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TECHNOLOGICAL ASPECTS AND ENVIRONMENTAL CONSEQUENCES OF MINING ENCRYPTION

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Introduction. The digital economy has significantly changed not only the types, forms and mechanism of payments, but also the form of money itself. Electronic money is becoming more popular, which increases the relevance and importance of the study of technical aspects and environmental consequences of mining encryption. The choice of equipment for cryptocurrency mining and its impact on the environment remains a rather debatable issue. It is also not clear how to calculate the costs of mining cryptocurrencies in order to determine the cost of such coins which creates obstacles to the normal reflection in the accounting of such activities in the future and the payment of the corresponding taxes on such operations where cryptocurrencies are involved.

Aim and tasks. The study aims is to investigate modern approaches to cryptocurrency mining and the characteristics of the mining process itself, as well as the selection of the main equipment and a list of costs to ensure this activity takes into account the environmental consequences of mining encryption.

Results. Cryptocurrency mining is the process of creating digital currencies. All transactions in the network are not processed by any central authority, but by any user connected to the network. The creation of cryptocurrency, i.e. its emission, is the acquisition of certain property rights. Determining the cost of mining, for example, one bitcoin depends on the amount of resources spent: the depreciation of the equipment that was used to generate new blockchain blocks and the monthly costs of its maintenance, the cost of high-speed Internet service, the configuration of the mining software product on a particular pool, combined electricity costs.

Conclusions. The development of the cryptocurrency market has both positive and negative consequences at the micro and macro levels. Advantages include independence from the state-regulated banking system and general accessibility; high economic efficiency of mining; transparency of transactions, confidentiality and anonymity, security of data owners; high data security against external influences and attacks; absence of time or territorial restrictions; general availability and lack of need to create centralized data repositories; effective mechanism against theft, counterfeiting and inflation, irreversible nature of transactions. At the macro level, the advantages are the high capitalization of cryptocurrencies, which can contribute to meeting the financial needs of the state as a whole and independence from the state. Therefore, further accounting of such a specific asset as cryptocurrency requires detailed research.

Keywords: cryptocurrencies, digital assets, green mining, electronic money.

1. Introduction.

The development of social and economic processes prompts the search for an ideal means of payment and measure of value, which directly affects the evolution of the monetary system and the search for new forms of currency. The rapid growth of the amount of information in the implementation of the operational process, the presence of information technologies in all spheres of life (in particular, the activities of the national school of cybernetics; the development of informatization concepts and programs; the creation of information and communication technologies and state-wide electronic information and analytical systems for various levels of management), the emergence of new information products and services, which are signs of the information society, caused a new round of development of the economy, which was called the digital economy. All modern processes take place in an electronic environment, which leads to the emergence of new approaches to the digital economy in terms of technological aspects and the impact of the consequences of cryptocurrency mining on the sustainable development of the economy. One of the main criteria is the environmental consequences for society and the disposal of information waste which is formed in the process of human activity or is the result of electronic and computing technology (Mushkudiani et al., 2020). Understanding the main principles and trends that exist behind the modern digital revolution helps to use the existing achievements of the IT sphere for the benefit of society.

The digital economy has significantly changed not only the types, forms and mechanism of payments, but also the form of money itself. The first ideas of creating virtual currencies (cryptocurrencies), the functioning of which depends on the level of science and the method of developing information encryption, that is cryptography, arose in the late 90s of the XX century. In the early 2000s, electronic money became more and more popular, which, according to the definition of the latest version of the Directive of the European Parliament and the Council 2009/110/EU, "means a monetary value stored in an electronic, including magnetic, form as a claim to the issuer, that is issued after receipt of funds for payment transactions, as defined in paragraph 5 of Article 4 of Directive 2007/64/EC, and that it is accepted by a natural or legal person other than the issuer of electronic money" (EUR-Lex, 2007; 2009). Thus, with the advent of electronic money, money as such loses its tangible form and changes to an information resource, becoming a virtual reality created with the help of technological means. In response to objective technological processes, in 2013 the Cabinet of Ministers of Ukraine approved the Strategy for the Development of the Information Society in Ukraine (Verkhovna Rada of Ukraine, 2013), which, in particular, provides an interpretation of the terms "electronic economy", "electronic commerce", "information infrastructure", etc., and on June 30, 2021, the Law "On Payment Services" (Verkhovna Rada of Ukraine, 2021) was adopted, which, in particular, "determines the general principles of the functioning of payment systems in Ukraine, the general principles of issuing and using electronic money and digital money of the National Bank of Ukraine in Ukraine".

Thus, there is a need to study the main technological approaches and environmental consequences during cryptocurrency mining as mining is a process of creating new coins, which consumes a significant amount of resources.

2. Literature review.

Blockchain technology and the principles of its use in simplifying society's life were studied as the possibilities of blockchain technology are almost limitless (Kumar and Mallick, 2018). This technology can be used in the energy industry to regulate demand in the electricity market; in voting for candidates and selecting them for power; analysis of ecological factors affecting the environment from human activity; search and decision-making in conditions of uncertainty, etc. Bitcoin cryptocurrency mining was studied, as it has high profitability.

At the same time, mining consumes a large amount of electricity, which significantly affects carbon dioxide emissions into the environment (Hajiaghapour-Moghimi et al., 2022). As a result, it is necessary to find new approaches to mining that are more environmentally friendly, taking into account the mining process and the conditions that encourage individuals and legal entities to engage in this activity. The relationship between the mining process, the increase in the network hashrate and the amount of electricity consumed was established (Erdogan et al., 2022). The potential bidirectional relationship between the price of cryptocurrency and electricity consumption remains unknown. In this regard, it is important to consider the economic and legal regulation of operations with cryptocurrencies as an integral part of digital assets (Vandezande, 2017).

It also states a critical problem regarding accounting and taxation of transactions with cryptocurrencies in Ukraine in the conditions of digital information space. The lack of a unified interpretation of the legal status of cryptocurrency caused ambiguity in the classification of this type of asset (Fostolovych, 2018).

3. Methodology.

During the conducted research, various methods of scientific knowledge of the given problem were used. The observation method was used to generalize the results of the assessment of the impact of mining equipment on the environmental component. The application of the system approach allowed to substantiate the calculation costs for carrying out such activities with a division into main components.

The structuring of the process of creating new crypto coins is based on blockchain technology on the one hand and existing equipment on the other. Since the technology of mining crypto-coins depends on the available equipment, which in turn specifies and sets which coins can be created on which equipment.

Examining the existing review results allowed us to determine the scope of the problem and raise previously unresolved issues, which was the impetus for this study.

4. Results.

For a better understanding of the creation of such an accounting object as cryptocurrency, it is advisable to analyze the mining process with the selection of certain cost calculation items and consider the main stages from which the activity of economic entities at the cryptocurrency market is formed. Obtaining digital assets (cryptocoins) is a long and costly process. Taking into account the cost of the equipment and the mining technology itself, as well as the approaches to such a process, it is possible to distinguish mining on special integrated circuits (Asic), mining on video cards (GPU), mining on personal computers, mining on communicators, cloud mining (virtual mining), browser mining.

Cryptocurrency mining is the process of creating digital currencies. All transactions in the network are not processed by any central authority, for example, the National Bank of Ukraine, but by any user connected to the network. The creation of cryptocurrency, i.e. its emission, is the acquisition of certain property rights.

Since there is no legally defined cryptocurrency issuer, any natural and/or legal entity whose statute provides for this type of economic activity, which becomes a "miner", can engage in its mining. According to the Green Paper "Regulation of the Cryptocurrency Market", the assessment of the mining market is extremely problematic, since the mined cryptocurrencies instantly become part of the global market and have no geographic reference (Samokhodskyi, & Shelest, 2018). At the same time, there are companies in Ukraine that offer turnkey installation of mining farms or rental of mining facilities. According to expert estimates (Back et al., 2014), as of 2018, the size of the mining segment may reach $100 million USA (Table 1).

Table 1. World economies in 2020 and Bitcoin exchange rate.

No	*No by globality in the world*	*Country*	*GDP, $ billion*	*Foreign debt, $ million*	*Exchange rate for 2020, $*
1	1	USA	20937	12000	-
2	2	China	14723	22554	6,9
3	11	India	1483	453	68,72
4	28	UAE	422	163	0,27
5	31	Argentina	383	150	141
6	55	Ukraine	155	78	26,95
7	64	Cuba	103	80	24,2
8	72	Luxembourg	73	45	1,01
9	82	Lithuania	56	29	9,6
10	90	Azerbaijan	43	22	14,4

01/17/2020 exchange rate 1 bitcoin (BTC) = $7,200;
05/06/2020 rate of 1 bitcoin (BTC) = $8,800;
09/05/2020 Bitcoin (BTC) rate = $12,170;

Source: developed by the author based on (Back et al., 2014; Fostolovych, 2018).

In 2017, a new approach to cryptocurrency mining appeared and gained quite intense momentum: cloud mining. Its activity is based on the rental of equipment in the virtual space. That is, for mining, one needs to go to the site of the lessor, pay a certain amount for the capacity of the equipment (terahash), determine the term of the lease, and then start the process of mining a specific coin (Park, & Park, 2017).

The first method consists in servicing the equipment, setting up and connecting to the Internet network is undertaken by the company that provides this service.

In most cases, the lessee can choose the cryptocurrency to mine and the mining pool to join.

Cloud mining can take the form of: renting a physical farm; renting a virtual farm (can be part of a large physical farm); rental of computing power (can be located on several physical farms).The second method is to rent the capacities of Thesh – virtual mining devices on the Internet for a certain amount to cover the costs that exist in the first method. Leasing the corresponding capacities somewhat reduces the initial capital investment of miners, however, taking into account the long-term perspective, it requires additional analysis (Park, & Park, 2017).

Below, the study will consider the costs that arise in the process of cryptocurrency mining, using the example of the most common ASIC technology in the world (Fig. 1).

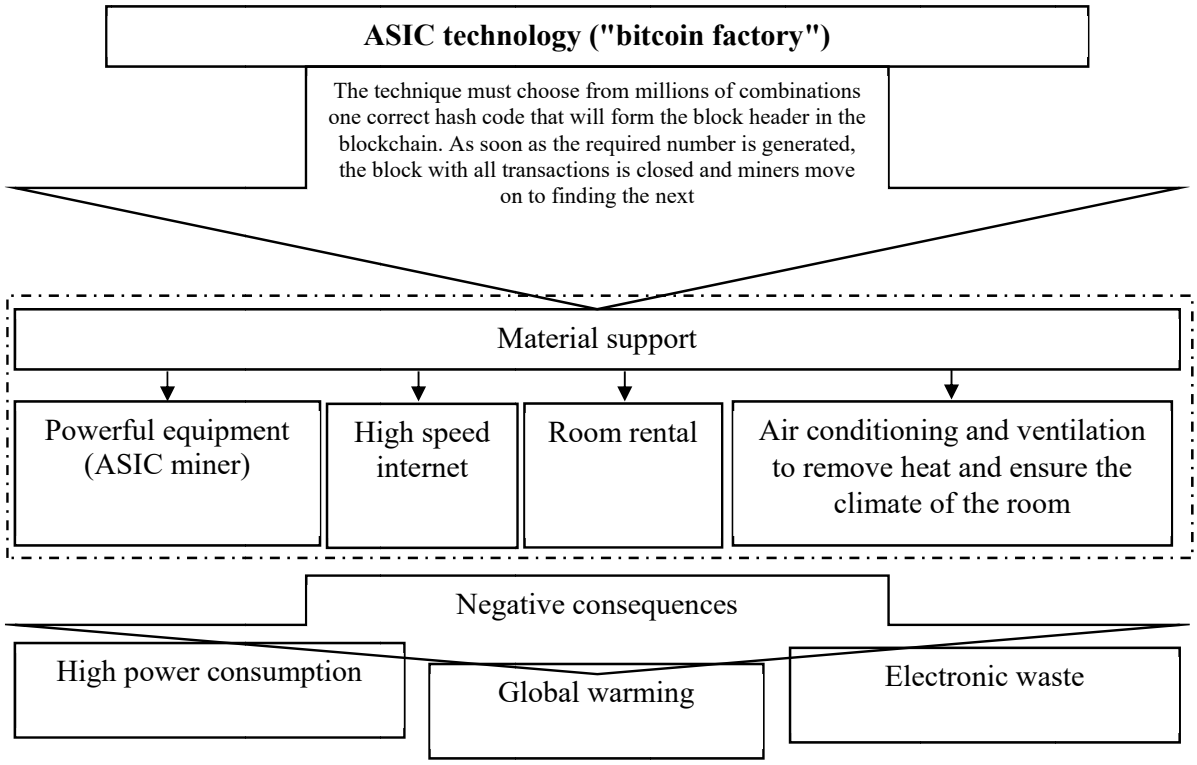

Fig. 1. Expenses incurred in the process of cryptocurrency mining.

As it can be seen from Figure 1, in addition to determining the relevant accounting objects, as well as the subsequent control and taxation of such operations, it is worth considering the significant costs accompanying the mining of cryptocurrencies.

Figure 2 and Figure 3 show the results of a study by the University of Cambridge, which testify the annual increase in electricity consumption during bitcoin mining.

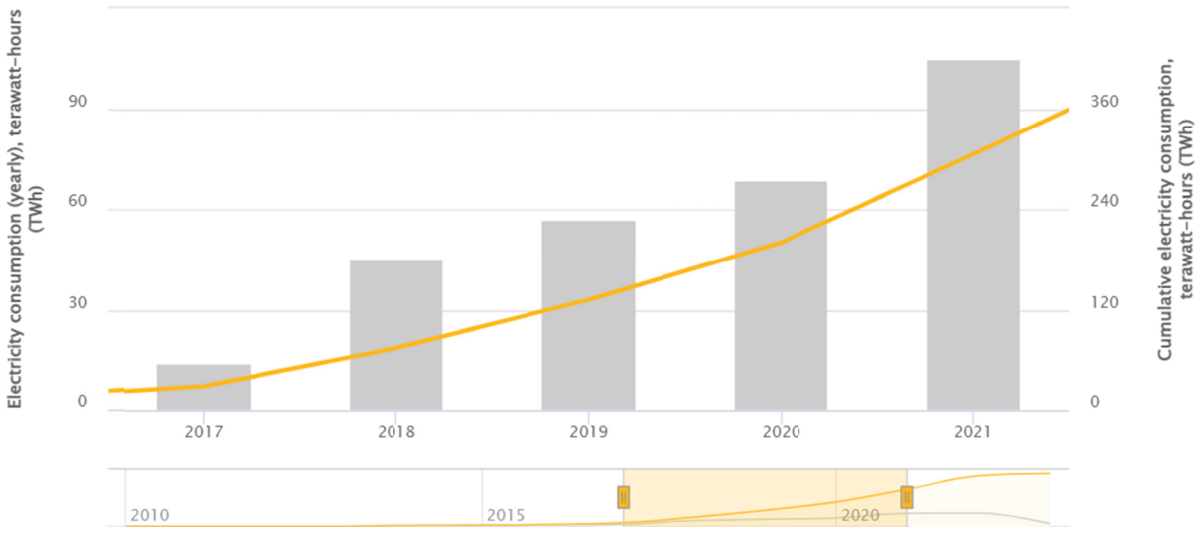

Fig. 2. Total electricity consumption during Bitcoin mining during 2017–2021.
Source: based on Samokhodskyi and Shelest (2018).

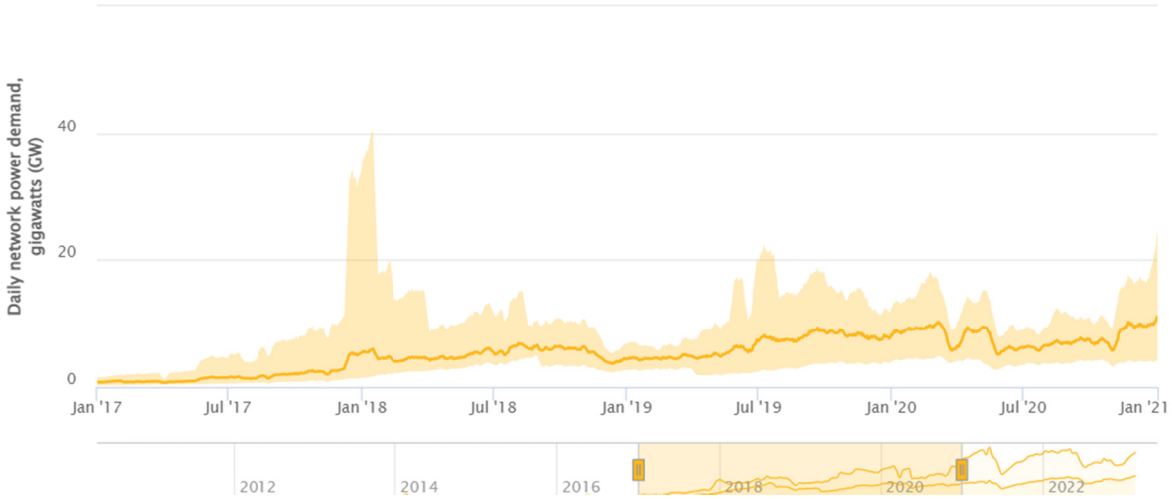

Fig. 3. Daily demand for electrical power during Bitcoin mining during 2017–2021.
Source: based on Regulation of Bitcoin in Selected Jurisdictions (2014).

As it can be seen from Figure 2, in 2021 Bitcoin production alone consumed about 104.89 TWh of electricity, while in 2020 it was 68.52 TWh, showing 153% increase in consumption in one year (Burnie et al., 2018). which exceeds the combined electricity consumption of countries such as Pakistan and the Philippines.

Thus, determining the cost of mining, for example, one bitcoin depends on the amount of resources spent. For example, depreciation of the equipment that was used to generate new blockchain blocks and the monthly costs of its maintenance, the cost of maintaining high-speed Internet, setting up a mining software product on a certain pool, total electricity costs (this item of costs is quite significant and requires special control, including conducting an energy audit, since miners often try to reduce electricity costs by stealing it), the amount of compensation for mining participants (the assessment of this cost item is complicated by the fact that miners receive compensation not only during the mining process, but also during confirmation of cryptocurrency transfer operations from one wallet to another or conversion of one cryptocurrency to another, when withdrawing it into fiat money), etc.

In addition, Figure 1 shows significant negative environmental consequences in the form of electronic waste, which requires finding ways to reduce it, which, accordingly, also requires additional costs, that is proven in the studies of Alex de Vries, Christian Stoll (2021): one transaction in the Bitcoin network accounts for 272 g of such waste in the form of computers and other electronics, and as of May 2021, the amount of electronic waste amounted to 30.7 thousand tons. Cryptocurrency generated approximately 0.11% of the estimated global volume of e-waste in 2021, which is 57.4 million tons according to Statista data (Stevens, 2017).

And, without a doubt, the main problem is the release of excess heat, which is produced by mining equipment. According to scientists' calculations, mining can cause additional emissions of 230 billion tons of carbon into the atmosphere and increase the average temperature of the Earth by 2°C (Cambridge Bitcoin Electricity Consumption Index, 2022).

Considering the negative environmental consequences and, at the same time, the need to adjust the activities of all entities in order to achieve the goals of sustainable development declared by the UN for the period until 2030 (De Vries and Stoll, 2021), the problem of turning mining into ecomining, or "green" mining is extremely critical.

Ecomining is distinguished, in particular, by: 1) the use of renewable energy sources (wind energy (windmills); geothermal energy; solar energy (solar panels); hydropower (hydroelectric plants)) with the location of the main mining capacities in the respective regions; 2) directing the excess heat to other economic needs.

Thus, mining may well become ecological and change the focus of its influence on the ecological and social development from negative to positive due to: 1) reducing the cost of electricity due to the utilization of surplus electricity and the development of "green" methods of its generation; 2) the migration of mining to poor, but convenient for mining countries (Venezuela, Myanmar, New Zealand) may have a positive effect on the economy of such regions (dying settlements will get a new life).

As any phenomenon or process, cryptocurrency and transactions with it have some disadvantages, some of which, in particular, have been identified in the global financial report on sustainable development in 2021 at the micro and macro levels. The micro level is characterized by:

1) the vagueness of this concept and the absence of a legal framework for carrying out such transactions both in Ukraine and in foreign economic activity, which causes an ambiguous attitude to it in different countries and complicates the reflection of transactions in the accounting and taxation system;

2) anonymity is an advantage, however, if the owner of the wallet is determined, it is possible to partially determine the transaction and the addresses of other crypto wallets associated with it;

3) cyber risk (certain vulnerability to hacker attacks) and transparency risk. In particular, as early as April 2014, anti-virus companies reported an increase in viral attacks aimed at stealing bitcoins, including through fraudulent wallet.dat key files, which store transaction passwords;

4) operational risk (there is a supply limit for most cryptocurrencies).

In turn, cryptocurrency and operations with it leave the mark on the macro level, that is why the problem of cryptocurrencies is urgent for any society and country:

1. The risk of using cryptocurrency for money laundering and terrorist financing.

2. Cryptoization, capital flows and restrictions.

3. Transmission of monetary policy.

4. Disintermediation of banks and financial intermediaries.

5. Negative environmental consequences due to the use of energy-intensive processes, the consumption of a significant amount of energy, an increase in carbon emissions and an increase in the temperature of the environment, an increase in the amount of electronic waste.

The risk of using cryptocurrency has an economic and legal nature. Its essence is that the value of cryptocurrency is determined by the ratio of supply and demand for it. When investing real money in cryptocurrency, the demand for it may not increase or decrease due to its lack of popularity.

But it is also worth noting that such an economic risk must be associated with a legal one, since the state can legalize transactions with cryptocurrency, but not with all, but only with a specific one, for example, with bitcoin and its "forks". Despite this, cryptocurrency is attracting increased interest from law enforcement, tax and regulatory authorities that are trying to gain more control over such assets.

According to research, operations with cryptocurrency as part of a decentralized financial market have the following advantages compared to operations with traditional money, including electronic (Munro, 2020):

– Security, as the decentralization of the financial system helps to reduce the influence of the banking system, such as a bank with low solvency, and provides numerous guarantees.

– Higher economic efficiency, since cryptocurrency miners are various entities that independently carry out transactions with cryptocurrencies, receiving income (without spending money on high salaries of managers servicing the centralized system). In addition, continuous connections in the network of nodes and the digital nature of cryptocurrency allow significantly reducing intermediary costs and reducing service costs. There are no fees for transactions between countries. Also, as an open ecosystem, all participants are forced to compete for actual value.

– Cooperation. Blockchain is a team effort, and the construction of a network of nodes has, to some extent, a synergistic effect, and is capable of multiplying the value and benefit of each of its participants.

By introducing more collaboration paradigms through data sharing agreements and relationships with other applications, business entities can reduce the resources they spend on competition and find new mutually beneficial ways to collaborate.

However, as in any system, there are limitations in resources in digital currency, but not physical, but computer (digital), which is what limits cryptocurrencies. In 2031, the amount of emission at the creation of a block will be less than one bitcoin and will continue to tend to zero. It is assumed that the emission will stop in the year 2140, since the reward for a block cannot exceed 10-8 BTC (the smallest unit of measurement is 0.00000001 BTC and is called a «satoshi»), but long before that, commission fees will gradually become the main source of reward for the formation of new blocks for the correct hash code and the miners will receive the reward.

However, considering that as of May 12, 2021, there were 18,7 million bitcoins in circulation, it can be predicted that the bitcoin emission will end much sooner (Makurin, 2021).

The smallest unit of measurement of rate changes on cryptocurrency exchanges is 0.0001 BTC and is called pips. Therefore, when planning the course of cryptocurrencies, the change in pips is paid attention to. But when transferring cryptocurrency from one wallet to another, the entire transaction is carried out to one satoshi.

However, when carrying out transactions with cryptocurrencies, in addition to the costs of their creation (the so-called initial assessment) and process support, it is worth considering such concepts as volatility (the speed at which the price of a cryptocurrency changes) and halving – halving the miner's reward for the mined block of information.

The price of any cryptocurrency has high volatility, which can be measured as a percentage, in monetary terms or through a cross rate, and which is almost impossible to predict, which significantly affects the value of Bitcoin when buying it on the exchange. Every new bitcoin in the system erodes the value of the cryptocurrency. In order for bitcoin inflation not to be excessive, its creator S. Nakamoto laid down a halving every 210,000 blocks in the initial mechanism of the cryptocurrency, i.e. once every 4 years, until the moment when 21 million coins are produced (probably in the year 2140) and bitcoin emission will be finished. Table 2 shows the halving of bitcoin during 2012–2014, and Figure 4 shows the impact of the halving on the value of the bitcoin cryptocurrency.

Table 2. Bitcoin halvings during 2012-2014.

Year	*Block height*	*Data block reward, BTC coins*	*Price for one BTC coin, USD*
2012	210 000	25,000	15 000
2016	420 000	12,500	900
2020	630 000	6,250	52 000
2024 (plan)	840 000	3,125	Unpredicted

Source: based on Regulation of Bitcoin in Selected Jurisdictions (2014).

In addition to mining, as mentioned above, one can get cryptocurrency by purchasing it on the exchange for cash. This type of transactions is available to everyone without restrictions, but legal entities need to improve the legal framework and develop recommendations for displaying these transactions in the accounting and taxation system. These operations are gaining popularity due to the rapid decline in the value of national currency and significant restrictions on foreign currency savings for legal entities.

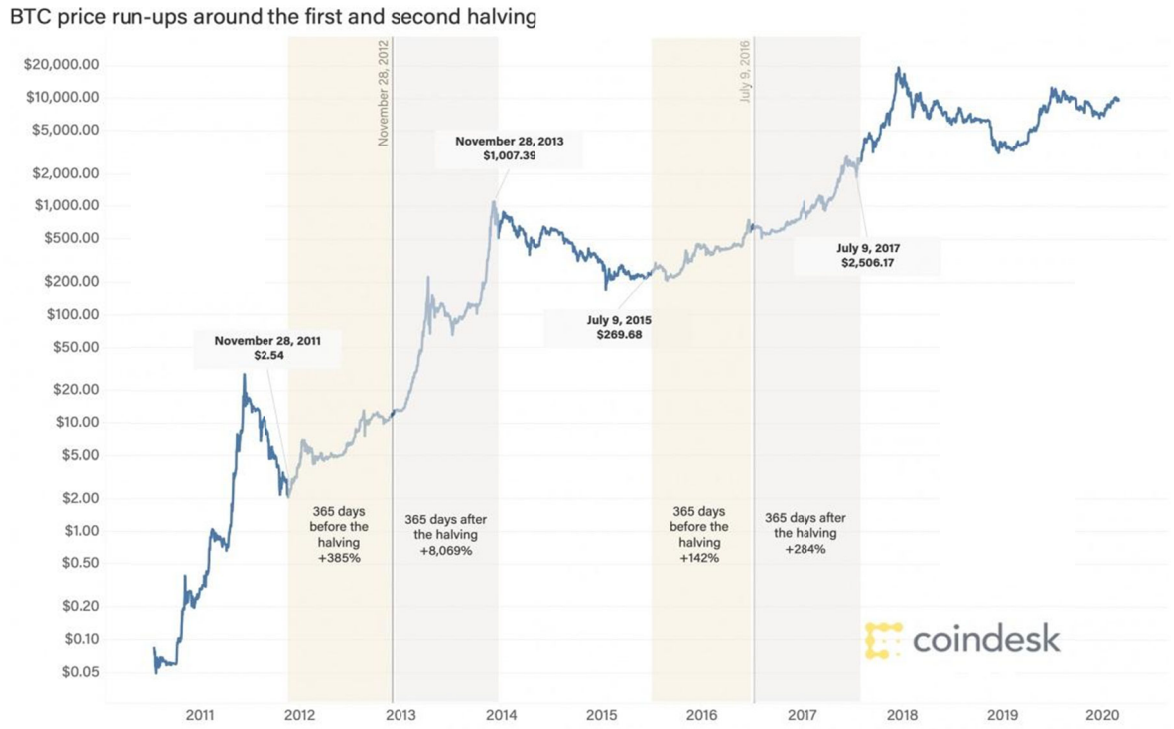

Fig. 4. The effect of halving on the value of the bitcoin cryptocurrency.

Source: based on Makurin (2021).

5. Conclusions.

The definition of the term "cryptocurrency" depends on the essence of the process of its generation. It has not been decided to include such a specific asset in the concept of money at the moment. Scientists offer their own theoretical and methodological approaches to the definition of this term, focusing their attention on the part of the word "crypto", which lays the foundations of technological functioning. There is still no consensus on the essence of digital money and the choice of an account for its record keeping, which requires further research.

Despite the rapid development of the cryptocurrency market, the concept of cryptocurrency as an accounting object has not been defined at the international and national level.

It has been proven that the recognition and evaluation of cryptocurrency as an accounting object depends on the way of obtaining it: mining (independent creation), acquisition on the stock exchange, receipt as compensation for shipped goods, performed work, rendered services.

Mining, which can be carried out both on own and leased facilities, affects the formation of costing items that determine its cost at creation, as well as operational costs associated with the need to take preventive measures or eliminate negative environmental consequences that arise with them. The development of the cryptocurrency market has both positive and negative consequences at the micro and macro levels. Advantages include independence from the state-regulated banking system and general accessibility; high economic efficiency of mining; transparency of transactions, confidentiality and anonymity, security of data owners; high data security against external influences and attacks; absence of temporal or territorial restrictions; general availability and lack of need to create centralized data repositories; effective mechanism against theft, counterfeiting and inflation, irreversible nature of transactions. At the macro level, the advantages are the high capitalization of cryptocurrencies, which can contribute to meeting the financial needs of the state as a whole and independence from the state. Therefore, further accounting of such a specific asset as cryptocurrency requires detailed research.

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