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CZECH
UNIVERSITY
OF LIFE SCIENCES PRAGUE

Bachelor Thesis

Economic Analysis of Bitcoin and other virtual currencies

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Faculty of Economics and Management

BACHELOR THESIS ASSIGNMENT

Illia Tyshchenko

Economics Policy and Administration
Business Administration

Thesis title

Economic Analysis of Bitcoin and other virtual currencies

Objectives of thesis

The goal of this thesis is to be able to contribute both with knowledge and in the ongoing discourse relating to bitcoin and virtual currencies.It begins by describing the functions and design of the Bitcoin system in detail .Other objectives would be to find the factors influencing the price of Bitcoin, determine its real value, identify the risks of trading , as well as determine future prospects for using virtual currencies.

Methodology

The theoretical part provides an overview of cryptocurrencies concept as well as the specifics of blockchain technology .The practical part is based on assumptions about the growth tendency of various cryptocurrencies, such as Bitcoin, etherium, litecoin, etc .Forecast of research data on the cryptocurrency market will be contained by mathematical and statistical analyses.

The proposed extent of the thesis

40 pages

Keywords

Bitcoin,money,price,blockchain,wallet,decentralized currency

Recommended information sources

BURNISKE, Chris a Jack TATAR. Cryptoassets: the innovative investor's guide to bitcoin and beyond. New York: McGraw-Hill, [2018]. ISBN 1260026671.

POPPER, Nathaniel. Digital gold: bitcoin and the inside story of the misfits and millionaires trying to reinvent money. New York: Harper, 2016. ISBN 9780062362506.

TAPSCOTT, Don a Alex TAPSCOTT. Blockchain revolution: how the technology behind bitcoins is changing money, business and the world. London: Portfolio/Penguin, 2016. ISBN 978-0-241-23785-4.

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Declaration

I declare that I have worked on my bachelor thesis titled "Economic Analysis of Bitcoin and virtual currencies" by myself and I have used only the sources mentioned at the end of the thesis. As the author of the bachelor thesis, I declare that the thesis does not break copyrights of any their person.

In Prague on 13.03.2020

Illia Tyshchenko

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Analýza bitcoinů a jiných virtuálních měn

Souhrn

Následující bakalářská práce je zaměřena na zjištění, zda cena bitcoinů závisí nebo koreluje s cenami jiných investičních statků a hodnotami integrálních indexů ekonomické výkonnosti a pokusit se předpovídat cenu bitcoinů v příštích 2 čtvrtletích, pokud předchozí analýza vede k závěru, že je to proveditelné. Cílem bylo zjistit, zda cena bitcoinů je mírně korelovaná s cenami jiných kryptoměn.

Tato práce se skládá ze dvou částí. Teoretická část je založena na výzkumu literatury a on-line článků. Zahrnuje koncept a povahu kryptoměn, jejich historii, typy. Teoretická část dále prochází právním statusem kryptoměn v různých zemích, jejich výhodami, riziky a rolí.Účelem analýzy poskytnuté v praktické části práce je vývoj teoretického modelu možné závislosti bitcoinové rychlosti na míře některých dalších kryptoměn (Ethereum, XRP / Ripple, LiteCoin), světových cen energetických zdrojů, jako je ropa Brent, ceny drahých kovů, jako je zlato a stříbro, a také o hlavních ukazatelích ekonomické výkonnosti: Dow Jones, Nasdaq a S&P 500.

Klíčová slova: Bitcoin, LiteCoin, Altcoin, kryptoměny, Dow Jones, Satoshi Nakomoto, transakce, platba, dolar, finance, burza, elektronická měna, blockchain, peer-to-peer, BitTorrent.

Economic Analysis of Bitcoin and other virtual currencies

Summary

The following bachelor thesis is focused on determining whether the price of Bitcoin depends on or correlates with prices of other investment goods and values of of integral economic performance indexes as well as to try to predict the price of Bitcoin in the next 2 quarters if the previous analysis leads to the conclusion that this is feasible. The aim was to identify whether price of Bitcoin at least moderately correlates with prices of other cryptocurrencies.

The thesis itself consists of two parts. The theoretical one is based on the literature and on-line articles research. It includes concept and nature of cryptocurrencies, their history,types. In addition, the theoretical part goes through the Legal status of cryptocurrencies in various countries their advantages, risks and role.

The purpose of the analysis provided in the practical part of the thesis is developing a theoretical model of possible Bitcoin rate's dependence on rates of some other cryptocurrencies (Ethereum, XRP/Ripple, LiteCoin), world prices of energy resources such as Brent oil, prices of precious metals such as gold and silver as well as on main indicators of economic performance: Dow Jones, Nasdaq, and S&P 500.

Keywords: Bitcoin, LiteCoin, Altcoin, cryptocurrencies, Dow Jones, Satoshi Nakomoto, transaction, payment, dollar, finance, stock exchange, electronic currency, blockchain, peer-to-peer, BitTorrent.

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1. Introduction

By itself money is nothing .But the value that money has it has nothing to do with the physical value of it. They were created long time ago as a medium of exchange. Money is used everywhere to make flows of goods and services possible within the economy. Money is also used to measure values of different goods and services as well as to store wealth.

In modern economies, money is always an instrument of monetary policies which is not tied to any real resources or wealth. As a result, rates of specific countries tend to fluctuate or even drop and surge significantly. Many people realized that can be the way of earning wealth using speculative methods of buying and selling currencies. Others just want to avoid additional risk and hedge their funds. Many people are also concerned with enormous governments' influence on monetary issues and the centralized nature of money in general. That is why cryptocurrencies, which emerged not so long ago and promised people that they would get rid of many, if not all, problems mentioned above, swiftly became a popular instrument of investing funds. Many believed – and some still do – that cryptocurrencies could lead to stability and wealth and that their rates, initially very low, would permanently rise. Bitcoin was and remains probably the most popular cryptocurrency in the world. Both businesses and people has shown interest in Bitcoin , because of decentralization and safety.

This thesis will be focused on understanding the nature of bitcoin and cryptocurrencies and analyse if Bitcoin can be attractive type of investment.

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2. Objectives and Methodology

2.1 Objectives

The general **purpose** of the thesis is to determine whether the price of Bitcoin depends on or correlates with prices of other investment goods and values of integral economic performance indexes as well as to try to predict the price of Bitcoin in the next 2 quarters if the previous analysis leads to the conclusion that this is feasible. The idea is to try to analyze whether Bitcoin can be regarded as a reliable tool of investment via possible prediction of its price based on prices of other financial and real assets generally accepted as investment goods by individual and institutional investors. The first objective is to provide the theoretical background to the cryptocurrencies issue by addressing such topics as concept and nature of cryptocurrencies, their types and history, their legal status, role, advantages and risks. The second objective is to draw a correlation matrix based on finding possible relations among prices of some cryptocurrencies and other investment goods as well as general economic performance indicators. The third objective is to conduct the correlation and regression (including autocorrelation and autoregression) analysis to determine whether the price of Bitcoin depends on the prices of other cryptocurrencies, investment goods, performance indicators, or previous historic prices of Bitcoin. The fourth objective is to make a conclusion as to whether such dependence or correlations exist or not as well as to try to predict future Bitcoin prices for the following two decades based on the analysis provided before.

2.2 Methodology

In theoretical part, such issues as the nature and history of cryptocurrencies, their types, legal status, advantages, risks and their role are addressed.

In the practical part of the thesis, a statistical and econometric analysis is conducted as regards the historic prices of Bitcoin and some other cryptocurrencies as well as of their possible dependence on or relation to prices of other investment goods such as oil, gold and silver and values of performance indexes such as Dow Jones, NASDAQ, and S&P500. The **hypothesis** is that price of Bitcoin at least moderately correlates with prices of other cryptocurrencies due to the similar economic nature of these assets and their frequent interchangeability from the perspective of individual and institutional investors; In order to determine such hypothesis, three correlation matrices are developed first, one for each type of indicators: prices of Bitcoin and other cryptocurrencies; prices of other investment goods ; and general economic performance indicators. All of them address the 2014-2019 time period divided into quarters, with prices and values indicated as of the first day of the respective quarter (i.e. January 1, April 1, July 1, and October 1 of each of the six years under consideration). In that way, 24 values are made available for each variable. Then, the correlation (including autocorrelation) and regression (including autoregression) analyses are conducted, statistical significance and reliability of results are assessed, and prediction of the future price of Bitcoin is made.

3. Theoretical Part

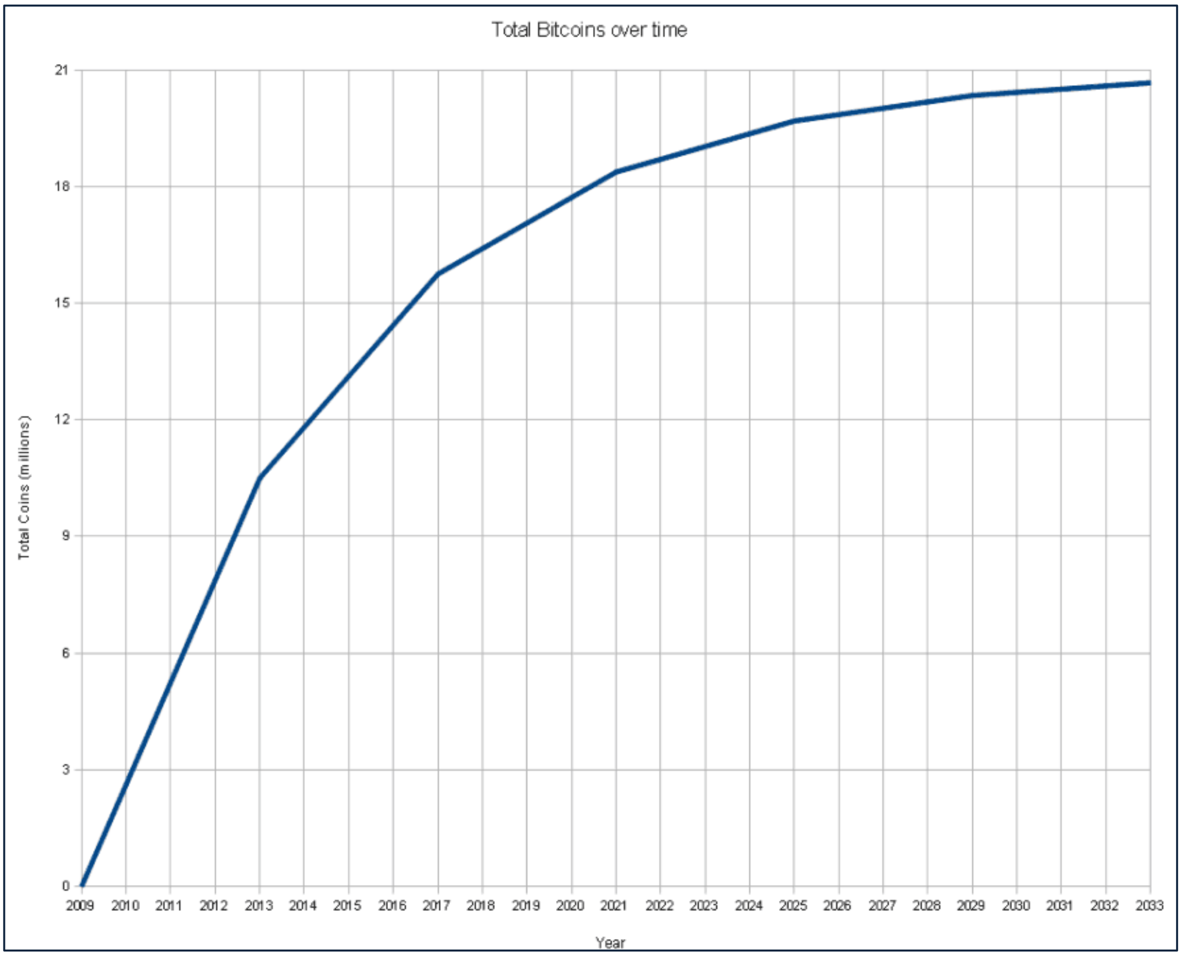
3.1 Concept and nature of cryptocurrencies

Money was invented long time ago when people started to divide labour among most members of a given society or community in order to raise the productivity level. The need for exchange of goods and services—and thus for trade—emerged (Krugman et al., 2011). Durable and dividable goods or other objects with or without an intrinsic value played a role of a medium of exchange and unit of account: grains, shells, stones, pieces of wool etc. Later, people found that precious metals can play a role of money because they are rare, as well as very durable and dividable, although their intrinsic value was doubtful (Krugman et al., 2011). Much later, governments started to issue paper promissory notes and other liability documents to confirm their promise to pay later. As a result, paper money emerged. It became popular among governments because it is virtually limitless and allows of shifting the load of economic problems on ordinary citizens without directly imposing new or raising existing taxes, i.e. without direct social disturbance. Moreover, it allowed of pursuing monetary policy that would influence the economic activity of people and enhance the raise of the standard of living within a specific country (Krugman et al., 2011).

Paper money was often reflected in banks' virtual current accounts even before the emergence of modern technologies. As technologies developed, electronic means emerged which reflected the balance on the holder's current account at a bank. Various internet-banking systems and virtual and electronic money of all types appeared such as PayPal etc. But none of them created new money: they just reflected the current accounts which had been replenished beforehand by more traditional sources of money (Krugman et al., 2011). They were used because of convenience, and they hardly allowed of speculating such money directly without tying them up to traditional currencies.

Then cryptocurrencies emerged in the beginning of the 21st century (Brito and Castillo 2013). They are a completely different story. Cryptocurrencies are in fact ordinary currencies created and used in an unordinary way, i.e. electronically and with no central ruling facility or issuing body. Cryptocurrencies have no intrinsic value and do not reflect the balance of a current account of any currency, although they can usually be exchanged for other currencies, and their market exists.

Fig. 3.1 Historic chart of the volume of bitcoins in 2009-2033



Source: (NAKAMOTO, 2008)

The stock of cryptocurrencies is usually strictly restricted to a specific figure which changes over time according to a specific formula, so that everyone knows at any given moment how much of this cryptocurrency has been created before and how much of it will have been created until any given moment in future (Chohan 2017). For example, the historic chart of the volume of bitcoins from the very moment of their launch in 2009 until 2033 is shown in Figure 3.1. There will never be more than 21 million bitcoins due to mathematic restrictions in the formula according to which this currency is created because in 2009, the creation rate was about 50 bitcoins every 10 minutes, and it is cut in half every 210,000 generation periods, i.e. approximately every 4 years.

The Merriam-Webster Dictionary (2019) defines *cryptocurrency* as “any form of currency that only exists digitally, that usually has no central issuing or regulating authority but instead uses a decentralized system to record transactions and manage the issuance of new units, and that relies on cryptography to prevent counterfeiting and fraudulent transactions.” Cryptocurrency is a type of digital currency, the creation and control of which is based on cryptographic methods. As a rule, cryptocurrency accounting is decentralized (Brito and Castillo 2013). The functioning of these systems is based on technologies such as blockchain, directed acyclic graph, consensus ledger etc. (Brito and Castillo 2013). Transaction information is usually not encrypted and is available to everyone. To ensure the invariability of the base of the chain of transaction blocks, cryptography elements are used (a digital signature based on a public-key system, sequential hashing etc.) (Chohan 2017).

The term emerged and consolidated after the publication of an article about the Bitcoin system which was named *Cryptocurrency* and published in 2011 in the Forbes magazine. The author and creator of Bitcoin himself, whose identity is unknown, like many others, used the term “electronic cash” (Chohan 2017).

Sometimes a new cryptocurrency appears as a branch (fork) from another cryptocurrency due to a change in parameters, which makes them incompatible. At the same time, both cryptocurrencies can have a common transaction history until they are split (Brito and Castillo 2013).

The emission of various cryptocurrencies can occur through mining, forging or ICO (initial coin offering). Discussions are ongoing about the economic nature and legal status of cryptocurrencies. In different countries, cryptocurrencies are considered as a means of payment, a specific product, or may have restrictions on circulation (for example, the prohibition of operations with them for banks and financial institutions).

A key feature of cryptocurrencies is the absence of any internal or external administrator. Therefore, banks, tax, judicial and other state or private bodies cannot influence the transactions of any participants in the payment system (Chohan 2017). The transfer of cryptocurrencies is irreversible: no one can cancel, block, doubt or force a transaction (without a private key). However, the parties to the transaction can voluntarily mutually block their cryptocurrencies temporarily as collateral or establish that the completion or cancellation of the transaction requires the consent of all (or arbitrary additional) parties of the transaction (Brito and Castillo 2013).

The technology of cryptocurrencies proceeds from the fact that the network does not have a trusted node: one whose actions are guaranteed to be true and who can confirm the correctness or validity of other people's operations. For the first time in history, this problem was solved in the Bitcoin system due to the artificial complication of making changes to the registry of the history of operations. To store data, transactions are combined into blocks from which a continuous chain (*blockchain*) is formed. Continuity is provided not so much by numbering as by the inclusion of the hash sum of the previous block in the current block, which does not allow of changing the information in the block without changing the hashes in all subsequent blocks. All hashes meet certain requirements; generating hashes that satisfy these requirements is time consuming or very expensive. Only the longest chain is considered true. In different cryptocurrencies, the right to form the next block is granted to the person who has performed a certain work (Proof-of-work), who has a certain amount in the account (Proof-of-stake), who has provided some resources (Proof-of-space), or another procedure is taken as the basis that is easy to verify but difficult to execute or fake (Chohan 2017).

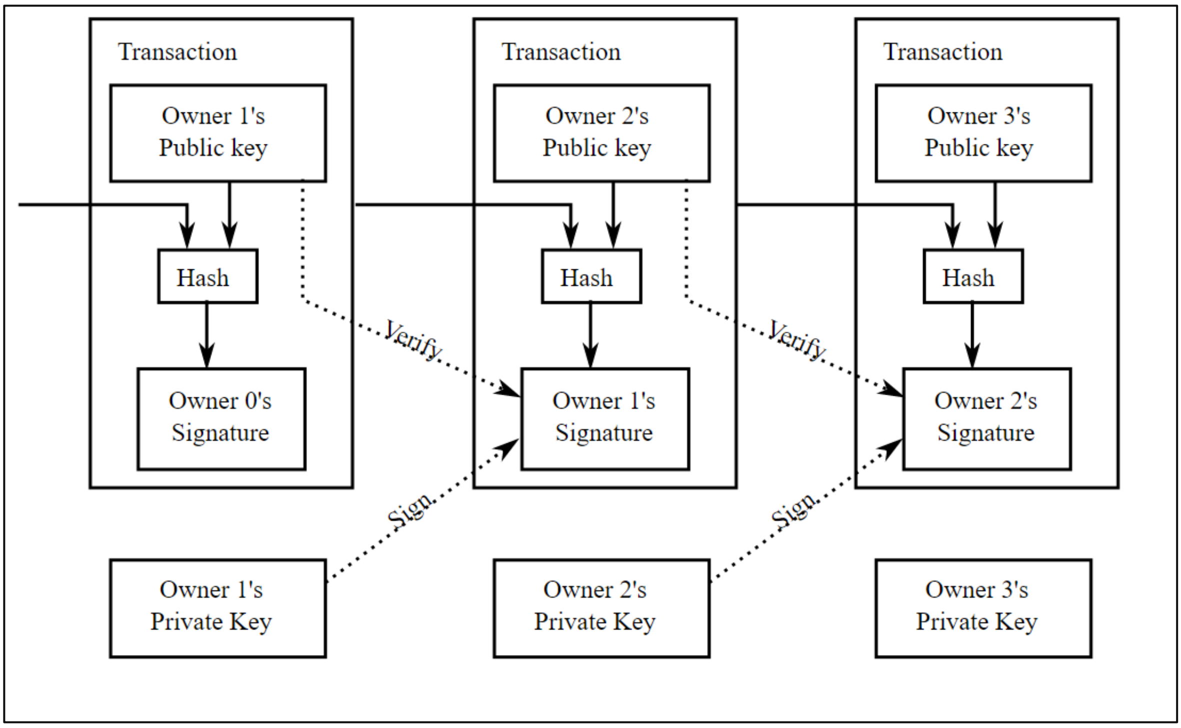
As a rule, in cryptocurrencies, developers initially specify the upper limit of the total volume of emissions. However, some cryptocurrencies, such as PPCoin, Novacoin, Sifcoin and others, do not have a fixed upper limit on the total volume of emission and both emission and demission are possible (by mandatory destruction of a fixed amount in each transaction).

Most cryptocurrencies provide pseudonymity - all transactions between all addresses are publicly available, but there is no data about the owners of the addresses. However, the identity of the owner can sometimes be established if additional information becomes known. ZeroCash provides the ability to replace pseudonymity with anonymity using a number of technological means such as cryptofixers etc.

There are various ways to acquire cryptocurrencies. Newly emitted quantities are distributed according to the originally agreed procedures specific for each of the cryptocurrencies (mining, forging, ICO). Mining and forging are aimed at building a blockchain: the creators of new blocks are rewarded with a certain amount of issued cryptocurrency. In this case, there is usually no other way for the circulation of new batches of crypto currency. ICO is a way to attract financing through the sale of lots of new cryptocurrency, which were originally generated and belonged to the organizer of the ICO. Then, others can receive the issued cryptocurrency from those who already own it - in exchange for ordinary money, or in exchange for the goods or services provided, either as donations or as a loan. The exchange can be carried out directly between interested parties without intermediaries or using any of the many digital currency exchange sites (Chohan 2017). The simplified scheme of the chain of ownership for the Bitcoin cryptocurrency is illustrated in Figure 3.2.

In mid-2017, the U.S. Securities and Exchange Commission (SEC) issued clarifications on ICOs and their risks and a comparison with traditional investing methods. The Commission emphasized that this technology can be used to provide fair and legitimate investment opportunities, and proposed to regulate placements in accordance with the US Securities Exchange Act of 1934, in particular, to register the offer and sale of tokens with the SEC. On September 4, 2017, seven Chinese financial regulators officially banned all ICOs in the People's Republic of China, demanding that the proceeds from all past ICOs be reimbursed to investors, otherwise the offender will be “severely punished by law” (Young 2017). This action on the part of Chinese regulators has led to large sales and a depreciation of most cryptocurrencies.

Fig. 3.2 Simplified scheme of the chain of ownership for Bitcoin



Source: (NAKAMOTO, 2008)

Prior to this ban, ICOs raised the equivalent of nearly $ 400 million from approximately 100,000 investors (Young 2017). However, a week later, a Chinese financial official announced on Chinese national television that the ban on ICOs was only temporary until the rules and standards governing ICOs appeared. ICOs are also banned in South Korea at the legislative level (Young 2017). In September 2017, the Australian Securities and Investments Commission (ASIC) published a guide on legal obligations for companies that organize ICOs.

Technically, operation of a cryptocurrency is usually based on the blockchain technology. Houben and Snyers (2018) define *blockchain* as “a particular type or subset of so-called distributed ledger technology (DLT). *DLT* is a way of recording and sharing data across multiple data stores (also known as ledgers), which each have the exact same data records and are collectively maintained and controlled by a distributed network of computer servers, which are called nodes.” The purpose of a blockchain is “to create and verify a continuously growing data structure—to which data can only be added and from which existing data cannot be removed—that takes the form of a chain of “transaction blocks,” which functions as a distributed ledger” (Houben and Snyers 2018).

In fact, blockchain is a sequential chain of blocks (a linked list) containing information, built according to certain rules. Most often, copies of block chains are stored on many different computers independently of each other.For the first time, the term appeared as the name of a fully replicated distributed database implemented in the Bitcoin system, which is why blockchain is often referred to as a means of conducting transactions in various cryptocurrencies; however, blockchain technology can be extended to any interconnected information blocks. Bitcoin became the first blockchain technology application in October 2008 (Iansiti and Lakhani 2017).

Transaction block is a special structure for recording a group of transactions in the Bitcoin system and similar ones. A transaction is considered completed and reliable ("confirmed") when its format and signatures are verified, and when the transaction itself is combined into a group with several others and recorded in a special structure: a block. The contents of the blocks can be checked, since each block contains information about the previous block. All blocks are lined up in one chain, which contains information about all the operations ever performed in the database. The very first block in the chain—the genesis block—is considered as a separate case, since it does not have a parent block (Houben and Snyers 2018).

A block consists of a header and a list of transactions. The block header includes its hash, the hash of the previous block, transaction hashes and additional overhead information. In the Bitcoin system, the first transaction in a block always indicates the receipt of a commission, which will be a reward to the miner for the created block. Next is a list of transactions formed from a queue of transactions that have not yet been written to the previous blocks (Iansiti and Lakhani 2017). The criterion for selection from the queue is set by the miner independently. It does not have to be a timeline. For example, only operations with a high commission or with the participation of a given list of addresses can be included. For transactions in the block, a tree hash is used, similar to generating a hash sum for a file in the BitTorrent protocol. Transactions, in addition to calculating the commission for creating a block, contain a link (inside the *input* parameter) to a transaction with the previous data state (in the Bitcoin system, for example, a link is given to the transaction from which consumable bitcoins were received). Operations on transferring commissions for creating a block to the miner do not have "input" transactions, therefore any information can be indicated in this parameter (for them, this field is called the *Coinbase parameter*) (Iansiti and Lakhani 2017).

The created block will be accepted by other users if the numerical value of the header hash is equal to or less than a certain target number, the value of which is periodically adjusted. Since the hash result of the SHA-256 function is considered irreversible, at the moment there is no algorithm for obtaining the desired result, except for random enumeration. If the hash does not satisfy the condition, then the nonce parameter is changed in the header and the hash is recalculated. Usually (statistically) a large number of recounts are required. When an option is found, the node sends the received block to other connected nodes that check the block. If there are no errors, then the block is considered added to the chain and the next block should include its hash (Houben and Snyers 2018).

In the Bitcoin system, the value of the target number to which the hash is compared is adjusted every 2016 blocks. It is planned that the entire Bitcoin system network should spend about 10 minutes generating one block, and about two weeks for 2016 blocks. If 2016 blocks are formed faster, then the objective decreases slightly and it becomes more difficult to achieve it, otherwise the objective increases. A change in the complexity of the calculations does not affect the reliability of the Bitcoin network and is only required for the system to generate blocks at an almost constant speed, independent of the computing power of the network participants (Iansiti and Lakhani 2017).

Currently, representatives of various fields and branches of economy are interested in blockchain technology. Moreover, the degree of interest of companies in different sectors of the economy varies significantly. The financial sector is actively preparing for the widespread introduction of blockchain, while manufacturing enterprises tend to ignore this technology (Iansiti and Lakhani 2017).

3.2 History of cryptocurrencies

Cryptography for confidential payments began to be used since 1990 in David Choma’s DigiCash system, whose company went bankrupt in 1998. This payment system was centralized (Chohan 2017).

In 1996, the United States National Security Agency published a paper *How to Make a Mint: the Cryptography of Anonymous Electronic Cash*which described a cryptocurrency system and its possible infrastructure: it was first published in a MIT mailing list in 1996, and later in 1997, in *The American Law Review*: Vol. 46, Issue 4 (Law et al. 1997, 1131-1162).

For the first time, the term “cryptocurrency” was used after the appearance of the Bitcoin payment system, which was developed in 2009 by a person or group of people under the pseudonym Satoshi Nakamoto (Niccolai 2013). His, her, or their identity as of October 2019 has not yet been established. The following forks of Bitcoin appeared later: Namecoin (decentralized DNS for registration within the .bit domain zone), Litecoin (uses scrypt hashing), PPCoin (uses a hybrid proof-of-work/proof-of-stake mechanism, does not have an upper limit on the volume of emission), Novacoin (similar to PPCoin, but uses scrypt) and many other similar cryptocurrencies (Chohan 2017).

Until July 2013, the software of all cryptocurrencies except Ripple was based on the open source system of the Bitcoin system. Since July 2013, other platforms began to appear that, in addition to cryptocurrencies, support various infrastructure: exchange trading, shops, instant messengers and more. Such crypto platforms include: BitShares, Mastercoin, Nxt (Chohan 2017). Other platforms have been announced and are expected.

Altcoins (alternative coin) are all cryptocurrencies that appeared after Bitcoin. The first altcoins appeared in 2011: Litecoin and Namecoin. Their developers sought to overcome a number of problems inherent in Bitcoin (for example, Litecoin has a higher transaction speed) or to use blockchain technology in other areas (Namecoin was developed to build alternative root DNS servers which would be decentralized and make internet censorship effectively impossible or difficult). Many altcoins are inherently very similar to Bitcoin, have similar characteristics, and the same equipment can be used to work with them as for Bitcoin, but some cryptocurrencies have significant differences. Ethereum has become a crypto platform through the use of “smart contracts.” Even more independent from Bitcoin is Ripple, which is actually a centralized system. A number of cryptocurrencies, such as Dash, have focused on enhancing anonymity (Chohan 2017). Acryptocurrency known as Peercoin was the first to apply in its operations a proof-of-stake / proof-of-work hybrid system. A number of countries including Venezuela and the United Kingdom announced they would study the advantages, risks, and role of cryptocurrencies and/or even develop their own ones (*UK Launches…* 2014).

The history of Bitcoin was interesting. In 2008, a person or group of people under the pseudonym Satoshi Nakamoto published a file with a description of the protocol and principle of operation of the payment system in the form of a peer-to-peer network. According to Satoshi, development began in 2007 (*Bitcoin Forum*, 2009). In 2009, he completed the development of the protocol and published the client program code.

On January 3, 2009, the first block and the first 50 bitcoins were generated (Mack 2013). The first Bitcoin transfer transaction took place on January 12, 2009: Satoshi Nakamoto sent 10 bitcoins to Hal Finney (Mack 2013). The first exchange of bitcoins for dollars occurred in September 2009: Martti Malmi sent 5050 bitcoins to a user with the pseudonym NewLibertyStandard, for which he received $5.02 onto his PayPal account (Mack 2013). NewLibertyStandart proposed to use the cost of electricity spent on generating to evaluate bitcoins. The first exchange of bitcoins for real goods occurred in May 2010: the American Laszlo Hanech received two pizzas with deliveryfor two thousand bitcoins (Mack 2013).

Further development is organized and coordinated by the developer community, and any significant changes to the Bitcoin protocol should be adopted by the majority of owners of mining pools.On August 1, 2017, the block structure in the blockchain was changed. A group of developers and miners launched a fork of Bitcoin called Bitcoin Cash. The new cryptocurrency has a common history with Bitcoin: it features the backward compatibility in the block structure before August 1, but has an incompatible structure after August 1 (Irrera and Chavez-Dreyfuss, 2017).

3.3 Types of cryptocurrencies: Bitcoin and other currencies

The first successful cryptocurrency was Bitcoin which appeared in 2009. Other cryptocurrencies soon followed Bitcoin. The emergence and unexpected large success of first cryptocurrencies in the late 2000s and early 2010s led to the appearance of a bulk of independent cryptocurrencies. Some of them were based on the same mathematical model and calculations as Bitcoin. It means that they virtually used the same conceptual platform; many of them derived from Bitcoin as a result of its forks and then became independent cryptocurrencies with a common history with their mother currency until the moment of fork (Irrera and Chavez-Dreyfuss, 2017). Other cryptocurrencies were completely independent and used the same idea but a different mathematical model and were developed used a different platform.

According to All Coins (2019), probably the most famous, reliable and trustworthy Internet portal relating to cryptocurrencies, there are 911 cryptocurrencies in the world as of October 14, 2019. Their joint market capitalization is about $230 billion, of which Bitcoin accounts for around $150 billion, that is 65% of the entire market. The prices differ greatly. For example, one Bitcoin costs $8,365 as of October 14, 2019 whereas two cryptocurrencies have a higher price per unit: $15,138 for one Project-X and $17,611 for one 42-coin. At the same time, the price of unit tells almost nothing but the trend of price. Market capitalization is price per unit times circulating supply. There are only 0,078 Project-X coins on the market, therefore its entire market capitalization is only $1,185, that is almost 150 million times lower than that of Bitcoin (All Coins 2019). Also, there are only 42 42-coins (which derives its name from the circulating supply supposed to equal 42 units all the time). That is why market capitalization of 42-coin is only $740,000, i.e. 200 thousand times lower than that of Bitcoin. At the same time, one Ethereum costs only $185 but there are more than 108 million units which implies that this cryptocurrency is the second one in the world by its market capitalization which reaches $20 billion, some 7.5 times lower than that of Bitcoin. The top-20 cryptocurrencies by their market capitalization are shown in Table 3.1.

Table 3.1 Top-20 cryptocurrencies by their market capitalization

#	Name	Symbol	Market Cap	Price	Circulating Supply
1	Bitcoin	BTC	$150 516 559 890	$8 365,37	17 992 825
2	Ethereum	ETH	$20 096 277 370	$185,82	108 152 054
3	XRP	XRP	$12 764 005 195	$0,295690	43 166 787 298 *
4	Bitcoin Cash	BCH	$4 088 516 041	$226,41	18 057 963
5	Litecoin	LTC	$3 605 833 981	$56,81	63 469 867
6	EOS	EOS	$2 934 737 364	$3,14	935 923 205 *
7	Binance Coin	BNB	$2 853 608 356	$18,35	155 536 713 *
8	Bitcoin SV	BSV	$1 546 957 071	$86,64	17 854 986
9	Stellar	XLM	$1 302 276 645	$0,065006	20 033 073 298 *
10	TRON	TRX	$1 116 320 216	$0,016741	66 682 072 191
11	Cardano	ADA	$1 073 598 890	$0,041408	25 927 070 538
12	Monero	XMR	$915 131 412	$53,02	17 258 841
13	IOTA	MIOTA	$793 715 363	$0,285557	2 779 530 283 *
14	Dash	DASH	$653 618 574	$71,86	9 095 875
15	Tezos	XTZ	$618 319 848	$0,936318	660 373 612 *
16	Cosmos	ATOM	$599 462 578	$3,14	190 688 439 *
17	Ethereum Classic	ETC	$543 961 633	$4,76	114 271 864
18	NEO	NEO	$533 258 905	$7,56	70 538 831 *
19	NEM	XEM	$351 917 027	$0,039102	8 999 999 999 *
20	Ontology	ONT	$344 042 765	$0,642049	535 851 170 *

Source: (All Coins, 2019)

Bitcoin is a peer-to-peer payment system that uses the unit of the same name to record transactions. Cryptographic methods are used to ensure the functioning and protection of the system, but at the same time, all information about transactions between the system addresses is available in open form (Chohan, 2017).

The minimum transmitted value (the smallest value possible), 10^{-8} bitcoinm was called *satoshi* in honor of the creator Satoshi Nakamoto, although he himself used the word *cent* in such cases (Chohan, 2017).

An electronic payment between two parties occurs without intermediaries and is irreversible: there is no mechanism for canceling a confirmed transaction (including cases when the payment was sent to an incorrect or non-existent address, or when the transaction was signed with a private key that became known to others). Nobody can block (arrest) funds, even temporarily, with the exception of the owner of the private key (or the person to whom it became known). But the provided multi-signature technology allows attracting a third party (arbiter) and implementing "reversible transactions." Using a special script language, it is possible to implement other variants of smart contracts (Chohan, 2017). However, it is not accessible from the graphical interface and is not Turing-complete, unlike the newer blockchain systems such as Ethereum.

Bitcoins can be used to exchange goods or services with sellers who agree to accept them. Exchange for regular currencies occurs through the online digital currency exchange service, other payment systems, exchange offices or directly between interested parties.

The commission for operations is appointed by the sender voluntarily; the size of the commission affects the priority in processing the transaction. Typically, the client program suggests the recommended size of the commission. Transactions without a commission are possible and also processed, but are not recommended, since their processing time is unknown and can be quite large.

Another popular cryptocurrency is Ethereum. It is not known why the creator of Ethereum, a Canadian programmer of Russian origin, Vitaly Buterin, called it that. Perhaps due to the fact that, unlike Bitcoin, the amount of Ethereum is unlimited. And it is possible due to the fact that Ethereum is the first cryptocurrency that uses the technology of "smart contracts", which means that it can "take the form" of any object (Irrera and Chavez-Dreyfuss, 2017).

How do these smart contracts work? A smart contract removes the agreed amount from the accounts and holds until the terms of the contract are met. This approach allows reducing human intervention and makes the machine do the work. In future, "smart contracts" can be applied in accounting, logistics, andlegal procedures.

The currency appeared in 2015, with funds raised by Buterin through crowdfunding, a voluntary donation of money via the Internet. By the way, donations were collected in bitcoins. Ethereum works almost the same way as Bitcoin, because the basic code for Ethereum is borrowed. Here, too, there are miners who “calculate” cryptocurrency and blockchains in which information about transactions is stored. Just like in the Bitcoin system, Ethereum blockchains are stored on each user's computer. Therefore, it is impossible to fake records because to do so, it would be necessary to fake records on all computers (Irrera and Chavez-Dreyfuss, 2017).

There are many differences between Bitcoin and Ethereum. For example, Bitcoins cannot be more than 21 million in number, while the amount of Ethereum is unlimited. Blocks for storing information in the Ethereum system appear every 10 to 15 seconds, in contrast to Bitcoin, which takes some 10 minutes to make a new block.

Another cryptocurrency Ripple is the fastest on the market. Most new cryptocurrencies appear due to small changes in the Bitcoin code, like Ethereum. But in the case of Ripple, the code was written from zero, under the order of venture funds (investment funds focused on working with innovative enterprises and projects, investing in securities or shares of enterprises with a high degree of risk in anticipation of extremely high profits) (Irrera and Chavez-Dreyfuss, 2017; Chohan, 2017).

Ripple was created to increase the speed of banking operations and save on them. The calculator on the official Ripple website shows that if the bank’s turnover is $5 million, and the number of transactions is 300 thousand per year, then one can save $3.4 per transaction. A bank can save more than a million dollars a year.

The Ripple technology is already being used by Bank of America and HSBC (Irrera and Chavez-Dreyfuss, 2017; Chohan, 2017). Unlike Bitcoin and Etherium, Ripple cryptocurrencies cannot be mined. This is a centralized system where all digital money already exists and belongs to one company, Ripple Lab. Currently, there are more than 38 billion units of cryptocurrency.

And whileBitcoin and Ethereum systems require vain mathematical calculations to “slow down” the creation of new blocks, Ripple Lab gives cryptocurrency as useful calculations - processing scientific data from different universities.

Litecoin appeared in 2011 thanks to the former Google engineer, Charles Lee. Litecoin, like Ethereum, is a Bitcoin hard fork outcome. One of the few differences of Lightcoin is the speed of transaction processing: it is faster than that of Bitcoin. In Bitcoin, blocks are created every 10 minutes; in Litecoin, this happens faster: every 2.5 minutes. That is why Litecoin can process more transactions than in the Bitcoin system. The number of cryptocurrencies is limited, and cannot exceed 84 million units.

3.4 Legal status of cryptocurrencies in various currencies

As a rule, the current legal status of cryptocurrencies is different in various countries and very often unclear. Cryptocurrency transactions are officially permitted in a number of countries. They are usually regarded as a good or investment asset and are subject to the relevant legislation for tax purposes. Sometimes Bitcoins are recognized as a currency (for example, in Germany), whereas in other countries (for example, Japan) Bitcoin is a legal tender with the purchase tax applied to it. In other countries (for example, China), operations with bitcoins are prohibited for banks, but allowed for individuals, while China is a leader in mining due to the availability of the largest production capacities. In Switzerland, the same rules apply to cryptocurrencies as to foreign currencies, and this country is one of the most favorable jurisdictions for Bitcoin startups and public blockchains. In Russia, as of 2017, there are no restrictions on the use of bitcoins. (*Regulation of Cryptocurrency Around the World*, 2018).

The practice of regulating the cryptocurrency market differs in various countries.Few sovereign regulators have developed specific solutions, and judicial precedents usually apply. In the European Union, transactions with bitcoins are considered as payment transactions with currencies, coins and banknotes, and Bitcoin is not classified as a taxable asset.

On October 22, 2015, the European Court of Justice ruled that transactions for exchanging Bitcoins for fiat currencies are exempt from VAT. The court decision clarifies that the VAT law applies to the supply of goods and the provision of services. Transactions in Bitcoins were attributed to payment transactions with currencies, coins and banknotes, and therefore are not subject to VAT. The court recommended that all EU member states exclude cryptocurrencies from taxable assets (*Regulation of Cryptocurrency Around the World*, 2018).

On November 27, 2017, the Act *On Combating Money Laundering and the Financing of Terrorism* came into force in Estonia, which provides for the possibility to provide services related to cryptocurrency and virtual values, based on the licenses of the "Virtual Wallet Service Provider" and "Exchange Service Provider". Licenses are issued by the Estonian Police and Border Guard Board (*Regulation of Cryptocurrency Around the World*, 2018).

In late August 2013, the Federal Ministry of Finance of the Federal Republic of Germany issued a statement stating that Bitcoin cannot be classified as electronic or foreign currency, but is more suitable for private money, which can be used to carry out multilateral clearing operations (*Regulation of Cryptocurrency Around the World*, 2018).

The National Bank of Croatia believes that Bitcoin is legal in Croatia, but it should not be regarded as electronic money, although it has some similarities with them. Cryptocurrencies can be legally used in the country, although they cannot be considered legal tender, that is, sellers are not required to accept them in Croatia along with the local currency (*Regulation of Cryptocurrency Around the World*, 2018).

Until March 2014, the Bank of Japan had no plans regarding the regulation of Bitcoin circulation. However, after the collapse of Mt. Gox based in Tokyo, Japanese authorities announced the need to regulate this market. The development of tax rules is expected (*Regulation of Cryptocurrency Around the World*, 2018).

According to a company from Bangkok, Bitcoin Co. Ltd., the Bank of Thailand, stated that operations with it require a license to conduct currency exchange operations, refusing to issue it, although it did not recognize Bitcoin as an independent currency. On July 29, 2013, the company suspended its exchange service. The company's website, citing a representative of the Bank of Thailand, declares that "due to the lack of legal grounds, buying/selling bitcoins, buying/selling any goods or services in exchange for bitcoins, sending bitcoins outside of Thailand, or accepting bitcoins from outside is illegal in Thailand" (*Regulation of Cryptocurrency Around the World*, 2018).

On December 5, 2013, the People's Bank of China banned Chinese financial companies from conducting Bitcoin transactions (*Regulation of Cryptocurrency Around the World*, 2018). The statement stated that Bitcoin is not a currency in the real sense of the word. Financial companies are prohibited not only to conduct operations with bitcoins, but also to publish quotes or insure financial products related to Bitcoin. At the same time, individuals are free to participate in online transactions at their own risk. At the same time, bitcoins are regarded as a kind of product, but not cash (*Regulation of Cryptocurrency Around the World*, 2018).At the end of March 2014, the People's Bank of China issued a circular according to which by April 15, 2014, Chinese banks and payment systems should close the accounts of fifteen Chinese websites that sell bitcoins. Disobedience would be punished, but the People's Bank of China did not specify how. The accounts were closed.

In official reports of the World Bank and the FBI, Bitcoin is considered a “virtual currency” (FBI, 2012) According to the FinCEN,a part of the US Treasury Department, Bitcoin is classified as “decentralized virtual currencies.”

In March 2013, FinCEN announced that transactions for exchanging any cryptocurrency for fiat money should be regulated in the same way as transactions for exchanging fiat money among themselves (for example, dollars for euros). Not only Bitcoin exchanges, but also exchange offices must register as a Money Service Business and report suspicious transactions to law enforcement agencies. Several U.S. exchange services, such as BitInstant, were forced to close before receiving the appropriate financial licenses (*Regulation of Cryptocurrency Around the World*, 2018).

Singapore tax authorities equated transactions with bitcoins with operations taxed on goods and services. A standard income tax is planned to be levied on companies involved in the purchase and sale of bitcoins. Long-term investing in bitcoins, equivalent to investing in capital, will not be taxed. When exchanging bitcoins for real goods and services, a 7% tax on goods and services will be levied (for non-residents, a tax on goods and services does not arise). The tax on goods and services will not be subject to the purchase of virtual goods and services, such as in-app purchases, for Bitcoins (*Regulation of Cryptocurrency Around the World*, 2018).

3.5 Advantages, risks and role of cryptocurrencies

Cryptocurrencies are not like any other asset. They use blockchain technology, new to humanity, which has made them a competitive alternative to bank transfers, electronic payment systems, and even government money (Brito and Castillo, 2013; Chohan, 2017). Compared to existing financial instruments, cryptocurrencies have several advantages.

Most cryptocurrencies function in a decentralized way, according to the algorithm laid down in them. They are not controlled by government bodies, and all communication centers have the same rights and are equal to each other. In networks such as Bitcoin, even the developers cannot change the algorithm of their functioning.

Transactions in cryptocurrency systems are carried out according to the P2P principle, without the participation of a central controlling authority. Reducing the costs of network maintenance can significantly reduce the commission for transfers. Unlike banking and electronic payment systems, users have the ability to independently set the size of the commission and even send transactions without it (Brito and Castillo, 2013; Chohan, 2017).

Cryptocurrency transactions have a high processing speed. In addition, after adding a transaction to the blockchain, it becomes irreversible. The irreversibility of transactions allows preventing falsification of records and fraud in the system.

Confidentiality is one of the main advantages of cryptocurrencies. To use the system, there is no need to specify any personal data, which allows maintaining anonymity and hide expenses from the government, financial institutions or marketing companies (Brito and Castillo, 2013).

Access to crypto coins on the wallet can be obtained only by providing a private key, which is located only with the owner. This means that no one can write off coins from the account or freeze their movement. Cryptocurrencies can become a means of protecting the capital. In the case the bank where the savings were stored declares bankrupt, or the government dishonestly performs its duties, the coins on the cryptocurrency wallet remain subservient to the user and thus become financial insurance (Brito and Castillo, 2013; Chohan, 2017).

When paying for goods and services, the buyer always risks his or her personal data, which can be intercepted at the time of payment or stolen from the seller, and subsequently used against the owner. In cryptocurrency transactions, no personal data is transmitted to the seller, so you can be sure that the information does not fall into the hands of attackers.

Cryptocurrencies have a sophisticated inflation prevention mechanism. In particular, in the Bitcoin network, inflation is prevented by several features: a limited issue of 21 million coins, which cannot be changed; new coins are issued strictly every 10 minutes; every 4 years, the issue of coins is halved.Each cryptocurrency network has similar methods, which allows you to predict in advance how many coins will exist in a certain period of time. In addition, there is no controlling body that could take a sole decision to increase emissions (Brito and Castillo, 2013; Chohan, 2017).

Digital coins have a new mechanism, which is designed to solve the shortcomings of other payment systems: in particular, to increase the speed of transactions, minimize costs, increase security, as well as implement the sending of micropayments to any corner of the world with minimal fees. The source codes of cryptocurrencies are presented in the public domain, which means that any developer can use them to create more advanced systems, which will inevitably lead to the improvement of financial models. In addition, the blockchain technology used in most cryptocurrencies can be applied in any industry where data protection and storage are required. Already, research is being carried out on its implementation in the banking system, the real estate market and insurance (Chohan, 2017).

But despite all the advantages, like any technology, cryptocurrencies are not without a number of disadvantages. Currently, the rate of cryptocurrencies is very variable and can change over a wide range over short intervals. It is likely that the initial volatility is caused by the novelty of the asset and, as the number of users increases, the cryptocurrency rate will become more stable.

Since cryptocurrencies exist in digital form, they can become the prey of cybercriminals. Cryptocurrency services must have a high level of security to prevent theft. It should be noted that this vulnerability is not caused by the very features of cryptocurrencies, but by the security of storing access keys. Cryptocurrency networks are also subject to the so-called 51% attack, when most of the network's power is concentrated in the hands of one person and he has the right to independently make decisions about transactions (Brito and Castillo, 2013; Chohan, 2017). This situation is fraught with double waste, obstructing the transactions of other users and selfish mining.

Confidentiality and decentralization of cryptocurrencies have repeatedly been reproached by them, since this makes them an attractive means of payment for the criminal world and a means of money laundering.

Therefore, cryptocurrencies have become a serious financial instrument which is considered safe and cheap in terms of transactions expenses, and is absolutely independent from governments. However, their rates are volatile, they are sometimes used for money laundering, and outcomes of their wide use cannot be predicted.

4. Practical Part

The purpose of the analysis provided in the practical part of the thesis is developing a theoretical model of possible Bitcoin rate's dependence on rates of some other cryptocurrencies (Ethereum, XRP/Ripple, LiteCoin), world prices of energy resources such as Brent oil, prices of precious metals such as gold and silver as well as on main indicators of economic performance: Dow Jones, Nasdaq, and S&P 500. The general underlying idea is to try to analyze whether Bitcoin can be regarded as a reliable tool of investment via possible prediction of its price based on prices of other financial and real assets generally accepted as investment goods by individual and institutional investors. The hypothesis is that price of Bitcoin at least moderately correlates with prices of other cryptocurrencies due to the similar economic nature of these assets and their frequent interchangeability from the perspective of individual and institutional investors; at the same time, price of Bitcoin shows no significant correlation with global prices of other investment assets such as energy resources and precious metals; neither does Bitcoin price correlate with main integratedindicators of economic performance.

The hypothetical model researched is as follows:

Bitcoin price = f (Ethereum price; XRP/Ripple price;LiteCoin price; Brent Oil price; gold price; silver price; Dow Jones indicator; Nasdaq indicator; S&P 500 indicator)

Theoretically, prices of main cryptocurrencies should be tied to each other to some extent, and the rise in the price of one cryptocurrency should beget the rise in the price of others. As for oil, rise in its price usually causes rise of dollar (and thus depreciation of a national currency) in oil-dependent countries, i.e. countries which depend on imports of oil needed for their economies such as China or Japan. A similar phenomenon is observed in the case of economic growth featured by increase of indicators of economic performance such as Dow Jones, Nasdaq, and S&P 500. As long as emergence of cryptocurrencies is regarded as a way or attempt to get rid of centralized bank systems, the rise of dollar can theoretically cause increase of demand for decentralized currencies. In this case, dollar and any cryptocurrency are substitutes. However, rise of dollar usually occurs in some countries whereas it does not occur in others at the same time.

4.1 Correlation between Bitcoin and other financial instruments

4.1.1 Correlation between Bitcoin and main cryprocurrencies

Table 4.1 Prices of main cryptocurrencies (Bitcoin, Ethereum, XRP/Ripple, LiteCoin) in 2014-2019, U.S. dollars

Quarter	Date	Bitcoin	Ethereum	XRP / Ripple	LiteCoin
1	01.01.2014	754.97	-	0.027365	24.35
2	01.04.2014	457	-	0.008785	12.77
3	01.07.2014	641.39	-	0.00378	8.96
4	01.10.2014	387.43	-	0.004645	4.47
5	01.01.2015	320.43	-	0.024455	2.72
6	01.04.2015	244.22	-	0.007772	1.65
7	01.07.2015	263.35	-	0.011317	4.09
8	01.10.2015	236	0.734307	0.005518	3.01
9	01.01.2016	430.72	0.933712	0.00604	3.48
10	01.04.2016	416.76	11.4	0.007391	3.25
11	01.07.2016	672.52	12.44	0.006651	4.19
12	01.10.2016	609.93	13.2	0.008839	3.85
13	01.01.2017	963.66	7.98	0.006523	4.33
14	01.04.2017	1071.71	50.03	0.021743	6.65
15	01.07.2017	2492.6	293.35	0.262855	40.4
16	01.10.2017	4341.05	301.55	0.197622	55.14
17	01.01.2018	14112.2	755.76	2.3	231.67
18	01.04.2018	7003.06	397.25	0.513854	116.9
19	01.07.2018	6411.68	455.24	0.465944	81.5
20	01.10.2018	6619.85	233.22	0.583511	61.1
21	01.01.2019	3746.71	133.42	0.352512	30.46
22	01.04.2019	4105.36	141.47	0.309195	60.77
23	01.07.2019	10796.9	290.27	0.3959	122.11
24	01.10.2019	8299.72	180.21	0.256213	56.09

Source: (CoinMarketCap, 2019)

This means that currency depreciation is usually a local and relative phenomenon reflecting rise of demand for some currencies and fall of demand for others. For this reason, any changes in cross-currency rates can hardly exert significant influence on Bitcoin prices as well as prices of other cryptocurrencies.

Correlation and regression analyses have been chosen as main methods of research. These methods allow of assessing the availability of interrelation between selected factors and results (function), evaluate the quality of developed econometric models and make the extrapolation of the results. The analysis will be based on 2014-2019 figures.

Table 4.1 illustrates Prices of main cryptocurrencies (Bitcoin, Ethereum, XRP/Ripple, LiteCoin) in 2014-2019. As analysis of the table shows, Bitcoin price demonstrates a very fast growth pace: its quarterly rise was $328 (11%). Ethereum price rose by 27% quarterly ($11.2), but Table 4.1 reflects both the lowest and the highest historical prices of Ethereum which emerged in 2015. Bitcoin emerged in 2009, and if its whole historical chart was taken into account, growth pace of its price would appear even more striking. Conversely, LiteCoin rose only by 3.7% ($1.38) quarterly and nearly doubled in 2014-2019, although it also experienced a time of price peak in the beginning of 2018 when its price was more than 4 times higher than today (in the end of 2019).

The interrelation of prices of Bitcoin and other cryptocurrencies can be research with the aid of correlation coefficients:

$$r_{xy} = b\frac{\sigma_x}{\sigma_y} = \frac{\mathrm{cov}(x,y)}{\sigma_x\sigma_y} = \frac{yx - y\cdot x}{\sigma_x\sigma_y} \quad (4.1)$$

The closer the correlation coefficient to 1, the larger the interrelation between factors and results. Estimations of the conjugated correlation coefficient are shown in Table 4.2.

Table 4.2 Estimations of the conjugated correlation coefficient between *y*and*x1*

Quarter	**y**	**x1**	**yx1**	**x1^2**	**y^2**
1	755.0	-	-	-	-
2	457.0	-	-	-	-
3	641.4	-	-	-	-
4	387.4	-	-	-	-

5	320.4	-	-	-	-
6	244.2	-	-	-	-
7	263.4	-	-	-	-
8	236.0	0.7	173.3	0.5	55696.0
9	430.7	0.9	402.2	0.9	185519.7
10	416.8	11.4	4751.1	130.0	173688.9
11	672.5	12.4	8366.1	154.8	452283.2
12	609.9	13.2	8051.1	174.2	372014.6
13	963.7	8.0	7690.0	63.7	928640.6
14	1071.7	50.0	53617.7	2503.0	1148562.3
15	2492.6	293.4	731204.2	86054.2	6213054.8
16	4341.1	301.6	1309043.6	90932.4	18844715.1
17	14112.2	755.8	10665436.3	571173.2	199154188.8
18	7003.1	397.3	2781965.6	157807.6	49042849.4
19	6411.7	455.2	2918853.2	207243.5	41109640.4
20	6619.9	233.2	1543881.4	54391.6	43822414.0
21	3746.7	133.4	499886.0	17800.9	14037835.8
22	4105.4	141.5	580785.3	20013.8	16853980.7
23	10796.9	290.3	3134024.9	84256.7	116573697.4
24	8299.7	180.2	1495692.5	32475.6	68885352.1
Average	3141.6	192.9	1514342.6	77951.6	33991419.6

Source: own calculation

We can calculate the correlation this way:

$$ryx1 = \frac{1514342.6 - 3141.6 \times 192.9}{\sqrt{(77951.6 - 192.9^2)(33991419.6 - 3141.6^2)}} = 0.891 \quad (4.2)$$

The actual results of the cross-cryptocurrency correlation analysis is shown in Table 4.3

Table 4.3 Conjugated correlation coefficient matrix between prices of Bitcoin and other cryptocurrencies (Ethereum, XRP/Ripple, LiteCoin) in 2014-2019

Currency	Bitcoin	Ethereum	XRP / Ripple	LiteCoin
Bitcoin	1.000	-	-	-
Ethereum	0.891	1.000	-	-
XRP / Ripple	0.831	0.879	1.000	-
LiteCoin	0.945	0.940	0.919	1.000

Source: own calculation

As Table 4.3 illustrates, there is a relatively strong direct relationship between prices of Bitcoin and other cryptocurrencies (Ethereum, XRP/Ripple, and LiteCoin): rise of price of any other cryptocurrency positively influences Bitcoin price, and vice versa. LiteCoin price correlates with Bitcoin price the most.

Additionally, it should be noted that significant interdependence of prices of Bitcoin and other cryptocurrencies on global markets causes the emergence of multicollinearity among factors (the correlation coefficient exceeds 0.8). The presence of multicollinearity in an econometric model would distort estimations of regression parameters. In order to get rid of multicollinearity, the best solution would be to level the duplication of factors by choosing the price of LiteCoin as the main factor which influences the price of Bitcoin the most (there is a 0.945 correlation value between these two variables).

4.1.2 Correlation between Bitcoin, and investment goods

Now, the interrelation among prices of Bitcoin, prices of Brent Oil, and prices of gold and silver can be analyzed based on their historical magnitudes in 2014-2019 (Table 4.4).

Table 4.4 Prices of Bitcoin, Brent Oil, gold and silver in 2014-2019, U.S. dollars

Quarter	Date	Bitcoin	Oil (Brent)	Gold	Silver
1	01.01.2014	754.97	106.4	1398.9	19.105
2	01.04.2014	457	108.07	1431.8	19.119
3	01.07.2014	641.39	106.02	1411.5	20.373
4	01.10.2014	387.43	85.86	1265.9	16.077
5	01.01.2015	320.43	52.99	1336.6	17.192
6	01.04.2015	244.22	66.78	1242	16.124

7	01.07.2015	263.35	52.21	1154.1	14.746
8	01.10.2015	236	49.56	1176.8	15.566
9	01.01.2016	430.72	34.74	1146.2	14.229
10	01.04.2016	416.76	48.13	1327.7	17.789
11	01.07.2016	672.52	42.46	1401.8	20.312
12	01.10.2016	609.93	48.3	1319.3	17.762
13	01.01.2017	963.66	55.7	1269.5	17.512
14	01.04.2017	1071.71	51.73	1324.2	17.191
15	01.07.2017	2492.6	52.65	1317.2	16.75
16	01.10.2017	4341.05	61.37	1320.6	16.645
17	01.01.2018	14112.2	69.05	1401.7	17.204
18	01.04.2018	7003.06	75.17	1377.8	16.312
19	01.07.2018	6411.68	74.25	1270.1	15.5
20	01.10.2018	6619.85	75.47	1250.8	14.229
21	01.01.2019	3746.71	61.89	1350	16.022
22	01.04.2019	4105.36	72.8	1303.6	15.069
23	01.07.2019	10796.9	65.17	1437.8	16.533
24	01.10.2019	8299.72	60.23	1514.8	18.067
Average		**3081.39**	**64.94**	**1317.12**	**16.82**

Source: (Investing.Com, 2019)

As Table 4.4 shows, in 2014-2019, the average price of Brent Oil equalled $65. The average prices of gold and silver were $1317.12 and $16.82, respectively. Because price of a good and the growth pace of this price to some extent reflect demand for a good, one can conclude that demand for cryptocurrencies including Bitcoin significantly exceeded demand for energy resources and precious metals in 2014-2019, in demand growth terms.

The possible presence and extent of interrelation among analyzed variables can be calculated by determining conjugated correlation coefficients (Table 4.5).

Table 4.5 Conjugated correlation coefficient matrix between prices of Bitcoin, Brent oil, gold, and silver in 2014-2019

Good	Bitcoin	BrentOil	Gold	Silver
Bitcoin	1	-	-	-
BrentOil	0.0829149	1	-	-
Gold	0.4272195	0.4056628	1	-
Silver	-0.173112	0.3379501	0.715135	1

Source: own calculation

As the correlation analysis of the Table 4.5 shows, no factor significantly influences the result. That is why prices of oil, gold and silver cannot be factors of econometric models which research impact of factors on Bitcoin price. Table 4.5 also shows that among these factors, only gold price shows anynoteworthy, though very weak (0.4272195), relation to Bitcoin price, which can, however, be neglected. Silver and gold prices held the strongest interrelation (0.715135), but they have nothing to do with Bitcoin or other cryptocurrencies.

4.1.3 Correlation between Bitcoin and basic economic pefromance indicators

Another important consideration is that Bitcoin price can be related to economic performance indicators such as Dow Jones, NASDAQ, and S&P 500. Their historical figures are shown in Table 4.6.

Table 4.6 Dynamics of basic economic performance indicators (Dow Jones, NASDAQ, and S&P 500) in 2014-2019

Quarter	Date	Dow Jones	NASDAQ	S&P 500
1	01.01.2014	15698.85	4103.88	1782.59
2	01.04.2014	16580.84	4114.56	1883.95
3	01.07.2014	16563.3	4369.77	1930.67
4	01.10.2014	17390.52	4630.74	2018.05
5	01.01.2015	17164.95	4635.24	1994.99
6	01.04.2015	17840.52	4941.42	2085.51
7	01.07.2015	17689.86	5128.28	2103.84

8	01.10.2015	17663.54	5053.75	2079.36
9	01.01.2016	16466.3	4613.95	1940.24
10	01.04.2016	17773.64	4775.36	2065.3
11	01.07.2016	18432.24	5162.13	2173.6
12	01.10.2016	18142.42	5189.14	2126.15
13	01.01.2017	19864.09	5614.79	2278.87
14	01.04.2017	20940.51	6047.61	2384.2
15	01.07.2017	21891.12	6348.12	2470.3
16	01.10.2017	23377.24	6727.67	2575.26
17	01.01.2018	26149.39	7411.48	2823.81
18	01.04.2018	24163.15	7066.27	2648.05
19	01.07.2018	25415.19	7671.79	2816.29
20	01.10.2018	25115.76	7305.9	2711.74
21	01.01.2019	24999.67	7281.74	2704.1
22	01.04.2019	26592.91	8095.39	2945.83
23	01.07.2019	26864.27	8175.42	2980.38
24	01.10.2019	27046.23	8292.36	3037.56
Average growth		2.4	3.1	2.3

Source: (Investing.Com, 2019)

During the 2014-2019 period, NASDAQ demonstrated the fastest growth pace. All of the indicators reflect economic growth, though. This growth may contribute to the rising demand for cryptocurrencies via increases in incomes of individual and institutional investors.

Table 4.7 shows correlation coefficients between price of Bitcoin and economic performance indicators: Dow Jones, NASDAQ, and S&P 500.

Table 4.7 Conjugated correlation coefficient matrix between price of Bitcoin and economic performance indicators: Dow Jones, NASDAQ, and S&P 500, in 2014-2019

Currency / Indicator	**Bitcoin**	**Dow Jones**	**NASDAQ**	**S&P 500**

Bitcoin	1	-	-	-
Dow Jones	0.85726	1	-	-
NASDAQ	0.82591	0.992970008	1	-
S&P 500	0.8378	0.994741224	0.99732866	1

Source: own calculation

As the analysis of the correlation matrix of Table 4.7 shows, there is a relatively strong relationship between Bitcoin and economic performance indicators. Moreover, a very strong interrelation exists among economic performance indicators per se: each of the correlation coefficient exceeds 0.99. This means there is multicollinearity between these factors. In order to get rid of duplication, only the Dow Jones indicator can be preserved for further analysis as the factor which correlates with Bitcoin price the most (0.85726). However, it should be noted that both NASDAQ and S&P 500 indicators show almost the same extent of correlation with Bitcoin price (0.82591 and 0.8378, respectively). But the necessity of getting rid of multicollinearity requires preservation of only Dow Jones as the strongest factor.

4.1.4 Correlation results

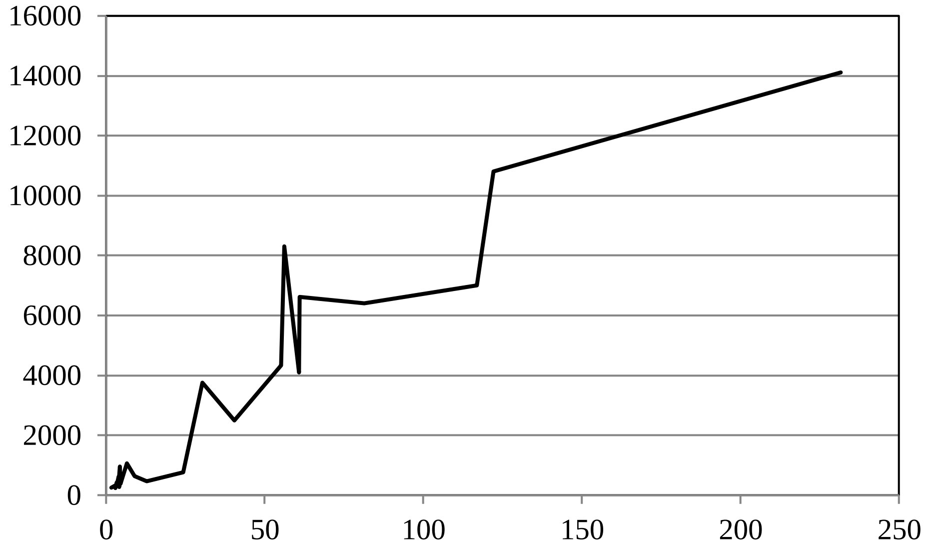
Taking into account all the findings received during the analysis, a conclusion can be drawn that among nine factors belonging to three groups selected as possible influencers on Bitcoin price, only prices of other cryptocurrencies and economic performance indicators have relatively strong correlation with Bitcoin price; prices of global goods such as oil, gold, or silver, have no correlation with Bitcoin price. cryptocurrencies and economic performance indicators, price of LiteCoin and value of Dow Jones indicator can be regarded as basic influencing factors; prices of other cryptocurrencies and other economic performance indicators correlate indeed with Bitcoin price as well, but taking them into account for further analysis would duplicate data and distort results. Therefore, price of LiteCoin and value of Dow Jones indicator should be selected as factors which will be used in an attempt to predict future prices of Bitcoin.

4.2 Dependence of Bitcoin price on different factors

4.2.1 Dependence of Bitcoin price on Litecoin and Dow jones indicator

A graphic representation of the interrelations between Bitcoin price and LiteCoin price as well as between Bitcoin price andthe value of Dow Jones indicator can be built using econometric methods. Figure 4.1 shows the interrelation between Bitcoin price and LiteCoin price.

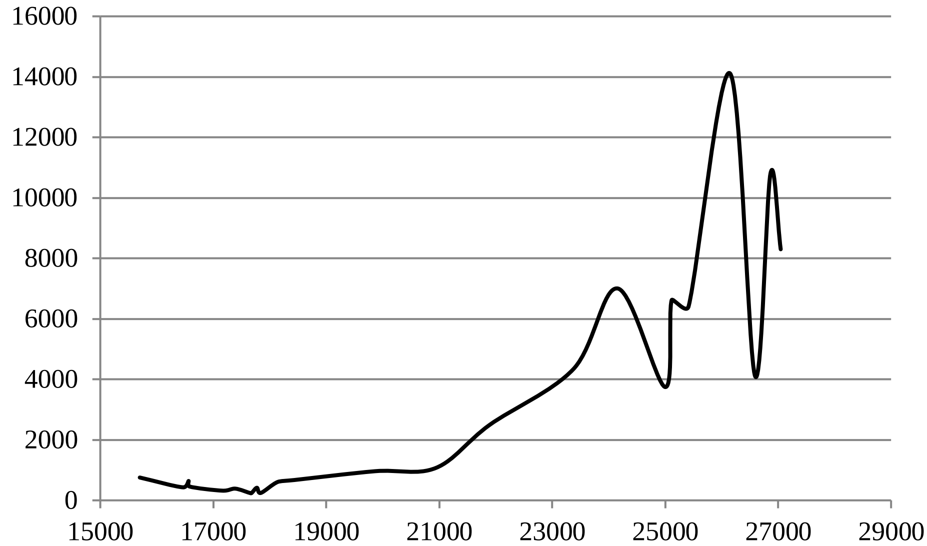
Fig. 4.1 Interrelation between Bitcoin price and LiteCoin price



Source: own calculation

Figure 4.2 illustrates the interrelation between Bitcoin price and Dow Jones indicator.

Fig. 4.2 Interrelation between Bitcoin price and Dow Jones indicator



Source: own calculation

As Figures 4.1 and 4.2 show, the value of function varies with respect to medium magnitudes of factors.A linear regression equation can be used for analysis:

$$y = a + b1 \times x1 + b2 \times x2 \quad (4.3)$$

Basic calculations are shown in Table 4.8 which reflects the development of the multiple correlation of the linear regression equation.

Table 4.8 Multiple correlation of the linear regression equation

Y	*x1*	*x2*	*x1^2*	*x2^2*	*yx1*	*yx2*	*x1x2*
754.97	24.35	15698.85	592.92	246453891.32	18383.52	11852160.78	382267.00
457.00	12.77	16580.84	163.07	274924255.11	5835.89	7577443.88	211737.33
641.39	8.96	16563.30	80.28	274342906.89	5746.85	10623534.99	148407.17
387.43	4.47	17390.52	19.98	302430185.87	1731.81	6737609.16	77735.62
320.43	2.72	17164.95	7.40	294635508.50	871.57	5500164.93	46688.66
244.22	1.65	17840.52	2.72	318284153.87	402.96	4357011.79	29436.86
263.35	4.09	17689.86	16.73	312931146.82	1077.10	4658624.63	72351.53
236.00	3.01	17663.54	9.06	312000645.33	710.36	4168595.44	53167.26
430.72	3.48	16466.30	12.11	271139035.69	1498.91	7092364.74	57302.72
416.76	3.25	17773.64	10.56	315902278.85	1354.47	7407342.21	57764.33
672.52	4.19	18432.24	17.56	339747471.42	2817.86	12396050.04	77231.09

609.93	3.85	18142.42	14.82	329147403.46	2348.23	11065606.23	69848.32
963.66	4.33	19864.09	18.75	394582071.53	4172.65	19142228.97	86011.51
1071.71	6.65	20940.51	44.22	438504959.06	7126.87	22442153.97	139254.39
2492.60	40.40	21891.12	1632.16	479221134.85	100701.04	54565805.71	884401.25
4341.05	55.14	23377.24	3040.42	546495350.02	239365.50	101481767.70	1289021.01
14112.20	231.67	26149.39	53670.99	683790597.37	3269373.37	369025421.56	6058029.18
7003.06	116.90	24163.15	13665.61	583857817.92	818657.71	169215989.24	2824672.24
6411.68	81.50	25415.19	6642.25	645931882.74	522551.92	162954065.42	2071337.99
6619.85	61.10	25115.76	3733.21	630801400.38	404472.84	166262563.84	1534572.94
3746.71	30.46	24999.67	927.81	624983500.11	114124.79	93666513.59	761489.95
4105.36	60.77	26592.91	3692.99	707182862.27	249482.73	109173469.00	1616051.14
10796.93	122.11	26864.27	14910.85	721689002.63	1318413.12	290051642.69	3280396.01
8299.72	56.09	27046.23	3146.09	731498557.21	465531.29	224476136.06	1517023.04
75399.25	**943.91**	**499826.51**	**106072.57**	**10780478019.22**	**7556753.37**	**1875894266.56**	**23346198.52**

Source: own calculation

The regression equation will be as follows:

$$y = -5944.9 + 48.11X1 + 0.35X2 + e$$

This means that Bitcoin price increases by 48.11 units when the LiteCoin price increases by 1 unit, provided the fixed value of the *X2* factor. Similarly, Bitcoin price increases by 0.35 units when the Dow Jones indicator increases by 1 unit, provided the fixed value of the *X1* factor.

In order to better determine the extent of influence of these factors on Bitcoin price, relative values measuring interrelations in a multifactor econometric model can be used based on partial correlation indexes:

$$ryx1 \cdot x2 = \frac{ryx1 - ryx2 \times rx1x2}{\sqrt{(1-r^2yx2)\times(1-r^2x1x2)}} = 0.91 \quad (4.4)$$

$$ryx2 \cdot x1 = \frac{ryx2 - ryx1 \times rx1x2}{\sqrt{(1-r^2yx1)\times(1-r^2x1x2)}} = 0.75 \quad (4.5)$$

Therefore, when there is an additional factor in the model, an inference can be drawn that LiteCoin price exerts more significant influence (namely 0.91) on the Bitcoin price than Dow Jones indicator (0.75).

Given the probability level of 95%, a hypothesis of the adequacy of the equation can be accepted within the analysis (F=213.2, the critical value of the F-distribution equals 3.47).

The statistical significance of the regression equation is confirmed by Student's t-test:

0.35 48.11 -5,944.97

(0.07) (4.87) (1262.35)

For the significance level of 5% and degrees of freedom of 21 all regression parameters exceed Student's factor of 2.08.

The quality of the model is confirmed by the high level of the determination coefficient R^2, which equals 0.95. This means that 95% of the results' variation is explained by variations of selected factors. Other factors account for only 5%.

The model can be assessed against the presence of heteroscedasticity (Tables 4.9 and 4.10) and autocorrelation (Table 4.11).

Table 4.9 assesses the model against the presence of heteroscedasticity with the aid of Goldfeld-Quandt test (LiteCoin being a factor).

Table 4.9 Heteroscedasticity and the Goldfeld-Quandt test (LiteCoin being a factor)

LiteCoin	***Bitcoin***	***Estimated Y, groups***	***E, groups***	***E^2, groups***
1.65	244.22	170.06	74.16	5499.50
2.72	320.43	334.22	-13.79	190.18
3.01	236	378.71	-142.71	20366.87
3.25	416.76	415.53	1.23	1.50
3.48	430.72	450.82	-20.10	404.01
3.85	609.93	507.59	102.34	10474.44
4.09	263.35	544.41	-281.06	78992.53
4.19	672.52	559.75	112.77	12717.50
4.33	963.66	581.23	382.43	146255.08

4.47	387.43	602.71	-215.28	46343.62	Σ321245.23

30.46	3746.71	3863.76	-117.05	13700.71	
40.40	2492.60	4391.66	-1899.06	3606429.94	
55.14	4341.05	5174.48	-833.43	694609.19	
56.09	8299.72	5224.94	3074.78	9454300.21	
60.77	4105.36	5473.48	-1368.12	1871763.36	
61.10	6619.85	5491.01	1128.84	1274279.99	
81.50	6411.68	6574.43	-162.75	26486.55	
116.90	7003.06	8454.47	-1451.41	2106602.80	
122.11	10796.93	8731.17	2065.76	4267363.24	
231.67	14112.20	14549.76	-437.56	191456.07	Σ23506992.06

Source: own calculation

Table 4.10 assesses the model against the presence of heteroscedasticity with the aid of Goldfeld-Quandt test (Dow Jones indicator being a factor).

Table 4.10 Heteroscedasticity and the Goldfeld-Quandt test (Dow Jones indicator being a factor)

Dow Jones	***Bitcoin***	***Estimated Y, groups***	***E, groups***	***E^2, groups***	
15698.85	754.97	699.26	55.71	3103.71	
16466.3	430.72	541.80	-111.08	12339.26	
16563.3	641.39	521.90	119.49	14277.66	
16580.84	457	518.30	-61.30	3757.96	
17164.95	320.43	398.46	-78.03	6088.84	
17390.52	387.43	352.18	35.25	1242.49	
17663.54	236	296.17	-60.17	3619.93	
17689.86	263.35	290.77	-27.42	751.63	
17773.64	416.76	273.58	143.18	20501.43	
17840.52	244.22	259.86	-15.64	244.46	Σ65927.36
21891.12	2492.6	2555.34	-62.74	3936.18	
23377.24	4341.05	4480.97	-139.92	19579.00	

24163.15	7003.06	5499.32	1503.74	2261246.77	
24999.67	3746.71	6583.23	-2836.52	8045870.01	
25115.76	6619.85	6733.66	-113.81	12952.17	
25415.19	6411.68	7121.64	-709.96	504047.75	
26149.39	14112.2	8072.98	6039.22	36472167.65	
26592.91	4105.36	8647.67	-4542.31	20632586.66	
26864.27	10796.93	8999.28	1797.65	3231528.60	
27046.23	8299.72	9235.06	-935.34	874858.83	Σ72058773.63

Source: own calculation

Calculation of the sums of the squares of the residuals for LiteCoin and Dow Jones indicator results in figures 73.2 and 1093, respectively. These figures exceed significantly the critical value of the F-test. This means there is a relation between each of the factors and a respective residual.Under the probability of 95%, the conclusion about the presence of heteroscedasticity of residuals for each of the selected factors can be drawn.

Because all data included in the model depend on the time factor, possible interrelation among residuals of each of the levels of the series can be checked. Let us put forward an H_0 hypothesis about the lack of autocorrelation of residuals. The model can be assessed using the Durbin-Watson test (Table 4.11).

Table 4.11 Assessment of the model using the Durbin-Watson test

Et	***Et-1***	***(Et-Et-1)^2***	***Et^2***
105.2402088	-	-	11075.5
59.71463951	105.2402088	2072.5775	3565.838
433.4680335	59.71463951	139691.6	187894.5
109.7635017	433.4680335	104784.62	12048.03
204.8818332	109.7635017	9047.497	41976.57
-53.22572941	204.8818332	66619.514	2832.978
-99.44165207	-53.2257294	2135.9115	9888.642
-65.73912955	-99.4416521	1135.86	4321.633
519.9569298	-65.7391295	343039.87	270355.2
65.43993778	519.9569298	206585.7	4282.385
48.46091067	65.43993778	288.28736	2348.46

102.3475248	48.46091067	2903.7672	10475.02
-161.7694437	102.3475248	69757.773	26169.35
-537.1886654	-161.769444	140939.59	288571.7
-1068.445789	-537.188665	282234.13	1141576
-442.5392424	-1068.44579	391759.01	195841
-122.1260949	-442.539242	102664.59	14914.78
-1023.378904	-122.126095	812256.63	1047304
-344.1368868	-1023.3789	461369.72	118430.2
948.9428326	-344.136887	1672055.2	900492.5
-409.9624931	948.9428326	1846623.7	168069.2
-2059.95415	-409.962493	2722472.5	4243411
1586.725031	-2059.95415	13298269	2517696
2202.966797	1586.725031	379753.91	4853063
		Σ23058461	Σ16076604

Source: own calculation

The value of the coefficient can be calculated using the Durbin-Watson formula:

$$d = \frac{\sum_{t=2}^{n}(Et-Et-1)^2}{\sum_{t=1}^{n} Et^2} = 1.43 \qquad (6)$$

The resulting value of the criterion falls into the range of the differential gap. In practice, this means presence of autocorrelation in residuals. The H_0 hypothesis should be refuted and denied.

The model cannot adequately assess the strength of each factor's influence on results due to the presence of heteroscedasticity and autocorrelation in residuals.

Therefore, the analysis provided above refuted any significant influence of all factors on Bitcoin price. This means there is a high level of probability of independence of Bitcoin price from standard indicators of economic growth and other factors analyzed in the model.

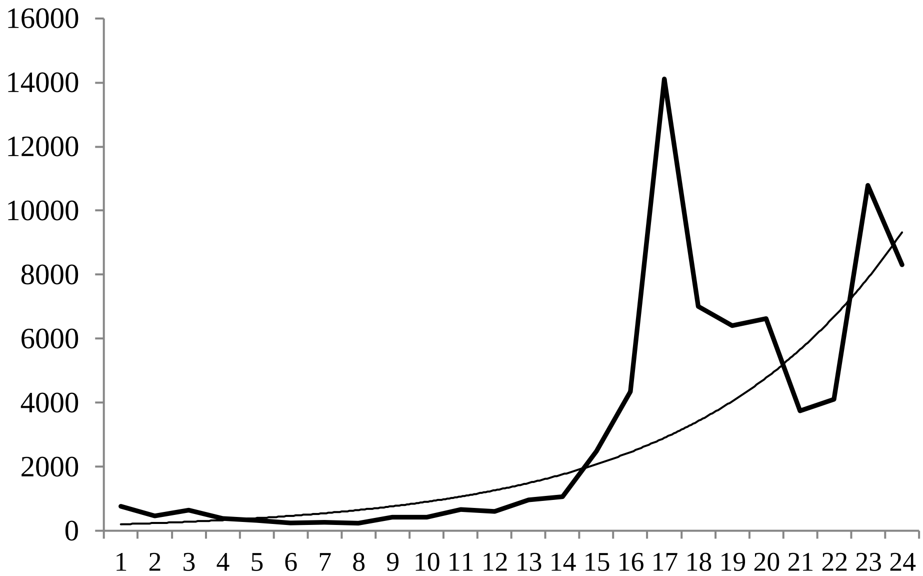
4.2.2 Dependence of Bitcoin price on time factor

Let us now consider possible dependence of Bitcoin price on time factor. The trend equation is needed for this purpose. Because basic differences of levels of the time series are not permanent, the nonlinear form fits the regression equation best (Fig. 4.3).

Taking into account the form of the curve in Fig. 4.3, the best-fitting form of the trend equation is the exponential equation: $y = ae^{bt}$. A system of equations of the following form should be elaborated:

$$\begin{cases} lny = nlna + b\sum t \\ \sum tlny = lna\sum t + b\sum t^2 \end{cases} (7)$$

Fig. 4.3 Dependence of Bitcoin price on time



Source: own calculation

Preliminary calculations required to get the regression equation are shown in Table 4.12.

The regression equation has the form of $Lny = 5.141655 + 0.166597t$. Or the same after translating the trend equation into the exponent form:

$$\hat{y} = 170.9985e^{0.166t} \qquad (8)$$

Parameter a characterizes the start level of the time series. Parameter b is the average of the growth coefficient of the levels of the series for a period of time. Therefore, the Bitcoin price rose 16.6% quarterly on average in 2014-2019.

Table 4.12 Calculations to get the trend equation

t	*Yt*	*ln Yt*	*t lnYt*	*t^2*
1	754.97	6.63	6.63	1
2	457	6.12	12.25	4
3	641.39	6.46	19.39	9
4	387.43	5.96	23.84	16
5	320.43	5.77	28.85	25
6	244.22	5.50	32.99	36
7	263.35	5.57	39.01	49
8	236	5.46	43.71	64
9	430.72	6.07	54.59	81
10	416.76	6.03	60.33	100
11	672.52	6.51	71.62	121
12	609.93	6.41	76.96	144
13	963.66	6.87	89.32	169
14	1071.71	6.98	97.68	196
15	2492.6	7.82	117.32	225
16	4341.05	8.38	134.01	256
17	14112.2	9.55	162.43	289
18	7003.06	8.85	159.37	324
19	6411.68	8.77	166.55	361
20	6619.85	8.80	175.96	400
21	3746.71	8.23	172.80	441
22	4105.36	8.32	183.04	484
23	10796.9	9.29	213.60	529
24	8299.72	9.02	216.58	576
Σ300	Σ 75399.3	Σ 173.379	Σ 2358.82	Σ 4900

Source: own calculation

Because the relation between the time factor and the Bitcoin price is most likely nonlinear, the empirical correlation ratio η can now be calculated. Its main difference from the linear coefficient of Pearson correlation is that it does not indicate a vector (direction) of the interrelation. The graph on Fig. 4.3 will help in solving this issue. Auxiliary calculations needed to determine the correlation are given in Table 4.13.

Table 4.13 Calculations of the correlation influence of the time factor on the Bitcoin price

Estimated Ln Y	*(Average LnYt-Y)^2*	*Et^2*	*(Estimated LnY- Average Y)*
5.31	0.36	1.74	3.67
5.47	1.21	0.42	3.06
5.64	0.58	0.68	2.50
5.81	1.60	0.02	2.01
5.97	2.12	0.04	1.56
6.14	2.98	0.41	1.17
6.31	2.72	0.54	0.84
6.47	3.10	1.02	0.56
6.64	1.34	0.33	0.34
6.81	1.42	0.60	0.17
6.97	0.51	0.21	0.06
7.14	0.66	0.53	0.01
7.31	0.12	0.19	0.01
7.47	0.06	0.25	0.06
7.64	0.36	0.03	0.17
7.81	1.33	0.32	0.34
7.97	5.43	2.50	0.56
8.14	2.66	0.51	0.84
8.31	2.38	0.21	1.17
8.47	2.48	0.11	1.56
8.64	1.01	0.17	2.01
8.81	1.20	0.24	2.50
8.97	4.26	0.10	3.06
9.14	3.24	0.01	3.67
Σ173.38	Σ 43.11	Σ 11.19	Σ 31.92

Source: own calculation

As a result:

$$\eta = \sqrt{\frac{\sum(\bar{y}-\hat{y}_t)^2}{\sum(y_t-\bar{y})^2}} = \sqrt{\frac{31.92}{43.11}} = 0.86 \quad (9)$$

Using the Chaddock scale and determining the dominant tendency between the factor and the product depicted in Fig. 4.3, a conclusion can be drawn that there is a relatively strong direct relation between time and the price of Bitcoin: each quarter, the price of Bitcoin increases, if analyzed on average.

Now the model quality can be assessed using the determination coefficient R^2:

$$R^2 = 1 - \frac{\sum Et^2}{\sum(y_t-\bar{y})^2} = 1 - \frac{11.19}{43.11} = 0.74 \quad (10)$$

Therefore, variation of the Bitcoin price depends on time in 74%. The impact of other factors which have not been included into the model is 26%. Therefore, the model quality is high.

Let us now explore the statistical significance of the parameters of the regression equation (8). The following coefficients can be calculated:

$$S_y = \sqrt{\frac{\sum Et^2}{n-p-1}}$$, where$p$is the number of factors in the equation (11)

$$S_b = S_y \times \frac{\sqrt{\sum t^2}}{n\sigma_t} \quad (12)$$

$$S_a = \frac{S_y}{\sqrt{n}\sigma_t} \quad (13)$$

If $\sigma_t = \sqrt{\frac{\sum t^2}{n} - \bar{t}^2}$=47.9 , then$S_y = 0.71$, $S_b = 0.021$, and$S_a = 0.3$.

The t-test for the parameters of the regression equation:

$$t_a = \frac{a}{S_a} = \frac{5.141655}{0.3} = 17.1 \quad (14)$$

$$t_b = \frac{b}{S_b} = \frac{0.0166597}{0.021} = 7.9 \quad (15)$$

Since the critical value of the Student’s t-factor is 2.07 under the level of significance of 0.05 and the number of degrees of value of *n-p-1*, there is a 95% possibility that the parameters of the regression equation are statistically significant. This means that the time factor does really influence the price of Bitcoin.

Let us now construct the limits of the *b* parameter of the regression equation:

$$b \pm t_{critical} \times S_b$$

0.0166597-2.07×0.021 and 0.01166597+2.07×0.021

Therefore, the limits of the regression strength are between 0.12 and 0.21. This confirms once again that there is a95% possibility that the *b*parameter of the regression equation is statistically significant.

Let us check the adequacy of the regression equation using the Fisher's test:

$$F = \frac{R^2}{1-R^2} \times \frac{n-p-1}{p} = 62.7 \qquad (16)$$

The critical value of F for one factor and 22 observations is 4.3. This means that there is a 95% possibility that the model is adequate.

Let us now test the model to determine the availability of heteroscedasticity using the Spearman test. Auxiliary calculations are presented in Table 4.14.

Table 4.14 Spearman's rank correlation

t	*E*	*Rank t*	*Rank modul E*	*d=Rank t-Rank modul E*	*d^2*
1	1.31843	1	23	-22	484
2	0.64983	2	16	-14	196
3	0.82219	3	21	-18	324
4	0.15149	4	2	2	4
5	-0.205	5	4	1	1
6	-0.6432	6	15	-9	81
7	-0.7344	7	19	-12	144
8	-1.0106	8	22	-14	196
9	-0.5756	9	14	-5	25

10	-0.7751	10	20	-10	100	
11	-0.4632	11	10	1	1	
12	-0.7275	12	18	-6	36	
13	-0.4367	13	8	5	25	
14	-0.497	14	12	2	4	
15	0.18047	15	3	12	144	
16	0.56866	16	13	3	9	
17	1.58099	17	24	-7	49	
18	0.7137	18	17	1	1	
19	0.45887	19	9	10	100	
20	0.32423	20	6	14	196	
21	-0.4116	21	7	14	196	
22	-0.4867	22	11	11	121	
23	0.31362	23	5	18	324	
24	-0.116	24	1	23	529	Σ3290

Source: own calculation

The Spearman’s correlation coefficient is:

$$p = 1 - 6 \times \frac{\sum d^2}{n^3 - n} = -0.43 \qquad (17)$$

Table 4.15 The Goldfeld-Quandt test

t	ln Yt	Ln Y estimated	Et^2	
1	6.63	6.38	0.06	
2	6.12	6.27	0.02	
3	6.46	6.17	0.09	
4	5.96	6.06	0.01	
5	5.77	5.95	0.03	
6	5.50	5.84	0.12	
7	5.57	5.73	0.03	
8	5.46	5.63	0.03	
9	6.07	5.52	0.30	Σ0.68

-	-	-	-	
16	8.38	8.79	0.17	
17	9.55	8.79	0.58	
18	8.85	8.79	0.00	
19	8.77	8.80	0.00	
20	8.80	8.80	0.00	
21	8.23	8.80	0.33	
22	8.32	8.81	0.24	
23	9.29	8.81	0.23	
24	9.02	8.81	0.04	Σ1.60

Source: own calculation

The relation between the residuals and the factor is weak and inverse. Then the t-factor for this coefficient can be calculated:

$$t_p = t \times \sqrt{\frac{1-p^2}{n-2}} = 0.4 \qquad (18)$$

Because the absolute value of the resulting number is smaller than *p*, there is a 95% possibility that the hypothesis implying availability of heteroscedasticity should be refuted.

The Goldfeld-Quandt test confirms lack of heteroscedasticity of the model as well (Table 4.15).

Since the ration between the sums of the squares of the residuals from the lowest and highest samples are lower than the critical value of the Fisher factor (1,6/0,68 = 2,3 < 5,32), there is a 95% possibility that the hypothesis implying lack of heteroscedasticity should not be rejected.

As long as the Bitcoin price is analyzed as the function of the time factor, it is justified to analyze the model for availability of autocorrelation in the residuals as a Durbin-Watson test (Table 4.16).

Let us calculate the ratio:

$$\frac{5{,}66}{11{,}19} = 0{,}5$$

The highest and lowest limits of the Durbin-Watson factor are 1.27 and 1.45, respectively. Our actual value falls into the range where the hypothesis implying the lack of autocorrelation in the residuals is refuted. This means that there is a 95% possibility that a positive autocorrelation of the residuals is available.

Table 4.16 The Durbin-Watson test

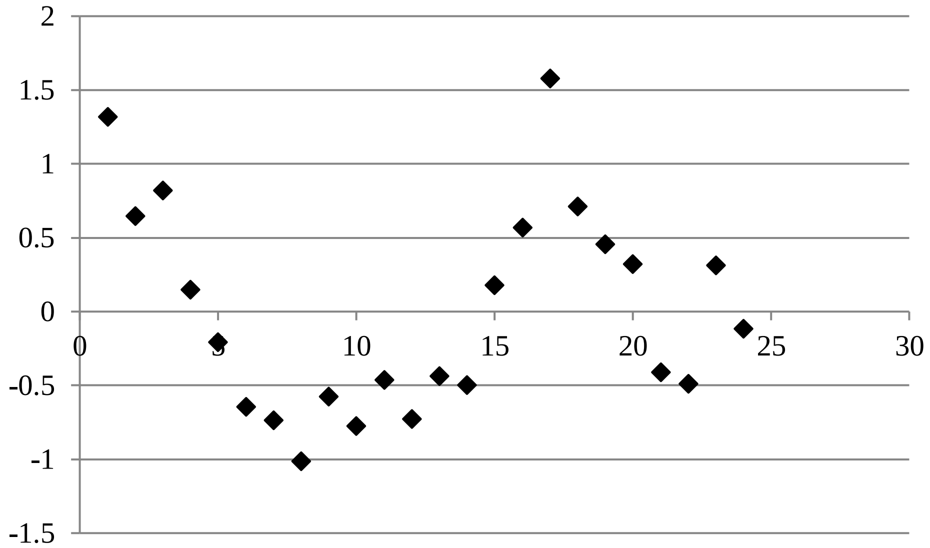
Et	*Et-1*	*(Et-Et-1)^2*	*Et^2*
1.32	-	-	1.74
0.65	1.32	0.45	0.42
0.82	0.65	0.03	0.68
0.15	0.82	0.45	0.02
-0.20	0.15	0.13	0.04
-0.64	-0.20	0.19	0.41
-0.73	-0.64	0.01	0.54
-1.01	-0.73	0.08	1.02
-0.58	-1.01	0.19	0.33
-0.78	-0.58	0.04	0.60
-0.46	-0.78	0.10	0.21
-0.73	-0.46	0.07	0.53
-0.44	-0.73	0.08	0.19
-0.50	-0.44	0.00	0.25
0.18	-0.50	0.46	0.03
0.57	0.18	0.15	0.32
1.58	0.57	1.02	2.50
0.71	1.58	0.75	0.51
0.46	0.71	0.06	0.21
0.32	0.46	0.02	0.11
-0.41	0.32	0.54	0.17
-0.49	-0.41	0.01	0.24
0.31	-0.49	0.64	0.10
-0.12	0.31	0.18	0.01

Σ0.00	Σ 0.12	Σ 5.66	Σ 11.19

Source: own calculation

The availability of the positive autocorrelation of the residuals can be connected with inertia of the Bitcoin price, which is confirmed by Fig. 4.4.

Fig. 4.4 The dependence of the regression residuals on the time factor



Source: own calculation

Therefore, the trend equation $\hat{y} = 170.9985e^{0.166t}$, which appeared to have the highest determination coefficient among all possible forms of regression equations, is not appropriate to process extrapolation because of the autocorrelation of the residuals in contains.

The fact that autocorrelation is available in this trend equation is natural if one takes into account that the price of Bitcoin is often set under the influence of demand for this cryptocurrency. Since this effect implies a time lag, let us consider the autoregression model which means the Bitcoin price is a function of its price in the previous time period.

In order to determine the size of the lag, it is justified to calculate autocorrelation coefficients with the maximum lag of $\frac{n}{4}$:

rYtYt-1	0,68
rYtYt-2	0,52

rYtYt-3	0,48
rYtYt-4	0,36

Since the maximum value of the autocorrelation coefficient is 0.68, let us construct the relation model $y_t = f(y_{t-1})$ with a quarterly lag (Table 4.17):

Table 4.17 Construction of the autoregression equation

Yt	*Yt-1*	*Yt*Yt-1*	*Yt-1^2*
754.97	-	-	-
457.00	754.97	345021.29	569979.70
641.39	457.00	293115.23	208849.00
387.43	641.39	248493.73	411381.13
320.43	387.43	124144.19	150102.00
244.22	320.43	78255.41	102675.38
263.35	244.22	64315.34	59643.41
236.00	263.35	62150.60	69353.22
430.72	236.00	101649.92	55696.00
416.76	430.72	179506.87	185519.72
672.52	416.76	280279.44	173688.90
609.93	672.52	410190.12	452283.15
963.66	609.93	587765.14	372014.60
1071.71	963.66	1032764.06	928640.60
2492.60	1071.71	2671344.35	1148562.32
4341.05	2492.60	10820501.23	6213054.76
14112.20	4341.05	61261765.81	18844715.10
7003.06	14112.20	98828583.33	199154188.84
6411.68	7003.06	44901379.74	49042849.36
6619.85	6411.68	42444359.85	41109640.42
3746.71	6619.85	24802658.19	43822414.02
4105.36	3746.71	15381593.37	14037835.82
10796.93	4105.36	44325284.54	16853980.73
8299.72	10796.93	89611495.86	116573697.42

Σ74644.28	Σ 67099.53	Σ 438856617.61	Σ 510540765.63

Source: own calculation

Therefore, the autoregresson equation has the form of:

$$y_t = 1196.4 + 0.7 \times y_{t-1} \quad (20)$$

As the price of Bitcoin in the previous quarter increases by 1 unit, its price in the current quarter increases by 0.7 units.Analytically, the trend implying the dominant increase of the Bitcoin price is confirmed as well.

The model quality is satisfactory: F=17.98 when the table F=4.3; $t_b = 4.2$ when the critical t=2.07. Therefore, there is a 95% possibility that the model is adequate and the *b* parameter is statistically significant.

The test of the autoregression model for availability of heteroscedasticity and autocorrelation in the residuals yields the following values (Tables 4.18 and 4.19).

Let us construct the model of dependence of the square of the residuals on the factor and its square:

$$e^2 = -291574.24 + 5808.6y_{t-1} - 0.4(y_{t-1})^2$$

Then the product of the number of observations and the determination coefficient can be calculated:

$$n \times R^2 = 23 \times 0.12 = 2.8$$

The critical value $\chi^2 = 11{,}6$. Again, there is a 95% possibility that there are no reasons to reject the hypothesis which implies lack of heteroscedasticity.

Table 4.18 The White test

E^2	*Yt-1*	*(Yt-1)^2*
-	-	-
1611967.301	754.97	569979.701
767310.0283	457	208849
1586162.374	641.39	411381.132
1318040.803	387.43	150102.005

1385827.784	320.43	102675.385
1220042.8	244.22	59643.4084
1311807.167	263.35	69353.2225
867528.5502	236	55696
1171015.039	430.72	185519.718
666785.9479	416.76	173688.898
1121044.018	672.52	452283.15
437057.6125	609.93	372014.605
642397.4139	963.66	928640.596
295396.2452	1071.71	1148562.32
1943196.992	2492.6	6213054.76
97355121.59	4341.05	18844715.1
16851646.04	14112.2	199154189
88017.08193	7003.06	49042849.4
846776.8613	6411.68	41109640.4
4406406.47	6619.85	43822414
76987.89688	3746.71	14037835.8
45119938.81	4105.36	16853980.7
230325.847	10796.93	116573697

Source: own calculation

As for the Durbin-Watson test, the actual number by criterion is 2.2. The highest and the lowest limits of the criterion according to the distribution table are 1.27 and 1.45, respectively. Our actual value falls into the range where there is lack of autocorrelation of the residuals. But taking into account that we analyze the autoregression model, it would be justified to check the result using the Durbin h-criterion:

$$h = (1 - \frac{d}{2}) \times \sqrt{\frac{n}{1 - n \times v}},$$

where d is the actual value of the Durbin-Watson criterion, and v is the squared deviation of the lag variable.

Table 4.19 The Durbin-Watson test

Et	Et-1	Et^2	(Et-Et-1)^2

-1269.63	-	1611967.30	-
-875.96	-1269.63	767310.03	154976.38
-1259.43	-875.96	1586162.37	147046.97
-1148.06	-1259.43	1318040.80	12403.23
-1177.21	-1148.06	1385827.78	849.86
-1104.56	-1177.21	1220042.80	5278.95
-1145.34	-1104.56	1311807.17	1663.50
-931.41	-1145.34	867528.55	45765.78
-1082.13	-931.41	1171015.04	22717.23
-816.57	-1082.13	666785.95	70524.70
-1058.79	-816.57	1121044.02	58672.49
-661.10	-1058.79	437057.61	158157.60
-801.50	-661.10	642397.41	19710.38
543.50	-801.50	295396.25	1809026.77
1393.99	543.50	1943196.99	723320.20
9866.87	1393.99	97355121.59	71789761.41
-4105.08	9866.87	16851646.04	195215262.24
296.68	-4105.08	88017.08	19375423.96
920.20	296.68	846776.86	388787.25
-2099.14	920.20	4406406.47	9116468.48
277.47	-2099.14	76987.90	5648280.57
6717.14	277.47	45119938.81	41469359.56
-479.92	6717.14	230325.85	51797679.06
Σ0.00	Σ 479.92	Σ 181320800.67	Σ 398031136.55

Source: own calculation

If h lies between -1.96 and 1.96, then there is no autocorrelation in the residuals. Our actual value is h = -0,012. Therefore, there is a 95% possibility that the hypothesis implying autocorrelation in the residuals should be refuted.

Therefore, the autoregression model:

$$y_t = 1196.4 + 0.7 \times y_{t-1}$$

is a model which is characterized by quality which allows of predicting the price of Bitcoin.

Let us extrapolate the Bitcoin price onto the next two quarters. Importantly, the more the deviation of the predicted value from the medium level of the factor, the less reliable the prediction is.

Because any value of the cryptocurrency's rate depends on its rate in the previous quarter, the price of Bitcoin in the first quarter of 2020 will equal:

$$y_t = 1196.4 + 0.7 \times y_{t-1} = 1196.4 + 0.7 \times 8299.72 = 7025.7$$

For the more reliable result, the limits of prediction can be calculated. The standard deviation of the result is:

$$S_y = \sqrt{\frac{\sum(y_t - \hat{y}_t)^2}{n-2}} = 2938.42$$

Then the critical value of the Student's factor multiplied by the standard deviation of the result should be added to or subtracted from the predicted value at the point:

$$7025.7 \pm 2.07 \times 2938.42$$

Therefore, there is a 95% possibility that in the beginning of the first quarter of 2020 (January 1, 2020), the Bitcoin price will fall into the range between \$943.18 and \$13,108.25. Any narrower ranges which could be predicted will result in a less reliable figure due to serious and generally unpredictable historic movements of the Bitcoin price up and down many times in the last 24 quarters analyzed in this thesis which means there is no distinct or precise trend which would describe its price behavior.

Similarly, the prediction for the beginning of the second quarter of 2020 (April 1, 2020) can be made. If the current trend preserves, the Bitcoin price will lie in the range between \$188.23 and \$12,073,6. So, the rate of Bitcoin can somewhat drop in the next two quarters, if all 24 previous quarters are accounted for in the analysis as we did. (If only the last 3 or 4 quarters were taken into account, the result could be quite different: the Bitcoin price does not have any historical fluctuation periods of a more or less distinct duration.) Again, any narrower ranges which could be predicted will result in a less reliable figure due to serious and generally unpredictable historic movements of the Bitcoin price, as was the case in the prediction for the first quarter of 2020. The general inference is that no precise or even approximately reliable prediction which could be practically useful can be made as for the future prices of Bitcoin.

4.3 Results

The analysis provided in the practical part of the thesis allows of indicating such its results and drawing the following conclusions:

1) The general underlying idea of the research was to try to analyze whether Bitcoin can be regarded as a reliable tool of investment via possible prediction of its price based on prices of other financial and real assets generally accepted as investment goods by individual and institutional investors. The hypothesis was that price of Bitcoin at least moderately correlates with prices of other cryptocurrencies due to the similar economic nature of these assets and their frequent interchangeability from the perspective of individual and institutional investors; at the same time, price of Bitcoin shows no significant correlation with global prices of other investment assets such as energy resources and precious metals; neither does Bitcoin price correlate with main integrated indicators of economic performance.

2) There is a relatively strong direct relationship between prices of Bitcoin and other cryptocurrencies (Ethereum, XRP/Ripple, and LiteCoin): rise of price of any other cryptocurrency positively influences Bitcoin price, and vice versa. LiteCoin price correlates with Bitcoin price the most.

3) Significant interdependence of prices of Bitcoin and other cryptocurrencies on global markets causes the emergence of multicollinearity among factors.

4) Prices of oil, gold and silver cannot be factors of econometric models which research impact of factors on Bitcoin price. Table 4.5 also shows that among these factors, only gold price shows any noteworthy, though very weak (0.4272195), relation to Bitcoin price, which can, however, be neglected.

5) There is a relatively strong relationship between Bitcoin and economic performance indicators but neither of them seems to have influenced the price of Bitcoin or vice versa. Rather, both Bitcoin prices and economic indicators increased in 2014-2019 due to good economic conditions and immense investment costs.

6) Among nine factors belonging to three groups selected as possible influencers on Bitcoin price, only prices of other cryptocurrencies and economic performance indicators have relatively strong correlation with Bitcoin price; prices of global goods such as oil, gold, or silver, have no correlation with Bitcoin price. cryptocurrencies and economic performance indicators, price of LiteCoin and value of Dow Jones indicator can be regarded as basic influencing factors; prices of other cryptocurrencies and other economic performance indicators correlate indeed with Bitcoin price as well, but taking them into account for further analysis would duplicate data and distort results. Therefore, price of LiteCoin and value of Dow Jones indicator were selected as factors which were used in an attempt to predict future prices of Bitcoin.

7) The statistical significance of the regression equation is confirmed by Student’s t-test. The quality of the model is confirmed by the high level of the determination coefficient , which equals 0.95. This means that 95% of the results’ variation is explained by variations of selected factors. Other factors account for only 5%.

8) Under the probability of 95%, the conclusion about the presence of heteroscedasticity of residuals for each of the selected factors can be drawn.

9) The model cannot adequately assess the strength of each factor’s influence on results due to the presence of heteroscedasticity and autocorrelation in residuals.

10) The analysis provided above refuted any significant influence of all factors on Bitcoin price. This means there is a high level of probability of independence of Bitcoin price from standard indicators of economic growth and other factors analyzed in the model.

11) There is a relatively strong direct relation between time and the price of Bitcoin: each quarter, the price of Bitcoin increases, if analyzed on average.

12) The variation of the Bitcoin price depends on time in 74%. The impact of other factors which have not been included into the model is 26%. Therefore, the model quality is high.

13) There is a 95% possibility that the parameters of the regression equation are statistically significant. There is a 95% possibility that the model is adequate. This means that the time factor does really influence the price of Bitcoin.

14) There is a 95% possibility that in the beginning of the first quarter of 2020 (January 1, 2020), the Bitcoin price will fall into the range between $943.18 and $13,108.25. If the current trend preserves, the Bitcoin price will lie in the range between $188.23 and $12,073,6. Any narrower ranges which could be predicted will result in a less reliable figure due to serious and generally unpredictable historic movements of the Bitcoin price up and down many times in the last 24 quarters analyzed in this thesis which means there is no distinct or precise trend which would describe its price behaviour.

15) No precise or even approximately reliable prediction which could be practically useful can be made as for the future prices of Bitcoin.

16) There is no factor which could be statistically significant enough to influence the price of Bitcoin.

The empirical and statistical analysis conducted in the practical part of the thesis leads to the conclusion that there is no factor which could be statistically significant enough to influence the price of Bitcoin. Therefore, an inference can be drawn that the process of formation of the price of this cryptocurrency is stochastic in its nature, and any predictions of future prices of this or other cryptocurrencies cannot be made with a satisfactory level of practical usefulness.

The price of Bitcoin seems to have some correlations with other cryptocurrencies, but since they are similar products and hence close substitutes, a conclusion can be made that this correlation does nor reflect influence of the price of any cryptocurrency on the prices of other cryptocurrencies. Instead, they simply seem to move in the same directions due to third factor, which are probably accidental in their essence and of a speculative nature because no correlation has been found between the price of Bitcoin and prices of other investment goods such as oil, gold, or silver.According to the correlation matrix, there is some relatively strong correlation between the price of Bitcoin and values of general economic performance indicators, but this correlation is not tight or distinct and may reflect the general trends of increasing prices of cryptocurrencies and increasing performance indexes under favorable economic conditions.The correlation and regression analysis found that there is no technical influence of any goods' prices or economic indicators on the price of Bitcoin; therefore, it can hardly be predicted within a satisfactory range which could be practically useful.

The only factor which appeared to exert influence on the price of Bitcoin at a some point of time is price of Bitcoin per se: according to the autoregression analysis, previous prices of Bitcoin seem to influence its future prices since there is a general trend which implies increases in the price of Bitcoin in the long run.

5. Conclusions

Cryptocurrencies emerged as an instrument of safe and decentralized payments which aimed at better security of investors and their independence from central authorities and their economic and monetary decisions. Cryptocurrencies are based on computer-processed mathematical operations which allow of "mining" units of cryptocurrencies. There are different types of cryptocurrencies: some secure absolute anonymity and safety, others are limited in supply based on specific mathematical formulas known to everyone. Some are completely independent while others emerged as results of other cryptocurrencies' forks and splits.

Cryptocurrencies, which emerged not so long ago and promised people that they would get rid of many, if not all, problems mentioned above, swiftly became a popular instrument of investing funds. Many believed – and some still do – that cryptocurrencies could lead to stability and wealth and that their rates, initially very low, would permanently rise. Bitcoin was and remains the most popular cryptocurrency in the world.

In this thesis, an attempt was made to statistically and econometrically determine whether the price of Bitcoin depends on or correlates with prices of other investment goods and values of integral economic performance indexes as well as to try to predict the price of Bitcoin in the next 2 quarters. For this reason, correlation matrices were built and correlation and regression (including autocorrelation and autoregression) analyses were conducted. The results of the statistical and econometrical analysis was that a conclusion should be drawn that the process of formation of the price of this cryptocurrency is stochastic in its nature, no other goods or economic indicators are responsible for changes in prices of Bitcoin and other cryptocurrencies, and any predictions of future prices of Bitcoin or other cryptocurrencies cannot be made with a satisfactory level of practical usefulness.

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