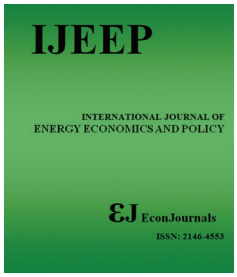

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Blockchain Infrastructure and Growth of Global Power Consumption

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ABSTRACT

The paper proposes the link between cryptocurrency implementation in the financial sector and energy consumption worldwide. The underlying mechanism of this blockchain infrastructure is described, practical cases of its adoption in various segments of the financial sector are provided. This paper tries to explain the power consumption of the cryptocurrency mining at the case of Bitcoin, Ethereum, Monero, Litecoin. Since mining is not regulated by the state, and even banned in some countries, it is difficult to find accurate data on how much electricity is spent on it. Method of Herfindahl–Hirschman is used for efficiency estimate of crypto market.

Keywords: Energy Consumption, Mining Pools, Bitcoin, Blockchain, Cryptocurrency, Cloud Mining
JEL Classifications: G32, G34, O33.

1. INTRODUCTION

Blockchain is one of the most popular terms associated with changes in the technological paradigm taking place within the framework of the so-called "fourth industrial revolution" (Bech and Garratt, 2017; Byström, 2016).

This concept came into use not only in professional, but also quasi-professional forums, as well as in discussions in the media. However, people do not always pay due attention to the mechanism of its functioning, the identification of potential benefits and difficulties associated with its implementation. This is also true for the financial sector, where the blockchain can be widely used as a technological basis for new instruments to attract external financing and organize corporate governance. With its help, it is possible to reduce the unproductive costs of financial institutions, which even in the US and leading European countries make up at least 2% of the attracted resources. However, this value has not decreased over the past decades (Bazot, 2017; Philippon, 2016).

In this context, it is advisable to analyze the mechanism of functioning of the blockchain in conjunction with the most significant examples of its use in finance. As such, innovations in the organization of exchange trading, investment and commercial banking, insurance, audit, accompanying changes in approaches to corporate governance, as well as in financial analysis are considered.

The article particularly focuses on the prospects of blockchain-based cryptocurrencies, which are issued for circulation by both private issuers and (potentially) central banks of sovereign states.

Blockchain is a continuous sequential chain of blocks containing information formed according to certain rules. As for economic processes, these blocks record information about transactions and

their characteristics. The key one is the timestamp of registering a single transaction in the block and forming the block as a whole.

2. LITERATURE REVIEW

The idea to organize the storage of information by means of related blocks was proposed originally by cryptography specialists (Haber and Stornetta, 1991). They considered it possible to develop a digital document (register), which records the time of the intellectual property right. In this case, the creators of creative products themselves, to whom the rights arose, had to provide the relevant information until the moment when someone had time to reproduce it.

The idea of decentralized filling of interconnected information blocks, along with the ability to verify the correctness of their filling by all participants, was developed in 2008, when an algorithm was developed, which could be implemented in practice (Nakamoto, 2008). In 2009, the first cryptocurrency (bitcoin) was released on its basis.

Blockchain technology, which is the basis of bitcoin, allows for the combining in one block, information about transactions with a total volume of 1 megabyte. The formation of one block takes 10 min on average. A chain of blocks is formed by hash functions, a cryptographic technology that allows you to encode and embed information about transactions made in the previous block into each subsequent one. This principle of chain formation practically guarantees its invulnerability to fraudulent attempts to change information about transactions in one of the blocks: The person who undertook a hacker attack would have had to make changes in all subsequent blocks by changing their hash-headlines. It is obvious that blockchain users would easily notice these attempts, since the emerging block chain is fully available for their monitoring[1]. In addition, it is extremely difficult in terms of resources required, since to "rewrite" one block significant processing power is required, which leads to high energy consumption.

It is worth noting that the decentralized blockchain technology is based on the computational efforts of the so-called miners who use special equipment to identify a suitable (from a cryptographic point of view) hash-headline for each block.

This search is carried out by trial and error, and the miner who finds the correct hash-headline receives a reward that is fixed in bitcoins. To a large extent, the work performed by miners provides protection of blockchain technology from hacker influences: The more resource-intensive the process of enabling an additional block, the higher the degree of security (Mikhaylov, 2018b).

Commissions are an additional source of income for miners that are paid for the accelerated recording of information about a particular transaction in the emerging block[2].

3. METHODS

In terms of economic theory, the organizational principles of blockchain operation can significantly reduce the costs associated with the verification of transactions and the creation of a distributed network (Catalini and Gans, 2016). This creates the potential for large-scale transformation of existing markets and the formation of new ones. Therefore, the blockchain can be considered as an example of a general-purpose technology, which is the fundamental factor of long-term economic growth.

Then, economic development is presented as a succession of this kind of technology. Nevertheless, it does not necessarily occur at regular intervals: There may be innovative pauses, which are often resolved through the crisis (Mikhaylov, 2018a). In this sense, the development and implementation of the blockchain following the global financial crisis of 2007-2009 looks symbolic.

American researchers of the digital economy Catalini and Gans (2016) believe that further penetration of blockchain technologies will be faster in areas where a high degree of standardization of transactions has already been achieved or where the state itself is ready to implement these technologies.

The first case is about the development of so-called smart contracts that provide, for example, foreign exchange transactions of banks, the trading of futures contracts, etc. At the same time, obviously, there will be a need for an external intermediary that plays the role of the operator of this technology, but the transactions between the counterparties will be carried out in a decentralized manner. In the second case, a lower degree of decentralization is envisaged: The functions of the technology operator and verification of the authenticity of transactions are reserved by the state.

The second case provides for a lower degree of decentralization: The functions of the technology operator and verification of the authenticity of transactions are reserved by the state. Sometimes this approach is called permissioned blockchain technology. Its application mainly covers the creation of public goods: Maintenance of property registers, issuance of official documents, etc.

For example, Massachusetts Institute of Technology introduced the accounting of diplomas issued on the basis of blockchain: In the summer of 2017, a group of 111 graduates was offered to receive, along with the traditional format, electronic diplomas that allow to certify their authenticity for the employer and other interested parties using blockchain. Leading universities in China and India, where there is an issue of fake diplomas, are considering introducing similar approaches. In Sweden and Brazil land rights are registered on the basis of blockchain technology.

Integration of blockchain with the internet of things is also promising. For example, air pollution sensors or weather sensors

1 When making transactions, you can maintain confidentiality by using nicknames or special protocols that allow you to completely anonymous transactions.

2 The presence of a limit on the amount of information to be recorded in each block, objectively reduces the ability to receive commission income. Blockchain technologies, which are the basis of cryptocurrencies alternative to bitcoin, provide storage in the block of information exceeding 1 megabyte, as well as a higher rate of block formation.

can transmit local information to a common network, including on a reimbursable basis, when such data transmission is mediated by payments using cryptocurrencies. Smartphones and other mobile devices (tablets) can be equipped with additional chips for cryptocurrency mining. (Mikhaylov et al., 2018).

Blockchain can increase the transparency of ownership of joint-stock property (Yermack, 2017). Similar to registers of various property rights, this technology allows to take into account changes in shareholders' shares.

With its widespread use, this would increase the efficiency of the stock market as a whole by reducing information asymmetry and dramatically complicating insider trading (Nyangarika, 2019a; Nyangarika, 2019b).

The most famous part of blockchain infrastructure is crypto market.

We use market concentration index calculated by the capitalization of the digital currencies (CR-4) and the Herfindahl—Hirschman Index (HHI), it is clear that this market remained essentially monocentric in 2014-2016.

$$H = \sum_{i=1}^{N} S_i^2 \quad (1)$$

Where S_i is the market share of crypto currency i in the crypto market, and N is the number of cryptocurrencies. We will use a normed Herfindahl index like here:

$$H^* = \frac{(H - 1/N)}{1 - 1/N} \text{ for } N > 1, H^* = 1 \text{ for } N = 1 \quad (2)$$

Where again, N is the number of cryptocurrencies in the market, and H is the usual Herfindahl index.

In general, the stock exchange infrastructure is promising for the use of blockchain technologies. In addition to registration and depository activities, they can be used to accelerate and reduce the cost of clearing operations.

The first platform that transferred this kind of transactions on the blockchain was the Sydney stock exchange. NASDAQ, the London stock exchange and a number of other leading securities trading centers are currently working on similar solutions. After the global financial crisis of 2007-2009, the regulation of trade in derivative financial instruments was tightened. In particular, settlements between participants in derivatives trading are now mandatory through a central counterparty performing clearing (Nyangarika at al., 2018).

4. RESULTS

The cost of bitcoin for break-even mining, including the cost of electricity and depreciation, is about $5000, the publication refers to unnamed experts. Bitcoin fell in December, 2018 to the price of $3200-it is 80% lower than last year, notes FT.

The bitcoin hash rate, a value that shows how much energy miners use, has fallen by more than 40% since August. It means that since September, about 1.5 million bitcoin mining farms have been shut down in 2018. The most profitable liquid crypto currency to mine XMR and LTC (Table 1).

Even though blockchain technologies can lead to a large-scale transformation of the financial sector, contributing to new forms of capital raising and significant cost savings arising from standard transactions, it is premature to argue that digital currencies based on them will be able to seriously compete with traditional ones in the coming years (Narayan et al., 2016; Narayan and Sharma, 2011).

On the back of the so-called industrial revolution, the qualitative characteristics of demand are changing. So, it is important, in particular, the environmental friendliness of electricity generation. Experts with reference to the data of the International energy Agency note that electricity is a source of 42% of anthropogenic greenhouse gas emissions, which leads not only to global warming, but also to an increase in government and business spending on

Table 1: Energy consumption and mining profitability for BTC, ETH, XMR, LTC

Indicator	BTC	ETH	XMR	LTC
Profitability	−76%	642%	335%	312%
Profit per day	$−2.18	$2.59	$9.66	$8.99
Day pool fee	$0.007116	$0.03025	$0.1267	$0.1199
Mined/day	BTC 0.0001962	ETH 0.02486	XMR 0.2620	LTC 0.2778
Power cost/day	$2.88	$0.4032	$2.88	$2.88
Profit per week	$−15.23	$18.14	$67.62	$62.90
Week pool fee	$0.04981	$0.2117	$0.8867	$0.8390
Mined/week	BTC 0.001374	ETH 0.1740	XMR 1.83	LTC 1.94
Power cost/week	$20.16	$2.82	$20.16	$20.16
Profit per month	$−65.27	$77.74	$289.82	$269.58
Month pool fee	$0.2135	$0.9075	$3.80	$3.60
Mined/month	BTC 0.005887	ETH 0.7458	XMR 7.86	LTC 8.34
Power cost/year	$1359.20	$147.17	$1261.44	$1051.20
Profit per year	$−794.06	$10.94	$3,526.10	$3,279.90
Year pool fee	$2.60	ETH 9.01	$46.24	$43.75

Source: Calculated by the authors according to https://coinmarketcap.com at the February 11, 2019. Mining costs calculated per KWh - 0.12 USD, Pool fee - 1%

the implementation of environmental and social programs in the field of health (Nandha and Faff, 2008).

Experts note that the digital transition in the electric power industry allows not only to increase the efficiency of the traditional energy system, but also opens up new opportunities for involving distributed generation in the energy exchange, including on the basis of renewable energy sources, energy storage systems, devices and complexes with regulated consumption, for the organization of a variety of energy services (Table 2).

There is a myriad of cryptocurrencies: According to the portal coinmarketcap.com, at the end of April 2018, their number approached 1600.[3] Externally, they have a number of similarities with fiat money, which is issued by Central banks, but does not perform, or does not fully perform the prescribed set of functions.

Cryptocurrencies are only partly inherent in the function of money as a universal equivalent, or measure of value. Currently, prices for a very limited range of goods and services are denominated in digital currencies. If consider the most famous of them — bitcoin, then, according to the portal coinmap.org at the end of April 2018, it was accepted by only about 12.3 thousand points of sale worldwide[4].

They are distributed very unevenly: The highest concentration is observed in Western Europe and the United States. There is a sporadic presence in South-East Asia and Latin America. At the same time, most of them are companies specializing in online trading. The number of well-known offline sellers that accept payments in bitcoins is very small: One can mention the manufacturer of computer equipment Dell and two air carriers — Air Baltic and Air Lituanica.

Since bitcoin does not fully perform the function of money as a measure of value, it is difficult to use it as a means of payment. Along with a relatively narrow geographical area of active use, operational risks act as a limiting factor.

Firstly, in a number of countries (China, Vietnam, Iceland, Bolivia, Ecuador) transactions using bitcoin are prohibited or are in the "gray" zone. In the vast majority of national jurisdictions, its status has yet to be determined. Therefore, international payments using bitcoin are often carried out "at your own risk." Secondly, as it is often the case at the stage of innovation, there are cases of outright fraud.

This is especially true for e-wallets, which are used for temporary storage of funds in cryptocurrency. They are bankrupted by the owners on purpose, and are subject to hacker attacks.

The non-transparent nature of many bitcoin-mediated transactions also has a negative impact. The legal gaps related to this cryptocurrency, do not allow to exclude the possibility that there might be transactions aimed at laundering of criminal proceeds, support for terrorist organizations, etc. With this in mind, it can be assumed that transactions in bitcoins and other cryptocurrencies can be banned in leading financial countries (USA and EU) in the case of detection of terrorist financing attacks (both occurred and potential).

It is worth mentioning that FATF was wary of the emergence of cryptocurrencies. In 2015, they put forward that it is necessary to assess the feasibility of their admission to circulation, among other instruments, using a risk-based approach that compares the benefits and costs of their official recognition at the state level (FATF, 2015).

As for the performance of bitcoin as a means of accumulation, a very high volatility of the cryptocurrency rate plays a negative role here.

After almost "vertical take-off" there was a sensitive correction, with intraday fluctuations in its rate reached several tens of percent. During February—April, 2018, it periodically fell below 7 thousand dollars (the peak was reached at $20,000).

This volatile dynamic has forced experts to talk about the high probability of an asset price bubble. In a review of studies on the modeling of bitcoin, the first signs of the explosive dynamics of the exchange rate of this cryptocurrency to the dollar appeared in 2012-2013 (Chapman et al., 2017; WTO, 2017).

We verify these statements by analyzing the ratio of the actual movement of the bitcoin exchange rate and the long-term stochastic trend of its dynamics, which is detected by the Hodrick-Prescott filter (Figures 1-4).

The figures show the actual values stable ratios of Bitcoin, Ethereum, Monero, Litecoin were established from November 2016 to March 2017, and in a much more pronounced form — in November 2017 - early January 2018.

3 https://coinmarketcap.com/all/views/all/

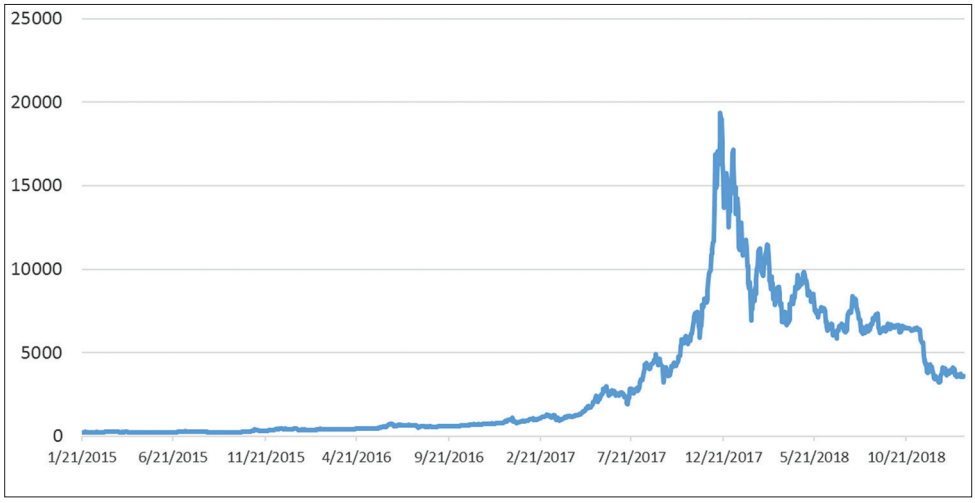
4 https://coinmap.org/#/world/55.72505411/37.62896485/3

Table 2: World electricity consumption, TWh

Region	2000	2005	2010	2015	2020	2025	Growth in 2015-2025, times
World	12,637.50	15,059.53	17,839.24	20,038.18	22,536.22	25,307.09	0.3
Europe	2.836.72	3139.27	3261.15	3,217.69	3,397.51	3,528.32	0.1
Asia	3248.50	4649.49	6666.03	8,447.23	10,409.81	12,487.89	0.5
Africa	358.59	457.73	539.06	611.95	708.73	866.51	0.4
Middle-East	379.01	503.00	728.08	905.69	993.51	1058.60	0.2
North America	3976.44	4236.63	4265.03	4280.39	4335.01	4383.31	0.0
Latin America	773.94	921.05	1101.47	1276.54	1333,96	1489.14	0.2
CIS	854.13	921.26	1024.88	1042.75	1100.80	1223.06	0.2
Pacific	210.16	231.09	253,53	255.94	256.88	270.25	0.1

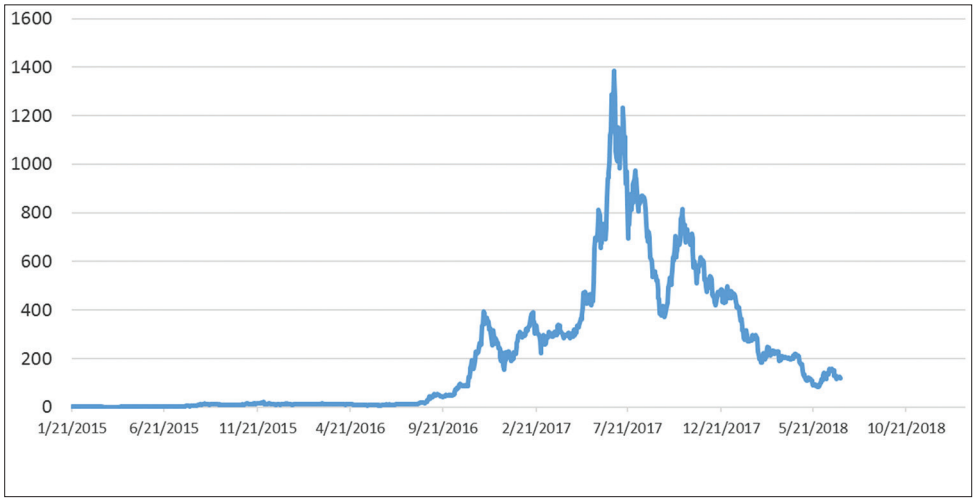
Source: Calculated by the authors according to https://eneroutlook.enerdata.net

Figure 1: BTC rate



Source: www.coinmarketcap.com, Thomson Reuters.

Figure 2: ETH rate



Source: www.coinmarketcap.com, Thomson Reuters

At the same time, the results indicate the presence of episodes of the boom in this market, but do not allow us to say directly that there was a transformation into an uncontrolled price growth, or a "bubble". Although the standard techniques for the recognition of "bubbles" in financial markets do not exist, for this purpose they often use the comparison of the identified boom episodes with some of the abnormal levels.

As such, the levels corresponding to one and a half or two standard deviations (SV) of the subtraction between the actual and trend dynamics are used (Jorda et al., 2015).

Figures 1-4 show that the episodes of the booming growth of the bitcoin exchange rate in 2013 and 2016 - early 2017 were not a "bubble". It was formed only at the last stage - at the end of November 2017, when the bitcoin rate "broke" both proposed levels.

It should be borne in mind that the high volatility of the bitcoin exchange rate is associated with a relatively small "depth" of this segment of the cryptocurrency market.

According to coindesk.com, the capitalization[5] of bitcoin on April 25, 2018 was about $160.7 billion. Other segments of the cryptocurrency market competing with it are characterized by significantly lower capitalization: For example, in the case of Ethereum — the most famous alternative to bitcoin - this parameter was approximately $66 billion. By the standards of modern financial markets, these indicators can hardly be considered impressive. The total capitalization of digital currencies in early 2018 reached $700 billion[6].

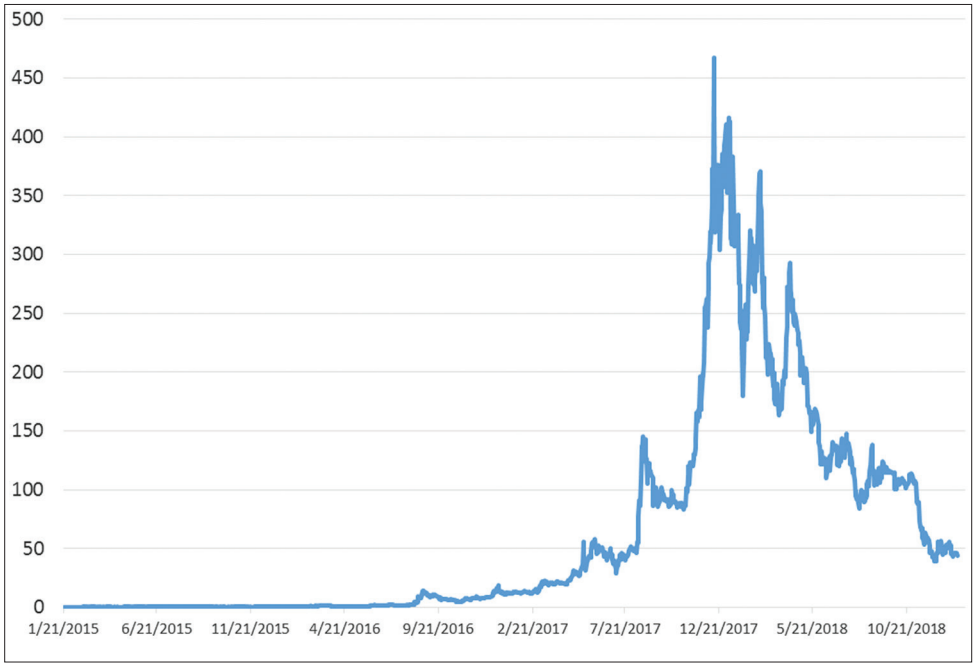
This value is comparable to the capitalization of Brazil's smaller equity markets ($759 billion) and Spain's (704 billion) at the end of 2016, accounting for only 2.6% of the capitalization of the U.S. market[7].

5 The capitalization of bitcoin as a segment of the cryptocurrency market is calculated by analogy with the capitalization of the stock market — as a product of the number of bitcoins in circulation at the value of their current exchange rate to the U.S. dollar.

6 https://coinmarketcap.com/charts

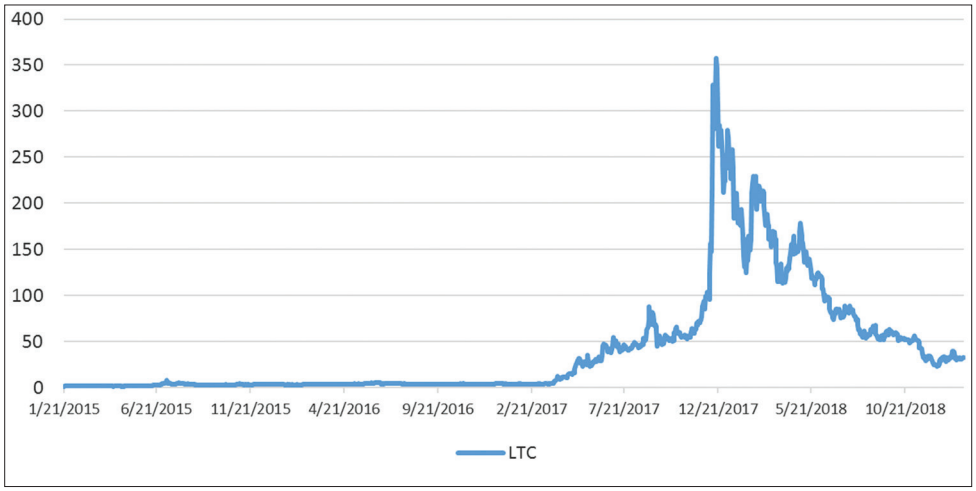
7 World Bank Data (https://data.worldbank.org/indicator/CM.MKT.LCAP.CD). Dynamics of bitcoin to the U.S. dollar exchange rate, July 2010-April 2018 (daily data).

Figure 3: XMR rate



Source: www.coinmarketcap.com, Thomson Reuters

Figure 4: LTC rate



Source: www.coinmarketcap.com, Thomson Reuters

High volatility of the cryptocurrency exchange rates and relatively low capitalization make it possible to assert that even bitcoin does not fully meet the criteria of information efficiency of the market. As shown in a number of empirical studies (Urquhart, 2016; Bariviera, 2017; Kumar Tiwari et al., 2018), bitcoin exchange rate shows signs of improvement in market efficiency not earlier than since 2014.

Therefore, institutional investors with significant investment volumes, but moderate risk appetite, will not come to the cryptocurrency market soon. Thus, it is doubtful whether they have the key function of money - absolute liquidity, and at the moment can hardly be considered to be real money.

It is appropriate to draw parallels between the competition among crypto-currencies and the concept of private money by F. Hayek. It presupposes the adversarial nature of different currencies, which should result in the rejection of inefficiently managed monetary systems (Cong and He, 2017; Makrichoriti and Moratis, 2016).

For now, it is difficult to say that in relation to cryptocurrencies this process is dynamic. Judging by the changes in the market concentration index calculated by the capitalization of the leading digital currencies (CR-4) and the HHI, it is clear that this market remained essentially monocentric in 2014-2016.

Only in the second half of 2017, with the drop in the share of bitcoin to 40%, there was a noticeable decrease in concentration (Table 3).

This balance of power among digital currencies is associated with their high volatility, demonstrating limited opportunities

for effective diversification and, as a result, a high probability of "herd behavior" of investors putting their money in these assets.

Sovereign States are justifiably distancing themselves from direct participation in such competition with digital assets that are not linked to a single emission center. But some of them do not exclude the use of blockchain technologies for the transition to electronic money along with paper, and then instead (Mbiti and Weil, 2011; Osah and Kyobe, 2017).

In this case, such an initiative should be interpreted as an implicit attempt to carry out a confiscation monetary reform, since the expected flight from the official currency, Bolívar, is taking place against the background of hyperinflation.

In addition, it is also a step towards restarting the country's international settlements in the conditions of economic sanctions and a steady reduction in gold and foreign exchange reserves. It is significant that the Venezuelan authorities have a negative attitude to the resolution of operations in bitcoins, apparently because that they believe that with the help of this cryptocurrency a massive withdrawal of capital from the country can be carried out, as happened during the political crisis in Argentina in 2015 (Raskin and Yermack, 2016).

In the article by Luther, Salter, 2017, it is also shown that against the background of the European financial crisis in the countries whose banking system was in the most vulnerable position (Spain, Italy), the number of downloads of applications that allow the purchase and sale of bitcoins has increased significantly. The authors found that the same reaction of the population was typical for Cyprus, where against the background of the banking crisis in 2013 an extreme form of financial repression policy (partial deposit haircuts) was applied.

5. CONCLUSION

The digital currency itself will become the third element of the monetary base along with cash and reserves of commercial banks. The rate of its emission will depend on the activity of users' transactions. At the same time, it is impossible to exclude, if necessary, the introduction of additional discretionary elements, such as the establishment of negative interest rates, as well as temporarily excessive emission of cryptocurrency to stimulate economic growth.

Blockchain technologies promise significant changes in the financial sector. It direct result of their implementation should be a significant reduction in the costs associated with the operation of financial intermediaries and markets.

Table 3: Concentration of the global cryptocurrency market, 2014-2018 (at the beginning of the year)

Coefficient	2014	2015	2016	2017	2018
CR-4	95.09	93.68	96.34	92.84	64.30
HHI	7714	6350	8353	7714	2232

Source: Calculated by the authors according to https://coinmarketcap.com/charts/#dominancepercentage

Decentralizing the interaction of economic agents and eliminating the excessive costs associated with many financial transactions can create conditions for more intense competition among existing financial institutions and reduce entry barriers for new players. In the long term, this will allow the transition from a predominantly oligopolistic structure of the financial sector in most countries to a more competitive structure — a contestable market, where large financial institutions may be present, but their market power is limited by the threat of virtually unimpeded entry of more flexible, innovation-oriented newcomers (He et al., 2017).

Nevertheless, for the practical implementation of such a scenario and achieving a noticeable gain in public welfare, it is necessary to adequately manage the risks associated with digital financial innovations, especially in terms of admission to free circulation and regulation of investments in cryptocurrencies.

At the moment, bitcoin consumes mainly very cheap electricity. As a result, the bitcoin network typically uses energy where it is abundant and cannot be stored or exported.

In countries where hydrocarbons are difficult to export, for example, in countries without access to the sea, bitcoin is extracted and "harmful" electricity. But most miners are powered by electricity from hydroelectric power plants, geysers, and geothermal vents that cannot be transported or stored.

Bitcoin will continue to look for such cheap and not used for other purposes sources of energy, as mining in cities or industrial centers will continue to be not profitable. It is possible that you spend on air conditioning or heating water more than the miner can afford.

If the price of bitcoin stabilizes, and enough miners come to this market, in the near future we can expect a fivefold increase in their energy consumption.

In the distant future, bitcoin mining will become less and less profitable. The current average value (12.5 bitcoins per block) will be halved every 4 years until it reaches zero. Transaction fees (currently two bitcoins per block) are likely to remain the same.

In this case, the energy consumed will depend on the size of the Commission and the price of bitcoin. If the price reaches $1 million per bitcoin, two bitcoins per block will lead to a situation where every 10 min electricity is burned at $2 million.

In light of all this, does bitcoin look like such a big burden on the neck of the world energy? Given the tendency of bitcoin mining to use renewable resources and the fact that the traditional banking system is not environmentally friendly, it is possible that the cryptocurrency has a positive impact on the environment.

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