3 + 0.1 + 0.1 + 1.4 - 1.5 = 0.6

Accordingly, in the above example, the number of outputs will be 6 (number of inputs + change)

Thus, if the user then wants to send 0.6 bitcoin after that, then the incoming transaction will be - 1 (the one that he received as change) and the outgoing transaction will also be one, since there is no change on it (the user sent everything he received).

The first stage of the transaction is validation checking - compliance with payment parameters and transaction standards. Nodes - the computers that produce the blocks check the entire history of the bitcoin transactions of the bitcoin sender. After the transaction is recognized as valid, it is included in the mempool, that is, in the queue for transactions and waits for its miner - the user, and packs it into a block. At this time, the transaction is not yet considered complete. The signal to conduct a transaction is sent only when the miner packs the transaction into a block. And the packing speed depends on the size of the commission, since the miner can and processes transactions with a higher commission faster than with a lower one. This means that miners from

the mempool choose transactions with a higher commission first, and then with a lower commission.

The second stage of the transaction is packing the transaction into a block. Transactions are combined into single blocks and checked every 10 minutes, using a mining operation. Until the transaction is included in the block, the system considers that the amount of bitcoins at a certain address remains unchanged. At this time, it is technically possible to execute several different transactions for the transfer of the same bitcoins from one address to different recipients. But as soon as one of such transactions is included in the block, the system will already ignore the rest of the transactions with the same bitcoins. For example, if a later transaction is included in the block, the earlier one will be considered erroneous. There is a small chance that during a fork, two such transactions will end up in blocks of different branches. Each of them will be considered correct, only when the branch dies out, one of the transactions will be considered erroneous. In this case, the time of the operation will not matter.

The third stage of the transaction is confirmation. A transaction entering a block is a confirmation of its authenticity, regardless of the presence of other transactions with the same bitcoins. Each new block is considered an additional "confirmation" of transactions from the previous blocks. If there are 3 blocks in the chain, then transactions from the last block will be confirmed 1 time, and those placed in the first block will have 3 confirmations. It is enough to wait for several confirmations to make the probability of the transaction canceled very low.

Factors affecting the commission

Based on the above, the author believes that the transaction fee is formed by market principles. But also based on the above, the author puts forward the following hypotheses on the presence of factors affecting the transaction fee:

- Since miners have the ability to choose transactions with a higher commission - hypothesis - the commission depends on the network load, which is clearly manifested by the size of the mempool.
- Hypothesis - the commission depends on the amount of all transactions in bitcoin per day
- Hypothesis - the commission depends on the number of transactions per day
- Hypothesis - the commission depends on the volume of exchange trading. Bitcoin trading volume shows how many bitcoins are bought and sold on specific exchanges. High trading volumes are likely to drive more activity on the network, such as when people deposit and withdraw funds.
- Hypothesis - the commission depends on the density of transactions in the block, since the greater the demand for transactions, the block density will increase

For calculations, the data published on the website are used. https://www.blockchain.com/charts#currency... For the analysis, a sample by days was used for the period from 09/04/2020 to 08/04/21 - a total of 364 observations for each factor corresponding to the hypotheses put forward above.

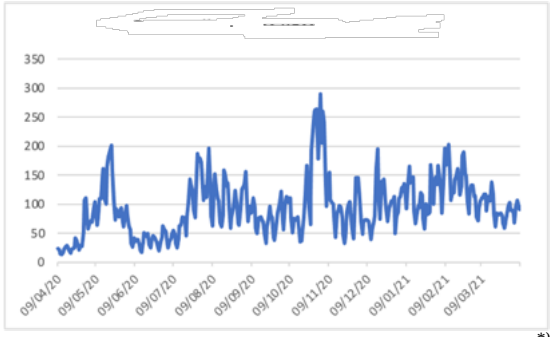


Diagram 1. Gross volume of commission in BTC *)

*) Diagram prepared by author

Diagram 1 shows the total commission for all Bitcoin transactions on the blockchain network. This information is presented on the blockchain.info website as an aggregation of data from the open blockchain. In order to be able to analyze the factors affecting the formation of this commission, it is necessary to exclude the influence of the volume of transactions on this data. To do this, using the formula for converting transactions to bytes, we calculate the commission rate by day (for a selected period of time) to one transaction byte:

$$x = \frac{\text{К} * 100000000}{\frac{Q}{Tb} * \text{Smb} * 1024 * 1024}$$

*) Equation developed by author

Where,
x - Commission in satoshi for 1 byte of the transaction
K - commission for each day of the sample
Q - the number of transactions per sample day
Tb - Transactions for 1 block
Smb - One block average size in Mb

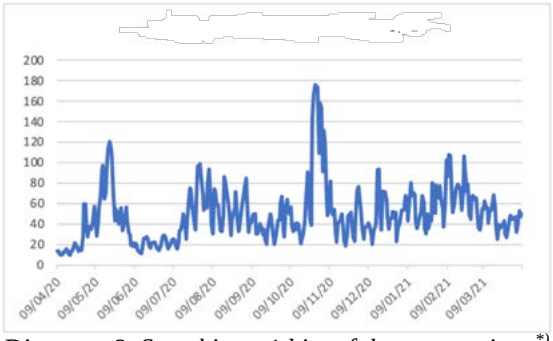


Diagram 2. Satoshi per 1 bite of the transaction *)

*) Diagram prepared by author

This calculated distribution of the commission per 1 byte in the selected period is the initial one for the correlation analysis and forms a list of Y values.

To test the hypotheses put forward by the author, a correlation analysis will be carried out according to several factors available for analysis on the Internet page - blockchain.com

- X1 - The size of the mempool (a list of transactions waiting to be packed into a block) - on the site metric - The number of Mempool transactions
- X2 - The sum of all transactions in bitcoin per day - on the site metric - Estimated transaction value (BTC)
- X3 - Number of transactions per day - on the site metric - Confirmed transactions per day
- X4 - Exchange trade volume - on the website metric - Exchange trade volume (USD)
- X5 - Density of transactions in the block - on the site metric - Average number of transactions per block

Table 1

The result of the correlation analysis is as follows: *)

	Y	*X1*	*X2*	*X3*	*X4*	*X5*
Y	1					
	0.74					
X1	252286	1				
	0.32	0.10				
X2	335907	752539	1			
	0.11	0.04	0.55			
X3	201232	167782	571392	1		
	0.31	0.26	0.42	0.29		
X4	57009	292614	783941	373679	1	
	0.59	0.41	0.50	0.51	0.28	
X5	259282	674559	600893	247329	73907	1

*) Correlation analysis prepared by Author

As can be seen from the results of the correlation analysis r for X2 and X4 = 0.32 and for X3 = 0.11, respectively, the correlation of X2, X3, X4 with Y is weak and the hypotheses that the formation of the transaction fee is influenced by:

- The sum of all transactions in bitcoin per day
- Number of transactions per day
- Exchange trading volume

are not confirmed.

In turn, r for X1 = 0.74, which indicates that the size of the mempool significantly affects the size of the commission.

And for X5 = 0.59 which means that the value of the commission also depends to some extent on the density of transactions in the block

Accordingly, further regression analysis will be carried out between Y, X1 and X5

Regression analysis

Table 2

Regression statistics *)

	Parameters
	0.805
Multiple R	23271
	0.648
R-square	39971
Normalized R-	0.646
square	45179
	16.66
Standard error	10037
Observations	364

*) The regression analysis was performed by Author using the EXCEL software product using two factors.

As follows from the calculated regression statistics, the calculated correlation coefficient is 0.81, which indicates a significant correlation between the commission for transferring Bitcoin on the blockchain network by the two selected factors: the average number of transactions in the mempool waiting to be processed and the average number of transactions “packed” into one block.

The calculated coefficient of determination of 0.65 indicates an acceptable accuracy of the approximation.

Table 3

ANOVA *)

	df	*SS*	*MS*	*F*	*Significance of F*
Regression		18480 0.49	9240 0.2448	332. 867046	1.1531 E-82
Remainder	61	10020 9,645	277. 589043		
Total	63	285,0 10,134			

*) Regression analysis prepared by Author

Calculated Fisher's test (F) = 332.87

For α = 0.05, in accordance with the tables (the number of degrees of freedom v1 = 2 (two factors) with the number of degrees of freedom v2 = 1) the boundary value of the Fisher criterion = 200. Since the calculated value is greater than the boundary value, the calculated regression equation is acceptable.

Table 4

	Odds	*Standard error*	*t-statistics*	*P-Value*	*Bottom 95%*	*Top 95%*	*Bottom 95.0%*	*Top 95.0%*
Y-intersection	-60.740249	8.65453052	-7.0183182	1.1176E-11	-77.759877	-43.720621	-77.759877	-43.720621
X1	0.04222717	0.0042335	9.97453479	7.4121E-21	0.03390176	0.05055259	0.03390176	0.05055259
X5	0.00070567	4.0398E-05	17.4678708	5,876E-50	0.00062623	0.00078512	0.00062623	0.00078512

Regression equation

$$Y = -60{,}740249 + 0{,}04222717 * X1 + 0{,}00070567 * X5.$$

*) Equation developed by author

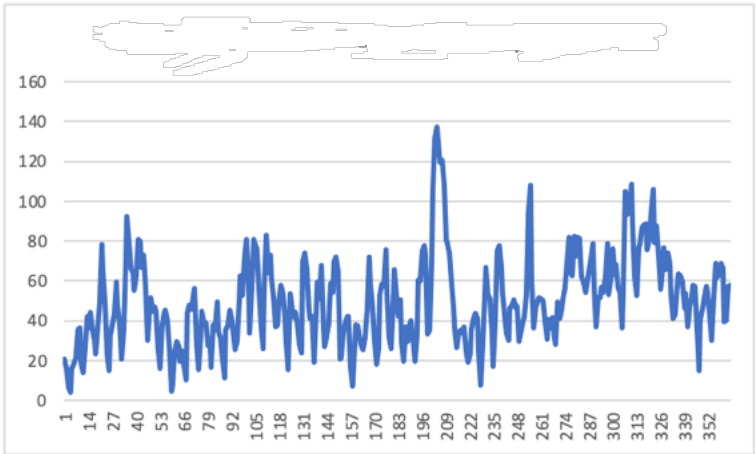


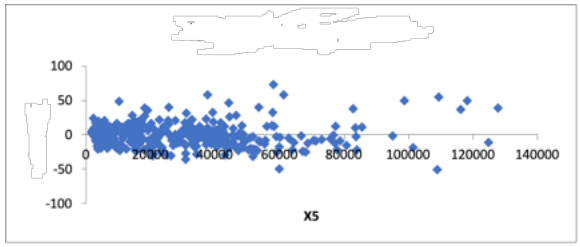
Diagram 3. Satoshi per 1 bite of the transaction based on regression equation[*)]

*) Diagram prepared by author

Comparing Diagram 3 and Diagram 2, author conclude that both diagrams are very similar, that additionally shows that developed regression equation reflects the real processes of the transaction commission forming.

Table 5

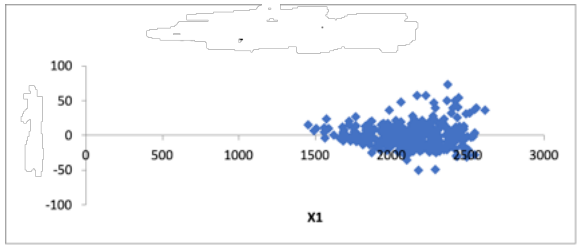
X5 Residual graph*)



**) Diagram prepared by author*

Table 6

X1 Residual graph*)



**) Diagram prepared by author*

Plotting residuals further indicates that there is no cross-correlation between factors.

Research results. In the result of the research, analyzing the Blockchain data, was found that the strong and confirmed by Econometrics regression method correlation between transaction price in the Bitcoin blockchain and two metrics of the blockchain:

- The size of the mempool
- Density of transactions in the block

Which allow to form the regression equation between these two parameters and transaction price in the Blockchain.

Conclusion. As follows from the above analysis, the commission for moving bitcoin via the blockchain depends on the average number of transactions in the mempool and the average number of transactions in the block.

The above factors are directly related to the number of miners connected to the network. Since the more miners in the network, the less the number of transactions in the mempool, since they would be quickly sorted out by the miners for processing. The average number of transactions in a block says the same thing.

Accordingly, only the number of miners affects the amount of the commission, and other market factors do not affect the commission.

Considering the above, as well as the fact that the complexity of the calculations is constantly increasing and crypto miners market is in the turbulence(Ramos, Pianese, Leach, & Oliveras, 2021) , there is a possibility that the number of miners will decrease, in view of the decrease in the profitability of this activity. With a decrease in the number of miners, the number of transactions in the mempool will increase and, accordingly, the transaction fee will increase. Since the commission is not related to either the volume of transactions or the volume of large transactions (as it was revealed in the framework of the correlation analysis), the profitability of using Blockchain will be less than that of traditional payment systems.

The lack of a direct connection between the commission in the blockchain and market factors, such as the number of transactions, their average amount and the volume of transactions,

suggests that in the current implementation of charging a commission when it is carried out in the blockchain, this technology is far behind the existing payment systems. This will be a prerequisite for the fact that transactions with crypto assets will be concentrated within one organization without displaying transactions in the Blockchain - for example, processing transactions with crypto assets within the framework of crypto exchange exchanges without displaying these transactions in the blockchain.

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Стаття надійшла до редакції 10 .12.2021
Статтю рекомендовано до друку 22.12.2021

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The article was received by the editors 10 .12.2021
The article is recommended for printing 22.12.2021

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АНАЛІЗ ЧИННИКІВ, ЩО ВПЛИВАЮТЬ НА ФОРМУВАННЯ ЦІНИ ТРАНЗАКЦІЇ В БЛОКЧЕЙНУ

Анотація. Блокчейн, як інструмент, був винайдений разом з біткойном і розвивається. Незважаючи на те, що з'явилися нові блокчейни, як Ethereum та інші, перший був недостатньо вивчений з точки зору розуміння залежностей між його елементами. Математичні та криптографічні залежності добре описані в науковій літературі, але дослідження та опис залежностей щодо їх економічного використання все ще відсутні.

Структура та механіка блокчейну передбачають, що транзакції, зареєстровані в блокчейні, не є безкоштовними для кінцевого користувача. Ціна транзакції в блокчейні існує. Ця ціна транзакції може бути визначальною для реалізації проекту з використанням блокчейну. Розуміння факторів, які впливають на це ціноутворення, допомагає зрозуміти фрейми, коли використання блокчейну є ефективним.

Враховуючи все вищезазначене, однією з цілей даної статті є аналіз життєвого циклу транзакцій у блокчейні та визначення факторів, які суттєво впливають на формування ціни транзакції в блокчейні Bitcoin.

З іншого боку, блокчейн вважається конкурентом або навіть «вбивцею» традиційних платіжних систем. Існує перелік елементів, які слід враховувати, порівнюючи обидва підходи до виконання транзакції. Цей список включає порівняння недоліків і переваг обох систем, наприклад, проблеми безпеки, проблеми зі швидкістю транзакцій тощо. З цієї точки зору на основі порівняння формування ціни транзакцій в обох системах автор оцінює перспективи використання транзакцій у Blockchain у порівнянні з традиційними платіжними системами.

Ключові слова: *електронні гроші, криптоактиви, розподілена книга, токени, монети, криптовалюти, фіатні гроші.*

Формул: 3; рис.: 5, табл.: 4, бібл.: 10.