TALLINN UNIVERISTY OF TECHNOLOGY
School of Business and Governance
Department of Business Administration

Roy Alexander Harjunpää

CRYPTOCURRENCY CORRELATION ANALYSIS

Bachelor's thesis

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Supervisor: Pavlo Illashenko

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Roy Harjunpää ……

(signature, date)

Student code: 156091TVTB

Student e-mail address: Harjroy@hotmail.com

Supervisor: Pavlo Illashenko:

The paper conforms to requirements in force

……

(signature, date)

Co-supervisor: - :

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……

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ABSTRACT

For a past year, cryptocurrencies have slowly getting recognition by media due to their tremendous rise in value. They were viewed as something intended for criminal usage for years, because of the intractability and lack of obligation to any financial institution. Since then, awareness of cryptocurrencies has risen and it has caught an eye of many worlds well know investors and influencers. As cryptocurrency is rather new phenomenon there has not been large number of studies about it.

This paper focuses on analysis correlation between eight different cryptocurrencies. The selected currencies have different prospects, aims and functions. The analyzes is done by using Person's correlation coefficient and cross-correlation calculations. The aim of the paper is to see if the two (Bitcoin & IOTA) most dissimilar cryptocurrencies have strong, weak or no correlation and what kind of correlation relationships the selected eight currencies have.

The first hypothesis assumes that the two dissimilar cryptocurrencies would have reasonably low correlation. The outcome of the analyze was just the opposite as these two had correlation coefficient of moderate ($0,5 < r < 0,7$) or even strong ($r > 0,7$). The second hypothesis examines the relationship between prices changes to correlation changes. The results show that cryptocurrency correlation tends to increase as respective prices decrease and vice versa. This is valuable base information for future researches about cryptocurrency portfolio's risk-return characteristics and investment opportunities.

Keywords: Cryptocurrency, Correlation analysis, Pearson's correlation, Cross-correlation.

INTRODUCTION

Today cryptocurrencies have become a global phenomenon and lately it has been one of the hottest topics around mundane and experienced investors. Due cryptocurrency's somewhat unexpected rise begun on late last year it has given more and more greater reason to look in-depth on cryptocurrencies value formation. One of the largest selling factors (in the side of huge profits) of cryptocurrencies has been their lack of correlation to established global financial markets such as stock markets and bond markets. Correlation, in financial world means the statistical measurement of the relationship of two or more securities. Low correlation should give cryptocurrency an edge on diversifying portfolios and lowering investing loss risks. The second selling factor has been that cryptocurrency market should be decentralized meaning that there is no one entity or third party to hold customers funds. Now days, it is almost impossible to find a single large bank, accounting firm or a government that have not researched nor published a paper about cryptocurrency. There has been numerous news about the currency mainly considering its tremendous rise in value in a short time and controversial arguments on its safety and involvement in criminal action. The reason of this association to illegal activity is because most of the crypto coins have untraceable transactions and they are known for to be used in crimes. It is no surprise that many government authorities from different countries have publicly open up their mind and have respectively been against or on the side of cryptocurrencies.

As for to give more perspective on the potential gains which these currencies have, Bitcoin's prices skyrocketed 1100% (from 1726,73 USD to 19497,4 USD) just in six months (17.05.2017-17.12.2017). The Bitcoin's market capitalization (the overall value of all of the bitcoins) of 17th of december was mind blowing 326,502,485,530 US dollaras (coinmarketcap.com). But not just Bitcoin's price was increasing. Numerous other cryptocurrenies were also "booming" which the general public did not even knew about. So, why does these crypto coins even have any value as it is indefinete ot intaglible? There are a lot of drives that affects on the value of the crypto coins for example, supply and demand, public perception. Ultimately, something has value when someone thinks its valuable. Furthermore, the more people see the usefulness of the cryptocurrencies, the more it drives the value, prices and the whole market up.

It is no news flash to anybody that Bitcoin has a huge domination over the cryptocurrency industry. Having massive 38,6% of the total market capitalization of the whole market, the assumption is that all of the more smaller currencies are almost forced to follow Bitcoin's footsteps on the market. Moreover, if Bitcoin would lose 50% of its value (we have seen things like this happen) it would drop the whole market cap by almost 20%. But not all cryptocurrencies are made to take over Fiat money and are more concentrated on technology and innovation. These currencies have no relationship to those, right? This is what we are here to find out. What is the correlation relationship between eight different cryptocurrencies and are the prices dependent of each other? In addition, we will look a bit on what similarities cryptocurrency correlation has to stock market correlation and how to take advantage of that.

The historical data used will be extracted from https://coinmarketcap.com which is the largest and most reliable source of cryptocurrency prices and data available. The data for the calculations will be taken from the dates 01.01.2016-01.04.2018. The correlation methods used in this paper will be cross-correlation and Pearson's correlation coefficient to indicate the statistical significance of coefficients. Pearson's correlation is one of the most popular correlation coefficients which gives us the relationships between the selected cryptocurrencies.

Correlation analysis gives us information how selected variables or in this case cryptocurrencies behave compared to each other. For example, from correlation matrix it is easy look and find cryptocurrencies with correlation which should decrease the risk factor of the investment, gain better position with investments and diversifying options.

1. Cryptocurrency and cryptocurrency markets

What is cryptocurrency we have been talking about? Most of us are very familiar with using digital currency in everyday life. Digital currency is the alternative option to use assets without tangible money such as coins, bills and checks. Most know digital currency methods are debit and credit cards, teller machines, point-of-sale chips (payment terminals) and the rise of e-commerce (Wealth Management, 2017).

Cryptocurrencies are meant to be a digital cash system which usually works as a peer-to-peer network. This means that transactions by user to another user will be sent directly without going through financial institution as they would with regular digital currency transactions. The problem with losing the financial institution is to find a way to prevent so-called double spending. Double-spending means the risk that the currency can be charged two times (Satoshi Nakamoto, 2008). To prevent this, most of the cryptocurrencies use cryptography technology as a tool to protect information and data. Cryptographies are fundamental part of Transport Layer Security (TLS) protocol which makes it relatively easy to combine strong encryption into many different applications (Boneh, 2015).

So, cryptocurrency is a digital asset which is designed to work as decentralized currency between peer-to-peer using cryptography. One would easily to conclude that cryptocurrencies are different money currencies like U.S dollar or euro and has one simple task: to be traded to something. Yes, Bitcoin's aim is this, but there are hundreds and thousands of altcoins (Bitcoin alternative) which have vastly different goals and functions. Many of these altcoins are just a projects or conceptions, but still have a huge following and faith behind them. To some of these currencies, the coin is just a little part of the scheme. Remember, that all the coins and tokens are called or viewed as cryptocurrency, although many of them do not function as a currency. It is not every cryptocurrency's goal to be traded as a currency in everyday use.

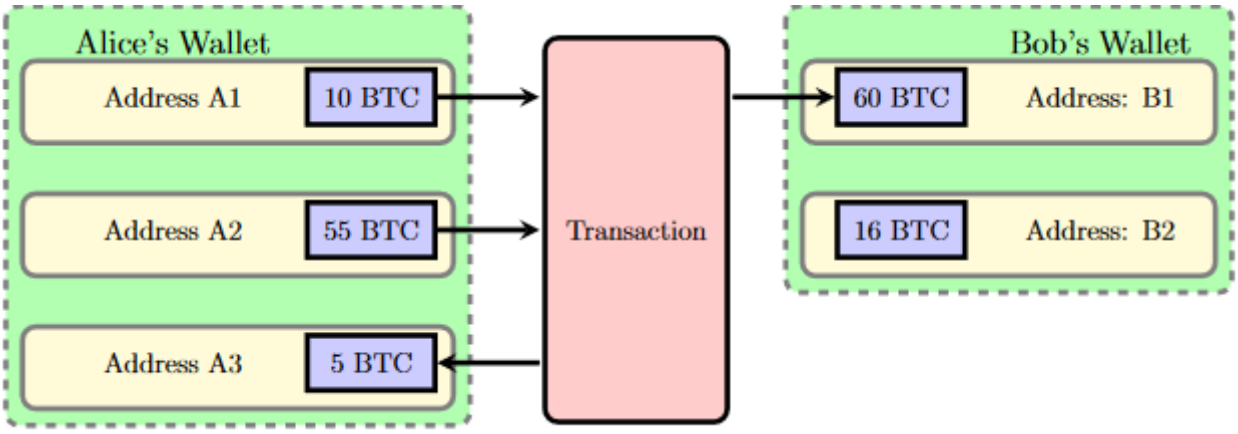
1.1. Overview of the main cryptocurrencies

In this paper we will be comparing 8 different cryptocurrencies. These currencies have something that makes them diverse compared to others. Some of the following coins can be ready as a project or just a concept of technology. It is important to keep in mind that even though all share the name "currency", the intention can be far away from the normal perception how people use currency.

Bitcoin (BTC) is the largest and the most successful cryptocurrency in the history. It has the market share of 38,6% ($150 641 526 688 in 22.4.2018). It was created by unknown person under the name of Satoshi Nakamoto in 2009. Bitcoin's main goal is to transfer value or assets between parties without any involvement from financial institution what so ever. (Badev, Chen; 2014)

It is important to realize that Bitcoin uses blockchain technology in the transactions between the parties. The blockchain is formed so that the actions of the users are not recorded in the data. This means that even though ledger is public, it is impossible to track down the evets in which the bitcoins changes ownership.
Bitcoin is way ahead of any other cryptocurrency by the means of its usefulness. For example, today one could by a house, boat, car with only bitcoin. Although Bitcoin is still the king of cryptos, it has been the point of criticism lately. The critics have mostly focused the slowness of the Bitcoin transactions which takes 10-60 minutes on average as an opposed to some newer cryptocurrencies which have transactions times of under 5 seconds.

Figure 1, Blockchain transactions



(Bitcoin Technical Background and data analysis; Badev, Chen, 2014)

IOTA (IOT), designed for the internet of things industry, is the 9th largest cryptocurrency in the world with market share of 1,5% (5 703 373 778$ in 22.4.2018). In IOTA's official internet page, they describe IOTA as following "The first open-source distributed ledger that is being built to power the future of the Internet of Things with feeless microtransactions and data integrity for machines." (www.iota.org). Like Bitcoin, IOTA does not need a third-party entity nor financial institute to handle and safeguard their records and data.

As Bitcoin uses blockchain technology, IOTA uses new technology to record their data called the Tangle. IOTA claims that the Tangle technology is far more advanced compared to blockchains. It gives the users more faster transaction speed, secure, scalable and feeless transaction settlement layer. In addition, it is possible to store information from the Tangle transactions. This is a huge difference to blockchain's anonymous and untraceable transactions (www.iota.org). The idea is that via the Tangle technology IOT enabled devices can send assets to each other as payment for services (www.iotatoken.io).

Ripple (XRP) is the third largest cryptocurrency with market share of 8,9% (34 650 590 030$ 22.4.2018) (marketcap.com). Via their own RippleNet their goal is to connect banks, payment providers, digital asset exchanges and corporates and provide ultrafast experience to send money globally. Like Bitcoin Ripple uses blockchain technology to make transactions, but they claim that their technology is farm more advanced than any other blockchain has. Ripple's transactions are traceable and this is one major reason why they have so many large companies as partners, customers or supporters. For example, large banks like Santander, American Express, SEB and Axis bank. Ripple offers its customer banks instant cross-border payments with end-to-end tracking with their xCurrent software.
(ripple.com, ripple whitepaper)

Ethereum (ETH) the so-called prince of the cryptocurrencies is the second largest cryptocurrency in the world with market share of 15,7% (61 360 704 534$ 22.4.2018). It is developed by non-profit swiss foundation Ether Foundation. Ether also known as the hearth of Ethereum network is advanced platform to blockchain technology. With Ether, developers can use this technology to create and run their own platforms and apps. They describe this like so "This enables developers to create markets, store registries of debts or promises, move funds in accordance with instructions given long in the past (like a will or a futures contract) and many other things that have not been

invented yet, all without a middleman or counterparty risk". (etherum.org). Many of today's large cryptocurrencies have built on top of Ethereum blockchain.

Funfair (FUN) is the 77th largest cryptocurrency with market share of 0,0056% (216 860 322$, 22.4.2018). Funfair is built on Ethereum based technology with aim to revolutionize online casino gaming industry by bringing blockchain to the gaming market. With Funfair one could develop their own online casino games. the FUN token is the essential way of interacting with Funfair platform games. The aim is that every online casino uses FUN as a currency to play online gambling games. (Funfair whitepaper, 6.2017)

Next (NXT) is 87th largest cryptocurrency with market share of 0,0053% ($204 823 959, 22.4.2018). Their goal is to build next generation stock trading platform (Next.Exchange) using blockchain technology. Next project is using initial coin offering (ICO) which means that the project is funded by sales of cryptocurrency tokens and in this case NXT tokens (James Gatto, 9.2017). They claim that due all of the regulations and boundaries holding down the financial market the barrier to entry has become too high. Next.Exchange trading platform will remove all unnecessary limitations and regulations of stock trading. (Next.Exchange whitepaper, 11.2017).

Steem (STEEM) is 31st largest cryptocurrency with market share on 0,2% (772 742 376$, 22.4.2018). Steem uses scalable blockchain technology which enables users to earn money by using their brain (Proof-of-Brain). Users can post their own content to the platform and earn currency by community voting. The aim is to inspire entrepreneurs, developers and content creators to great new innovative content (Steem bluepaper). Steem has paid 40 150 000 USD in rewards and has 920 800 user accounts (steem.io). -

Dai (MKR) is the 40th largest cryptocurrency with marker share of 0,015% (570 969 203$, 22.4.2018). Dai stablecoin system run on Etherneum blockchain and is s price stabilized against the value of the U.S. Dollar. Dai clamis that Bitcoin and Etherneum are too volatile to be used as a everyday currency. To solve this volatility MRK token is stable relative to the US dollar and because of this has true potential to be a real blockchain techology asset. (Dai whitepaper, 12.2017) They say that without stable digital currency the next generation of finacial applications will not be possible (makerdao.com).
From the table 1. below we can see that Bitcoin is clearly dominating the market share.

Table 1. Market capitalization of the eight selected cryptocurrencies as a comparison (22.4.2018)

Name	Market cap USD	Market share %
Total of all cryptocurrencies	389 934 507 441	100%
Bitcoin	150 641 526 688	38,6%
Ethereum	61 360 704 534	15,7%
Ripple	34 650 590 030	8,9%
IOTA	5 703 373 778	1,5%
Steem	772 742 376	0,2%
Dai	570 969 203	0,015%
FunFair	216 860 322	0,0056%
Next	204 823 959	0,0053%

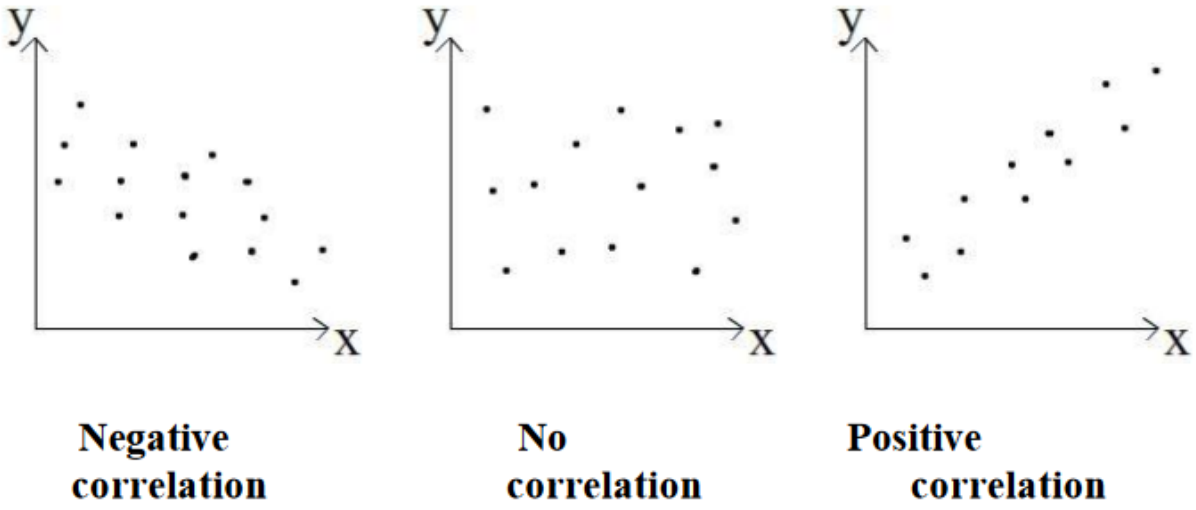
https://coinmarketcap.com

1.2. Introduction on correlation

Now we have introduced the selected eight cryptocurrencies and went through how they operate and why they are different from each other. On this segment we will look on correlation.

So, what is correlation? It is one of the most foundational and basic statistical analysis which measures association between two variables. It gives a degree to which theses share a common relationship. For example, if we would have two variables “X” and “Y”, if both variables increase at similar rate we would call that positive correlation. As a opposite if one of the variables decreases and one increases we would call this phenomenon negative correlation. No correlation is event where the other variable does not tend to increase or decrease when the other does. (Understanding correlation, University of Arizona) This figure helps to illustrates these events.

Figure 2. Positive, negative and no correlation.



(http://www.statstutor.ac.uk)

Correlation is usually given as a symbol *r* and it ranges from -1 to +1. In this paper we will use most commonly used correlation coefficient know as Pearson's correlation or Pearson's *r*. Our variables will have linear relationship together. The *r* will be defined as follow. Having two variables X and Y with values of *n* (X1, X2, … Xn and Y1, Y2, … Yn). The formula is:

$$r = \frac{\sum(X_i - \bar{X})(Y_i - \bar{Y})}{\sqrt{\sum(X_i - \bar{X})^2 \sum(Y_i - \bar{Y})^2}}$$

The summation proceeds across all *n* possible values of X and Y (Clegg, 9.1977)

The general ruler for value of *r* is based on this:

Absolute value of r	Strength of the relationship
r < 0.3	None or very weak
0,3 < r < 0,5	Weak
0,5 < r < 0,7	moderate
r > 0,7	Strong

(Mindrila, Balentyne; Scatterplots and Correlation)

1.1.2. Advantages of cryptocurrency correlation analysis

Buying or investing in cryptocurrency has always its own degree of risk. The market is known to be very volatile with enormous possible losses in very little period of time. To demonstrate more this in the period of only one-month price of one Bitcoin increased 191% (11.2017-12.2017) and after that decreased 224% (12.2017-2.2018) in three months (coinmarketcap.com). Of course, there were many factors influenced these, but either way if you invested in Bitcoin in December 2017 you made huge losses.

At this point we have our selected eight currencies and we know how the correlation is calculated between them. Next let us go through what possible advantages and disadvantages one could find from this cryptocurrency analysis.

One of the tools to reduce investing risk is to use technique called Hedging. In general, this doesn't stop a negative occasion to happen, but the impact of it may be reduced. Hedging is basically attempt of securing against negative events for example, house or life insurance. In financial markets this means hedging one investment by making another investment. Furthermore, one tries to find two securities from the correlation analysis that have negative correlation and invest in both. On the flip side, usually reducing risk will reduce potential return on the investment. Low levels of risk are associated with low potential returns. One could use futures contract to lock exchange rates in place and count on that hedging will pay off over time. In the cryptocurrency world the case might be that there is no possibility to try or use hedging properly, because the cryptocurrency correlation is not diverged enough. (Boyd, 4.2016)

Another way to reduce risk using correlation analysis is to use Modern Portfolio Theory. The theory implies that by reducing the correlation between the variables or the securities the investors could diversify away from the risk of investment loss. Investors should select assets that are less likely to decrease or increase in value at the same time using correlation coefficient. Although, the major critic to this theory has been that it assumes that the assets are fixed and predictable, but in the real world the relationships of the selected assets will not remain constant, thus, making the modern portfolio theory less useful in during times of uncertainty. (Ross, 6.2017)

In addition, investing to securities that have negative correlation relationship can cancel each other out meaning that virtually one has no position when the other increase gets nullified by the others decrease. In cryptocurrency perspective when someday there will be an option to short (play

against the increase) one could double their position. In short-term investments is good to keep in mind to not to invest in a pair with negative or positive correlation.
In general, one of the most basic rules or guides is to diversify. Diversifying means to invest to multiple alternatives instead of just one. Diversifying portfolio lowers the risk of investment loss a great deal when you are not counting just one, but in multiple different variables. When building portfolio, it is good to take look on the correlations. Basically, concentrate on the variables which have constantly correlation close to 0.
Can anything go wrong with good old correlation analysis before investing? Yes, correlation coefficient is more like guideline which is good to take in account when investing on something or going through current portfolio. The correlations are constantly on the move and huge changes between variables can easily happen. As cryptocurrency markets point of view this is even more accurate as the market is still very young and looking for its place. The markets are driven by the media hyping up big innovations and new large partners. Cryptocurrency market is very volatile, but with a little look to correlations one could take a step to more risk-free environment.

1.2. Previous studies on correlation

Let's look on to some previous researches that can give us some interesting knowledge on how should we analyse our findings. There have been numerous studies regarding stock market correlation and currency correlation. Both markets have a lot of similarities with cryptocurrencies and could very well behaving as them, even though cryptocurrency markets are decentralized and they are not.

As said previously, one of the marketing tool or ideas of Bitcoin or any cryptocurrency in matter of fact has been its independence considering financial authorities. They are decentralized and does not need a third party to control over its transactions. So, in general they should not have any relationship with stock markets. The research "Bitcoin as an investment, the added value of bitcoin in a global market portfolio" (Klabbers, 6. 2017) has very in depth look on Bitcoin and stock market correlation. In the text Klabbers points furthermore that if the variables have same correlation, positive or negative, it is not usually good investment considering one's portfolio. He also says that "The high correlations between stocks markets during bad times are troublesome for investors because it undermines the diversification principle". Bad times meaning times where the markets take huge hit in prices for example, natural catastrophes, financial crisis (dot-com, black

Monday) or man maid disasters. On the contrary, for example Gold, Silver and Platinum have low correlation with stock hence they are generally kept as good diversification options with stock market portfolio. In this research there is a table (Table 2) comparing correlation of 6 stock market indexes (S&P 500, FTSE, DAX, NIKKEI, Shanghai a share, MCSI world) 3 bonds (American, European, Asian), a community index, real estate index, Bitcoin.

Table 2, Correlation values of financial assets

	S&P 500	FTSE 100	NIKKEI 225	Shanghai A share	DAX 30	MSCI World	US Bond	UK Bond	Japan Bond	Commodity	Real Estate	$ - GBP	$- €	Gold	**Bitcoin**
S&P 500	1.00	0,81	0,95	0,2	0,78	0,95	-0,52	-0,42	-0,2	0,5	0,6	0,3	0,22	0,06	**0,08**
FTSE 100	0,81	1,00	0,56	0,22	0,81	0,88	-0,42	-0,32	-0,21	0,052	0,61	0,18	0,13	0,05	**0,09**
NIKKEI 225	0,95	0,56	1,00	0,24	0,59	0,62	-0,37	-0,37	-0,28	0,26	0,38	0,23	0,00	-0,15	**0,08**
Shanghai A share	0,2	0,22	0,24	1,00	0,21	0,24	-0,05	0,00	0,12	0,13	0,11	0,08	0,08	0,08	**0,08**
DAX 30	0,78	0,81	0,59	0,21	1,00	0,84	-0,5	-0,44	-0,22	0,41	0,54	0,30	0,07	-0,07	**0,13**
MSCI World	0,95	0,88	0,62	0,24	0,84	1,00	-0,50	0,45	-0,21	0,56	0,57	0,44	0,35	0,10	**0,09**
US Bond	-0,52	-0,42	-0,37	-0,05	-0,5	-0,5	1,00	0,81	0,49	-0,34	-0,05	-0,17	-0,09	0,28	**-0,09**
UK Bond	-0,42	-0,34	-0,37	-0,05	-0,44	-0,45	0,81	1,00	0,47	-0,32	-0,01	-0,34	-0,15	0,27	**-0,09**
Japan Bond	-0,20	-0,21	-0,28	0,00	-0,22	-0,21	0,49	0,47	1,00	-0,15	-0,02	-0,08	0,00	0,2	**0,00**
Commodity Index	0,50	0,52	0,26	0,12	0,41	0,56	-0,34	-0,32	-0,15	1,00	0,21	0,35	0,28	0,26	**0,03**
Real Estate	0,60	0,61	0,38	0,13	0,54	0,57	-0,05	-0,01	-0,02	0,21	1,00	0,04	0,27	0,03	**0,04**
$- GBP	0,30	0,18	0,23	0,11	0,30	0,44	-0,17	-0,34	-0,08	0,35	-0,04	1,00	0,56	0,16	**0,01**
$- €	0,22	0,13	0,00	0,08	0,07	0,35	-0,09	-0,15	0,00	0,28	-0,27	0,56	1,00	0,16	**0,00**
Gold	0,06	0,05	-0,15	0,08	-0,07	0,10	0,28	0,27	0,20	0,26	0,03	0,16	0,34	1,00	**-0,04**
Bitcoin	**0,08**	**0,09**	**0,08**	**0,08**	**0,13**	**0,09**	**-0,09**	**-0,09**	**0,00**	**0,03**	**0,04**	**0,01**	**0,00**	**-0,04**	**1,00**

Bitcoin as an investment (Klabbers, 6. 2017)

The Table 2 demonstrates the correlation values. All three bonds have negative correlations to other assets excluding gold. Gold has negative correlation to Nikkei 225 and Dax 30. The most important observation is that Bitcoin has very low correlation values to everything, meaning the prices of Bitcoin almost do not have any connection to any other asset. Low correlation makes Bitcoin excellent diversification asset to portfolio. Klabbers also calculated the same table on years 2010-2013 and 2014-2016 and Bitcoin's correlation was highest as 0,12 and lowest as -0,14. Later

on the paper when we will do a correlation analyse on all of the selected eight cryptocurrencies this will be very important factor to keep in mind.

2. CRYPTOCURRENCY CORRELATION

On the next following segments, we are going to do different correlation calculations and analyses the findings. The data for tables is gathered from www.coinmarketcap.com. The first segment is comparing two most different cryptocurrencies from the selected eight. We will do 30- and 60-day rolling correlation calculations, their overall history correlation and comparing Bitcoin and IOTA relationship to overall market capitalization of cryptocurrency. Next, we'll look if BTC/ETC and BTC/IOT has same the same feature as stock markets, more over if the correlation gets stronger as prices decreases and vice versa. The third part will be correlation matrix calculation of eight cryptocurrencies, showing connection to each other and analyzing the findings. On last part we will go through the hypothesis comparing them to the findings of the analyses and see if they are supported or not.

2.1. Hypothesis for the correlation analyses

H1: Bitcoin and IOTA will not have strong correlation, because of they are very different as whole. Some level of correlation is expected as Bitcoin is kept as market driver.
H2: Correlation between cryptocurrencies will increase as prices decrease.

2.2. Relationship of Bitcoin and IOTA

In this section we will be comparing Bitcoin and IOTA. These two cryptocurrencies should be very different products overall. Let's look the main differences of these two.

BITCOIN	**IOTA**
Uses Blockchain technology to collet, store data and send assets to other users.	Uses Tangle technology which enables IoT devices to communicate with each other and send data and assets.
Peer-to-peer (P2P).	Machine-to-machine (M2M).

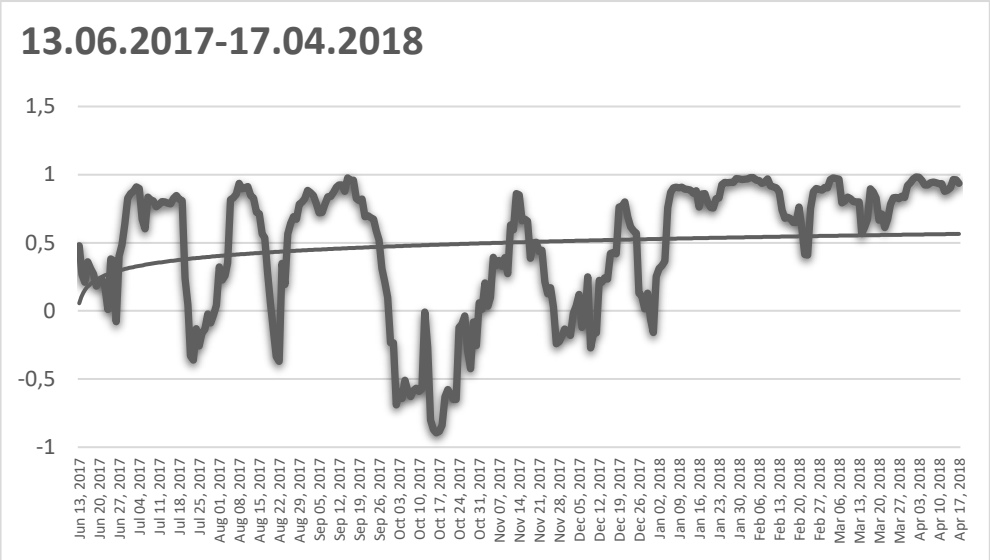
Goal is to replace regular currency.	Via Internet-Of-Things helps devices to send assets to each other. Later the IOTA currency and be changed to regular one.
Has transaction fees	Does not have any transaction fees
Transaction time on average 10-60 minutes.	Transaction time only seconds.
Counts on “miners” to do the transactions.	Transactions are processed by devices.
One transaction need a lot of energy.	Really low energy costs compared to blockchain.
Gets slower as the network grows	Scales almost unlimitedly.
Developer unknown	Developers and founders well known.

(IOTA.org, iotatoken.io, Bitcoin.com)

So, basically even though these both are cryptocurrencies they are very different as a whole. From this we could assume that the correlation coefficient between IOTA and Bitcoin should be low. The Graph 1 shows correlation between the two from first day of IOTA came to the market. The correlation has been changing a lot throughout the year. The average appears to be near positive 0,5. This is reserved as moderate correlation coefficient. Seems like news and announcement have impact on the correlation.

For example, in end of December IOTA was announced to be selected to Tokyo Metropolitan Government’s accelerator program (article, Schiener, 2017) and to have partnership with Bosch a multi engineering company. September 2017 later declared false information hit news. Many large publishers made an article about it, like Forbes.com: “MIT And BU Researchers Uncover Critical Security Flaw In $2B Cryptocurrency IOTA” (Castor, 9.2017). Even though the information was false it really dropped IOTA’s price. News like this really affects IOTA’s or in other cases Bitcoin’s price more than the others so correlation drops.

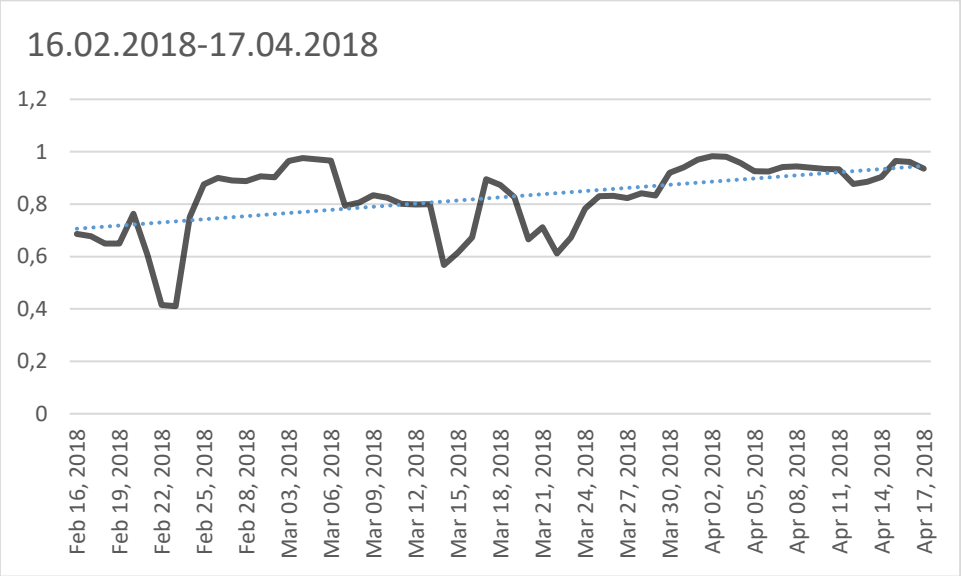
Graph 1, 309-days Rolling Correlation between IOTA and Bitcoin.



In the long run the correlation seems to be changing a lot, but how about a bit more recent day? The Graph 2 shows us the relationship in last 60 days (16.02.2018.17.04.2018). In the Graph 2, it appears that correlation have not been changing as dramatically. The average correlation coefficient is ≈ 0,8 (very strong relationship).

As already addressed in 2.1, stock correlation tends to increase when there is “bad times” or when the prices fall. Total market cap of cryptocurrency has been on decreasing trend since January 2018. And if we look at Graph 2 once again, which shows market capitalization from 16.02.2018-17.04.2018 (same as Graph 3.) it displays that cryptocurrency behaves as stock markets in so called bad times. As prices fall correlation coefficient increases.

Graph 2. 60-days Rolling Correlation between IOTA and Bitcoin

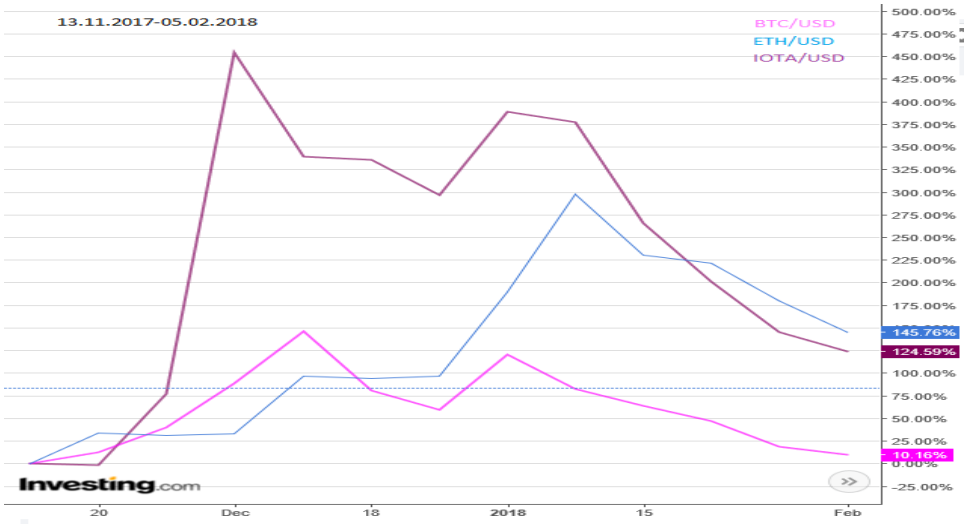


Graph 3, Cryptocurrency market capitalization 16.02.2018-17.04.2018

https://coinmarketcap.com/charts/

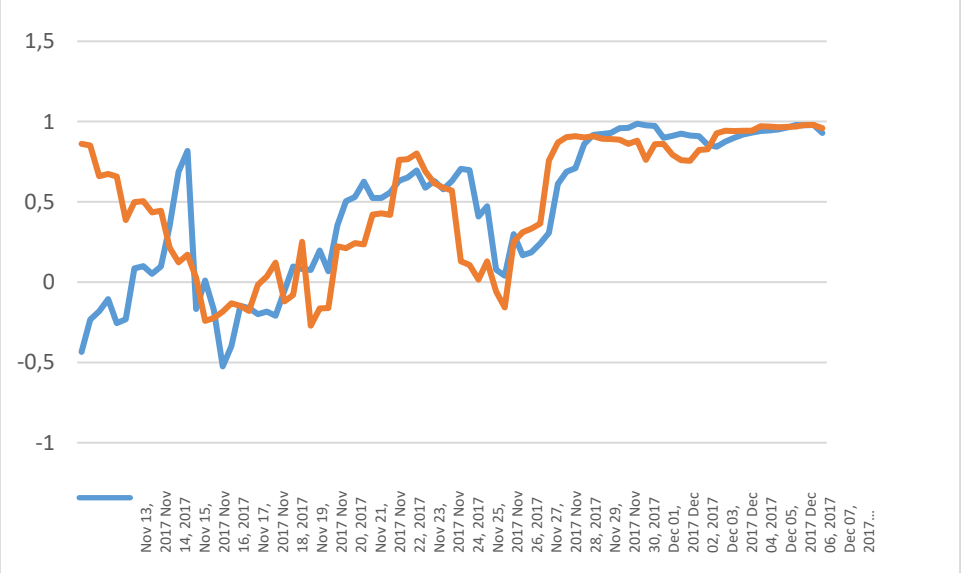
To look more closely if really correlation increases as prices fall. Let's compare if BTC/ETH and BTC/IOT. The correlation gets stronger as their respective prices gets lower. As a date 13.11.2017-05.02.201, because in that period the market had huge increase in prices which followed almost as big decrease. By looking at the Graphs 4 and 5, the arguments seem valid. During December the prices rose and correlation decreased and in January prices decreased and correlation got stronger.

Graph 4, Percentage rise in prices of ETC, BTC and IOT prices 13.11.2017-05.02.2018



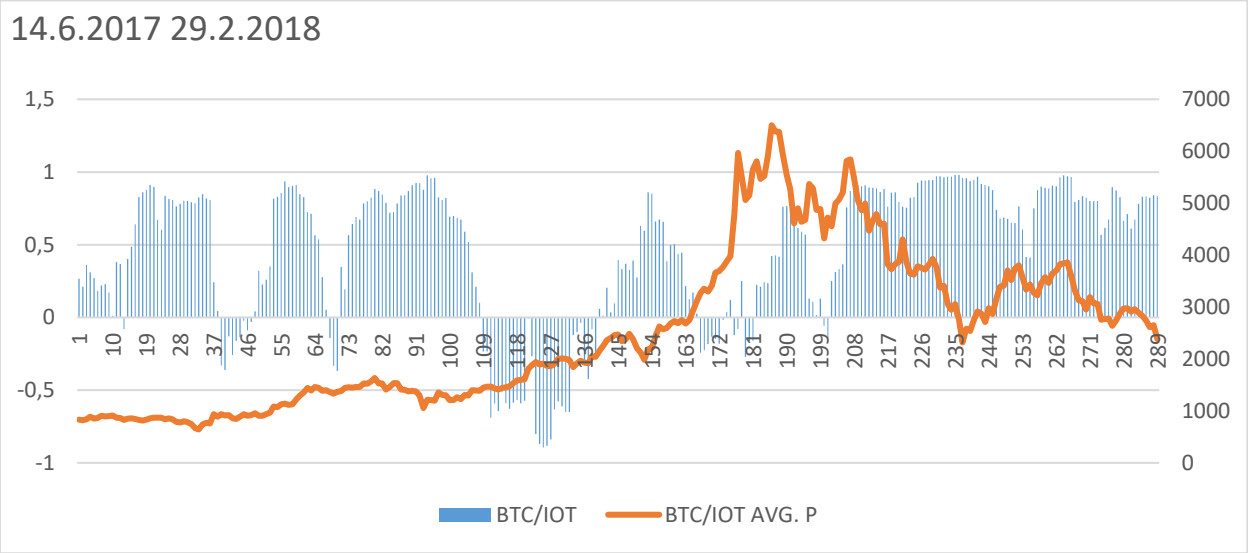
(investing.com)

Graph 5, Correlation of BTC/ETH (blue) and BTC/IOT 13.11.2017-05.02.2018



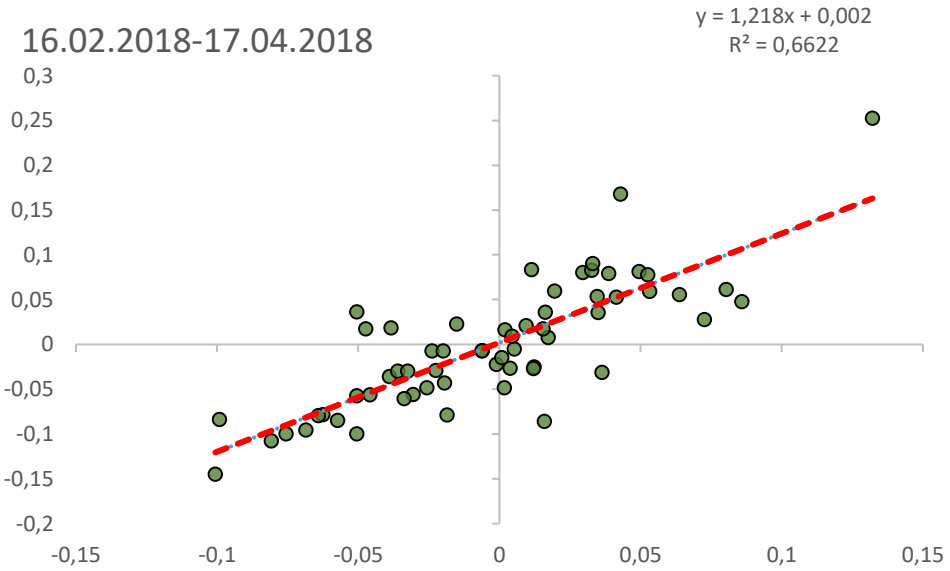
Graph 6, tells us that price/correlation relationship trend is not just in the crises or in huge drops and rises. Moreover, the trend has been exceptionally accurate on the history of the two currencies. To conclude, by looking at the graphs mentioned we see that cryptocurrencies have same correlation trends with each other as stock markets does. In addition, with cryptocurrencies the event which pushes correlation up and prices down do not have to be "catastrophe" as we see this phenomenon already in smaller changes.

Graph 6, Correlation BTC/IOT and Average price of BTC/IOT 14.6.2017 29.2.2018



Scatterplot graphical representation (Graph 7) gives us the equation y = 1,218x + 0,002, where y= IOTA and x= Bitcoin. By plotting a number on place of a variable we can calculate the respective number through solving x=y. The R (0,66) shows the strength of the relationship as an absolute value. According to table given in 1.1.1 the relationship is moderate and very close to strong.

Graph 7, Scatterplot of Correlation between IOTA and Bitcoin



2.3. Cryptocurrency matrix analyse

If Bitcoin and IOTA have strong or moderate relationship with each other despite being really different products. Let's compare the correlation of the eight selected cryptocurrencies. The assumption is that correlation between should at least moderate, because if IOTA had strong relationship so should the others. Even though, I chose IOTA and Bitcoin to be most different overall it is good to keep in mind that the rest are very unique products themselves too and there might be more uncorrelated currency among the selected once.

The matrix below (Table 3) shows us that only Dai has one negative value and it is with Bitcoin. The strongest relationship is between Ethereum and Steem with correlation coefficient of 0,580. The second strongest is between Bitcoin and Steem with correlation coefficient of 0,567. Overall currency which has the closest correlation to zero is Dai. It seems to have almost no relationship to any other cryptocurrency in hand. This is no surprise as price of Dai cryptocurrency is stabilized on price of US dollar. Dai has marketed itself as it will not have connection to other currencies and they are not wrong. Closest coefficient to zero is between Dai and Next with 0,015. The overall correlation coefficient of the matrix is 0,317 which is expected after analyses in the section 2.1. The most remarkable thing is that IOTA is nowhere near to be the most uncorrelated assets. The top three currencies with correlation coefficient closest to zero in order are Dai, Ripple and Funfair. Ripples low correlation is really unexpected as a product it is fair to say it is the least different from the rest (in the side of Bitcoin). (03.11.2017 is the first date where all the coins existed)

Table 3, Correlation matrix of eight selected cryptocurrencies (03.11.2017-01.04.2018)

	BITCOIN	IOTA	ETHEREUM	RIPPLE	NEXT	FUNFAIR	DAI (MAKER)	STEEM
BITCOIN	1	0,457184698	0,52549285	0,25786877	0,52294887	0,387922001	-0,0204227	0,56745533
IOTA	0,4571847	1	0,45286059	0,258178552	0,30878692	0,412064859	0,077393751	0,36142674
ETHEREUM	0,52549285	0,45286059	1	0,463277249	0,40259545	0,505290619	0,080119807	0,58078683
RIPPLE	0,25786877	0,258178552	0,46327725	1	0,1718529	0,353883308	0,043188091	0,34227028
NEXT	0,52294887	0,308786922	0,40259545	0,171852896	1	0,292519251	0,014955474	0,49546155
FUNFAIR	0,387922	0,412064859	0,50529062	0,353883308	0,29251925	1	0,028598533	0,25442988
DAI (MAKER)	-0,020422	0,077393751	0,08011981	0,043188091	0,01495547	0,028598533	1	0,25442988
STEEM	0,56745533	0,361426742	0,58078683	0,342270278	0,49546155	0,254429882	0,254429882	1

Data: Marketcap.com

In most cases, it is advised to look correlation when doing diversification of a portfolio. Correctly done diversification will decrease investing risk and as well as make sure that one's portfolio is not doomed by single variables drop in prices. The correlation matrix helps one to choose the assets to invest on. Strong positive correlation = very risky as if one drops both drops. Strong negative correlation = a bit pointless as one increases the other decreases. By choosing assets as close to zero as possible will give the best outcome profitability and risk wise.
On the table 2, we saw that Bitcoin has very low correlation coefficient to any other financial assets. This means Bitcoin is very useful diversifier for example, S&P 500 portfolio. Bitcoin seems to be even better option than normally used commodities like Gold or Silver. From that we can make an assumption that cryptocurrencies with high positive correlation with Bitcoin will be also possible diversification options, but let's not get too into that in this paper. And as Manjo Singh said in his 3.2018 "During hard economic times, uncorrelated assets may seem to have vanished, but diversification still serves its purpose".

2.4. Results and findings

The aim of this study was to see what kind of correlation coefficient eight cryptocurrencies have that are very different as product or uses dissimilar technology. The research was done by using quotative research methods and the data was mainly extracted form the biggest cryptocurrency database: coinmarketcap.com. The correlation coefficients were calculated by using Pearson's correlation coefficient and preparing correlation matrices. The paper focused the most on relationship between IOTA and Bitcoin as these two seemed to be the most different from each other. Let's look on the hypothesizes and see what were the results on the findings.

H1: Bitcoin and IOTA will not have strong correlation, because of they are very different as whole. Some level of correlation is expected as Bitcoin is kept as market driver.
As we discussed the differences of these two, it was clear that they very distant aims and purposes. IOTA specializes on device and machine communication and uses Tangle technology to verify transactions. On the other hand, Bitcoin aims to displace regular centralized currency and uses blockchain technology to deliver transactions on everyday use. The hypothesis was clear, the correlation should not be very strong.

As the correlation calculation were done we saw that the correlation varies a lot on longer period of time going form almost negative 1 to positive 1 time to time. In the 60-day correlation calculation the average coefficient was close to 0,8 never dropping below 0,4. It seems like that news and announcements have a big effect on the correlation. Even though, the correlation shifted a lot in the long run it certain that IOTA and Bitcoin has overall positive correlation. The average correlation coefficient is in the likely hood of 0,4-0,8 which is kept as mediate or strong relationship thus the hypothesis 1 is not supported.

H1.1: If IOTA and Bitcoin have moderate or strong correlation, so will the other selected currencies too.

The assumption is that single cryptocurrency's prices are not driven as individual, but by the whole market. When one entity has 38,6% of the total market capitalization, it is not strange to assume that everything that happens to that will not affect the whole market. If every altcoin is dependent on Bitcoin's movement they will have strong relationship with each other automatically. As an example, if Bitcoin rises and Ripple and Next are correlated with it, they will have positive correlation with each other. To answer the hypothesis a correlation matrix was calculated. Correlation matrix shows the relationship between all variables. Surprisingly the correlation coefficient results were relatively low. Bitcoin had < 0,5 coefficient only with three of the seven selected ones. The overall average correlation of the matrix was only 0,37 which is weak relationship. Many of the currencies had correlation coefficient a lot closer to zero than IOTA or Bitcoin. Because of the overall correlation coefficient is so low the hypothesis 3 is not supported.

H2: Correlation between cryptocurrencies will increase as prices decrease.

As Klabbers said in his research "Bitcoin as an investment, the added value of bitcoin in a global market portfolio (Klabbers, 6. 2017)" that stock market correlation tends to decrease as prices drop due to some crisis or catastrophe will correlation level increase at the same time. As a contrast, as prices go up again, the correlation relationship falls. The hypothesis suggest that cryptocurrency markets behave as stock markets in scenarios like this. We compared historical data of cryptocurrency market capitalization between 13.11.2017-05.02.2018 to cryptocurrency correlation at the same giving period. In this period, we had huge rises and drops to the price percentage. In the comparison, as the percentage of price increases and decreases the correlation behaved the opposite. We could say that situations like this (huge ups and downs) are rare and these could possible simulate the crises and the abundance of the market. In addition, to prove that the correlation moves to opposite of the prices and has been doing so in the past, we looked at the

whole relationship period (14.6.2017 29.2.2018) that Bitcoin and IOTA has had and it follows trend. Cryptocurrency correlation tends to increase in price decrease and vice versa. Hence, the hypothesis 2 is supported.

The result of the hypothesizes were overall very surprising. The fact that in my opinion the two most different cryptocurrencies had fairly strong correlation and on the other hand the ones which were not as different had almost no correlation what so ever. In my opinion this indicates that the product itself is not the one that drives the prices of a currency or makes it independent form the rest. The one reason that could be that for example why Ripple has lower correlation than IOTA is because of Ripple has more larger following and trust behind it. IOTA is still in its development phase with intention revolutionize technology industry itself. This makes IOTA investors hope on the hype train when the market is rising and hope off when it is not. IOTA has so called FUD (fear, uncertainty, doubt) around it and makes it follow the market and that's how it is correlated with the market whale Bitcoin. As for Ripple, it is ready project, has huge following and has shown to people that it works in the real world. One could make an argument about why Bitcoin and Ethereum have strong correlation then even though Ethereum is the second largest cryptocurrency with working product and large following. This is an interesting question which has to be left for the further researches.
As the result of Bitcoin and IOTA correlation was so high the correlation between the other cryptocurrencies should logically be even higher. As it turns out this is not true. By looking at

As talked in section 1.2, Bitcoin has low correlation to financial assets such as stock and bond markets giving it potential to improve portfolio's risk-return characteristics. The calculation to prove this were not made in this paper, but for the future research we could assume that there are a lot of cryptocurrencies which have strong correlation with Bitcoin hence there are other valuable cryptocurrencies which can be used to diversify one's portfolio. Furthermore, in this paper it was the top eight most different. What correlation coefficient could be found if an analyze for the top 50 alike currencies were made. But as said this need more research to be done (Markowitz mean-variance framework, portfolio mix etc.).

CONCLUSION

Cryptocurrency has been a very hot topic almost a year in the media and with financial authorities and investors. It was kept as something intended for criminal usage for years, because of intractability and lack of obligation to any financial institution. Since then, awareness of cryptocurrencies has risen and it has caught an eye of many worlds well know investors and influencers. The cryptocurrency market is still very young, volatile, evolving and in general there has not been that many studies made about it. There are hundreds of different cryptocurrencies and many of them are very unique and interesting. Some of the currencies are made to replace current FIAT currencies like USD or Euro which are controlled by financial institutions. On the other hand, some of the have goals to make our everyday life better with great innovative technologies. It is safe to say there there is no limit on what cryptocurrencies can be used for.
As of now it is commonly agreed on that the market is driven by Bitcoin which has the market share of 38,6% (22.4.2018). So, if the Bitcoin has so large portion of the market, are the other cryptocurrecies following it's prices? Are the correalted with Bitcoin or with each other?

The purpose of this paper was to see the correlation relationship with eight cryptocurrencies. The currencies selected are the eight most different cryptos as a product. As they are very different product with different goals and fundamentals the first assumption is that they should not have price relationship with each other.

Correlation analysis gives valuable information on relationships of variables. The data can be used for example, to take advantage of changing market, diversifying portfolio and lower the investing risk. The correlation methods used in this paper were cross-correlation and Pearson's correlation coefficient to indicate the statistical significance of coefficients. Pearson's correlation is one of the most popular correlation coefficients which gives us the relationships between the selected cryptocurrencies.

In the first analyze we compared Bitcoin and IOTA which are completely different products. IOTA's goal is to use their Tangle technology which enables IoT devices to communicate with each other and send data and assets. So, basically a communication between machines. Bitcoin goals are to use blockchain technology to displace normal currency which is controlled financial institutions. Because of those differences, in hypothesis 1 we assumed that the correlation between these two to be very low.

But as looking at the results of Graph 1 and 2 we discovered that is not the case. Even though the correlation coefficient has been shifting a lot in a long run the average coefficient is moderate (0,5 < r < 0,7) or even strong (r > 0,7).

As the result of Bitcoin and IOTA correlation was so high the correlation between the other cryptocurrencies should logically be even higher. As it turns out this is not true. By looking at the Table 3 Correlation matrix we see that there are many currencies which have low or almost close to zero correlation. This finding was truly surprising. The most uncorrelated currency was Dai with average coefficient of 0,0420. Following Dai were Ripple (0,27) and Funfair (0,285).

The second analyze was about correlation change and price change relationship. Stock market correlation tends to increase as prices decrease and we examined is this also happening with cryptocurrencies. As an investor this is important to know and as to refer what Klabbers said in 2016 “The high correlations between stocks markets during bad times are troublesome for investors because it undermines the diversification principle”. We investigated this phenomenon in cryptocurrencies by using three graphs (Graph 4, 5 and 6). First in the Graphs 4 and 5 we looked this in a period (13.11.2017-05.02.2018) which had a huge rise in prices followed by huge drop. The trend was clear, correlation increased as prices decreases and vice versa. Graph 6 looked if this is the same case in longer period. With exception of few circumstances the price and correlation has always had this kind of relationship. Is safe to say that cryptocurrencies tend to behave like stock markets, but for the further research about the matter I suggest using larger quantity of variables.

In Klabbers’ study he found out that Bitcoin has has low correlation to financial assets such as stock and bond markets giving it potential to improve portfolio's risk-return characteristics. As the result from the analysis in this paper we can assume that there are a lot of cryptocurrencies which have strong correlation with Bitcoin hence there are other valuable cryptocurrencies which can be used to diversify one’s portfolio. I suggest that future research could use 50 or more variables to find cryptocurrencies which are also have potential to improve one’s risk-return on portfolio. For example, using Markowitz mean-variance framework, portfolio mix etc.

As the lest words, lets conclude the findings and suggestions for future studies.

Cryptocurrency correlation does not depend on uniqueness of the product. Two similar products can have lower correlation coefficient that two almost completely different. I assume that the reason is more on the following and the believe product has behind it.

Very risky or unsure projects seems to have higher correlation than those that have showed that their product is ready and will be “the future”. More in-depth look should be done to say for sure. Like with stock markets, cryptocurrency correlation tends to increase as prices drop and vice versa. To see if there are other cryptocurrencies beside Bitcoin to have potential to improve portfolio's risk-return characteristics a more specific correlation analysis must be made (in addition to Person’s). From our findings this seems to be very possible. As addressed before, the cryptocurrency markets young and evolving in fast phase so constant research has to be made about the markets. Who knows, in few years cryptocurrencies will be larger than we can now even dream of or they might die out altogether.

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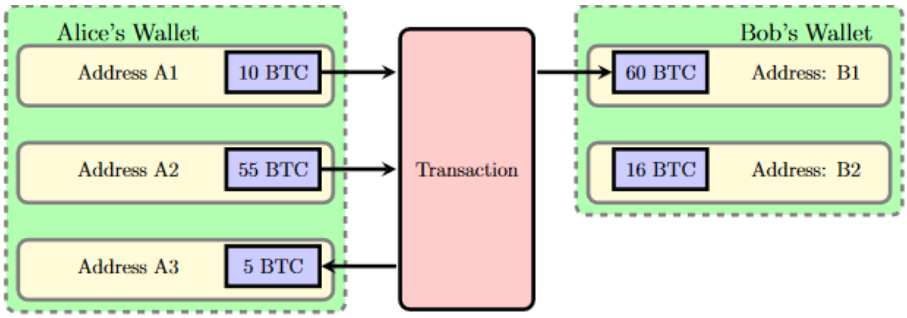
APPENDICES

Appendix 1. Figure 1, Blockchain transactions



Source: Bitcoin Technical Background and data analysis

Made by; Badev, Chen, 2014.

Appendix 2. Table 1, Market capitalization of the eight selected cryptocurrencies as a comparison

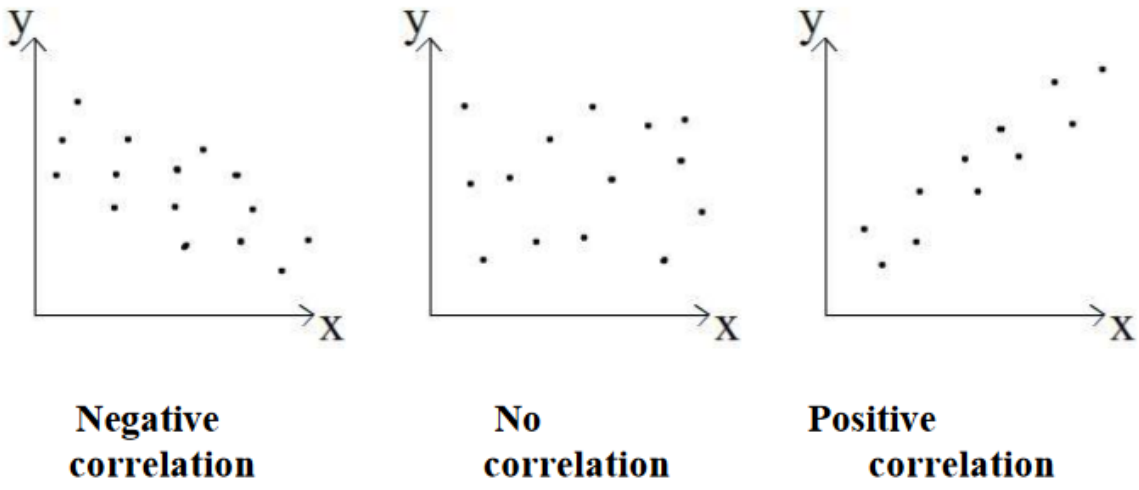
Name	Market cap USD	Market share %
Total of all cryptocurrencies	389 934 507 441	100%
Bitcoin	150 641 526 688	38,6%
Ethereum	61 360 704 534	15,7%
Ripple	34 650 590 030	8,9%
IOTA	5 703 373 778	1,5%
Steem	772 742 376	0,2%

Dai	570 969 203	0,015%
FunFair	216 860 322	0,0056%
Next	204 823 959	0,0053%

Source: https://coinmarketcap.com

Made by: Author

Appendix 3. Figure 2. Positive, negative and no correlation.



Source: http://www.statstutor.ac.uk

Appendix 4. The general ruler for value of *r*

Absolute value of r	Strength of the relationship
r < 0.3	None or very weak
0,3 < r < 0,5	Weak
0,5 < r < 0,7	moderate
r > 0,7	Strong

Source: Scatterplots and Correlation; Mindrila, Balentyne

Made by: Author

Appendix 5. Table 2, Correlation values of financial assets

	S&P 500	FTSE 100	NIKKEI 225	Shanghai A share	DAX 30	MSCI World	US Bond	UK Bond	Japan Bond	Commodity	Real Estate	$ - GBP	$- €	Gold	**Bitcoin**
S&P 500	1.00	0,81	0,95	0,2	0,78	0,95	-0,52	-0,42	-0,2	0,5	0,6	0,3	0,22	0,06	**0,08**
FTSE 100	0,81	1,00	0,56	0,22	0,81	0,88	-0,42	-0,32	-0,21	0,052	0,61	0,18	0,13	0,05	**0,09**
NIKKEI 225	0,95	0,56	1,00	0,24	0,59	0,62	-0,37	-0,37	-0,28	0,26	0,38	0,23	0,00	-0,15	**0,08**
Shanghai A share	0,2	0,22	0,24	1,00	0,21	0,24	-0,05	0,00	0,12	0,13	0,11	0,08	0,08	0,08	**0,08**
DAX 30	0,78	0,81	0,59	0,21	1,00	0,84	-0,5	-0,44	-0,22	0,41	0,54	0,30	0,07	-0,07	**0,13**
MSCI World	0,95	0,88	0,62	0,24	0,84	1,00	-0,50	0,45	-0,21	0,56	0,57	0,44	0,35	0,10	**0,09**
US Bond	-0,52	-0,42	-0,37	-0,05	-0,5	-0,5	1,00	0,81	0,49	-0,34	-0,05	-0,17	-0,09	0,28	**-0,09**
UK Bond	-0,42	-0,34	-0,37	-0,05	-0,44	-0,45	0,81	1,00	0,47	-0,32	-0,01	-0,34	-0,15	0,27	**-0,09**
Japan Bond	-0,20	-0,21	-0,28	0,00	-0,22	-0,21	0,49	0,47	1,00	-0,15	-0,02	-0,08	0,00	0,2	**0,00**
Commodity Index	0,50	0,52	0,26	0,12	0,41	0,56	-0,34	-0,32	-0,15	1,00	0,21	0,35	0,28	0,26	**0,03**
Real Estate	0,60	0,61	0,38	0,13	0,54	0,57	-0,05	-0,01	-0,02	0,21	1,00	0,04	0,27	0,03	**0,04**
$- GBP	0,30	0,18	0,23	0,11	0,30	0,44	-0,17	-0,34	-0,08	0,35	-0,04	1,00	0,56	0,16	**0,01**
$- €	0,22	0,13	0,00	0,08	0,07	0,35	-0,09	-0,15	0,00	0,28	-0,27	0,56	1,00	0,16	**0,00**

Gold	0,06	0,05	-0,15	0,08	-0,07	0,10	0,28	0,27	0,20	0,26	0,03	0,16	0,34	1,00	**-0,04**
Bitcoin	**0,08**	**0,09**	**0,08**	**0,08**	**0,13**	**0,09**	**-0,09**	**-0,09**	**0,00**	**0,03**	**0,04**	**0,01**	**0,00**	**-0,04**	**1,00**

Source: Bitcoin as an investment, Klabbers, 6. 2017

Made by: Author

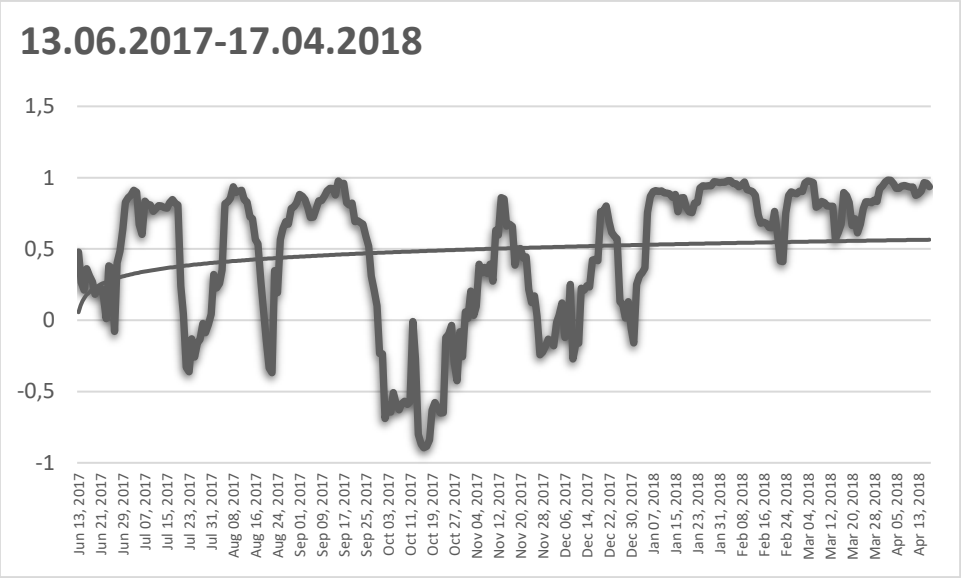
Appendix 6. Differences between Bitcoin and IOTA

BITCOIN	IOTA
Uses Blockchain technology to collet, store data and send assets to other users.	Uses Tangle technology which enables IoT devices to communicate with each other and send data and assets.
Peer-to-peer (P2P).	Machine-to-machine (M2M).
Goal is to replace regular currency.	Via Internet-Of-Things helps devices to send assets to each other. Later the IOTA currency and be changed to regular one.
Has transaction fees	Does not have any transaction fees
Transaction time on average 10-60 minutes.	Transaction time only seconds.
Counts on “miners” to do the transactions.	Transactions are processed by devices.
One transaction need a lot of energy.	Really low energy costs compared to blockchain.
Gets slower as the network grows	Scales almost unlimitedly.
Developer unknown	Developers and founders well known.

Source: IOTA.org, iotatoken.io, Bitcoin.com

Made by: Author

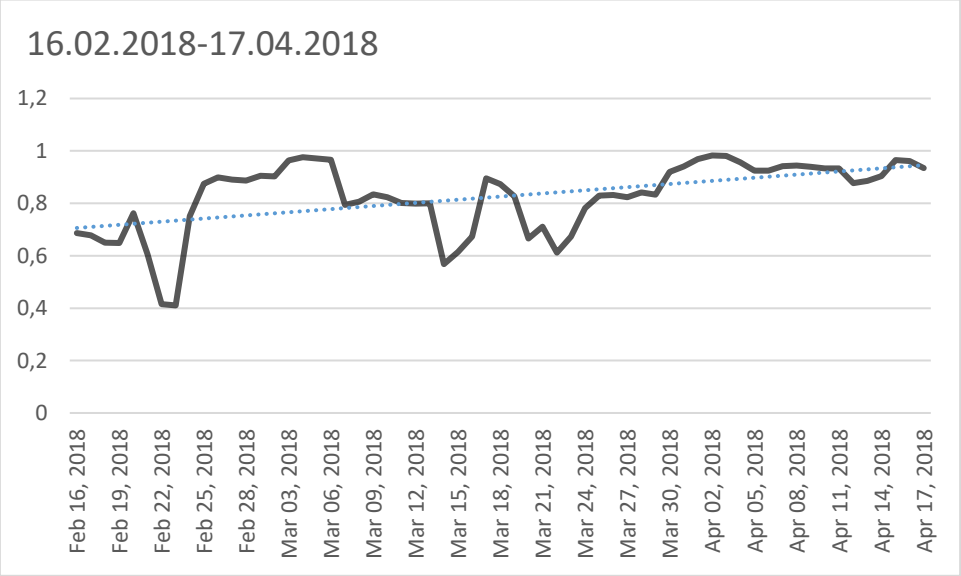
Appendix 7. Graph 1, 309-days Rolling Correlation between IOTA and Bitcoin



Source: Coinmarketcap.com

Made by: Author

Appendix 8. Graph 2, 60-days Rolling Correlation between IOTA and Bitcoin



Source: Coinmarketcap.com

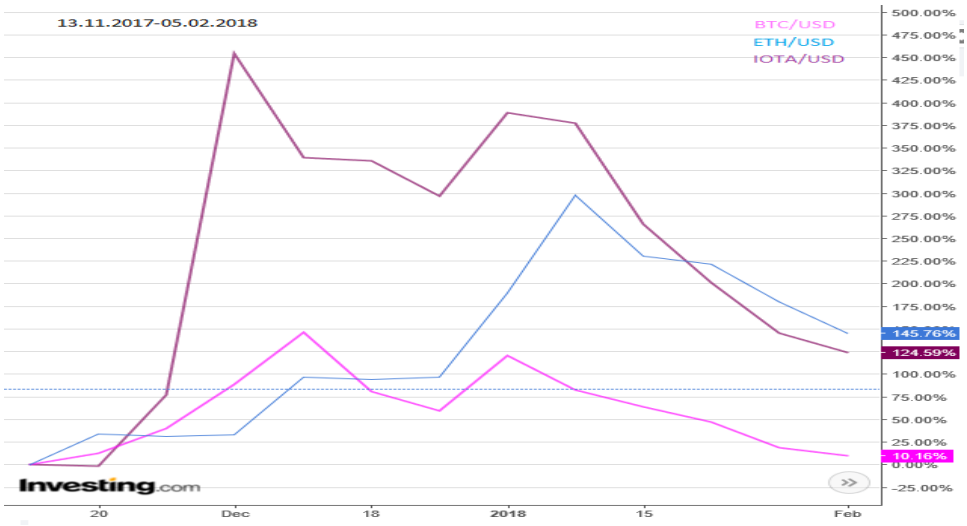
Made by: Author

Appendix 9. Graph 3, Cryptocurrency market capitalization 16.02.2018-17.04.2018

Source: www.coinmarketcap.com

Made by: Author

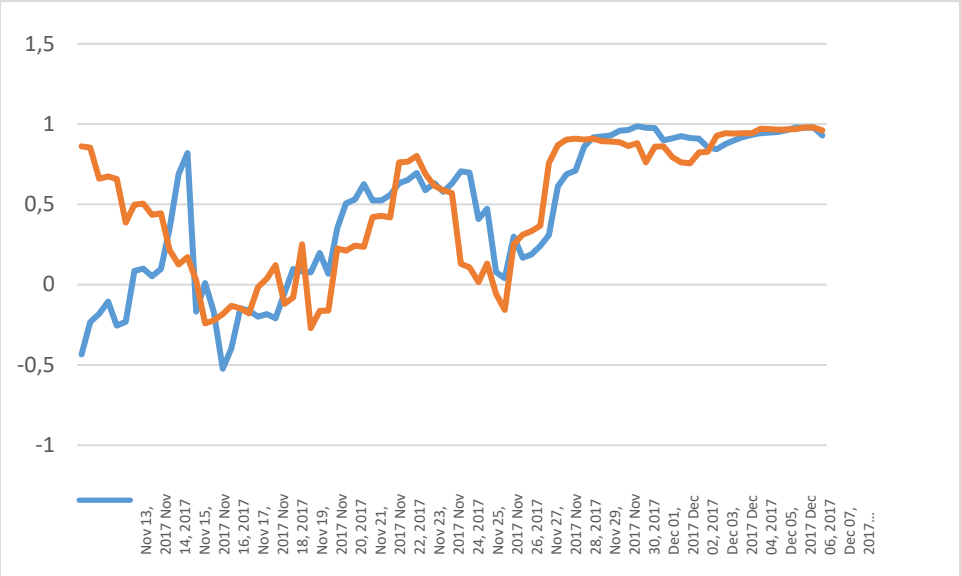
Appendix 10. Graph 4, Percentage rise in prices of ETC, BTC and IOT prices 13.11.2017-05.02.2018



Source: www.investing.com

Made by: Author

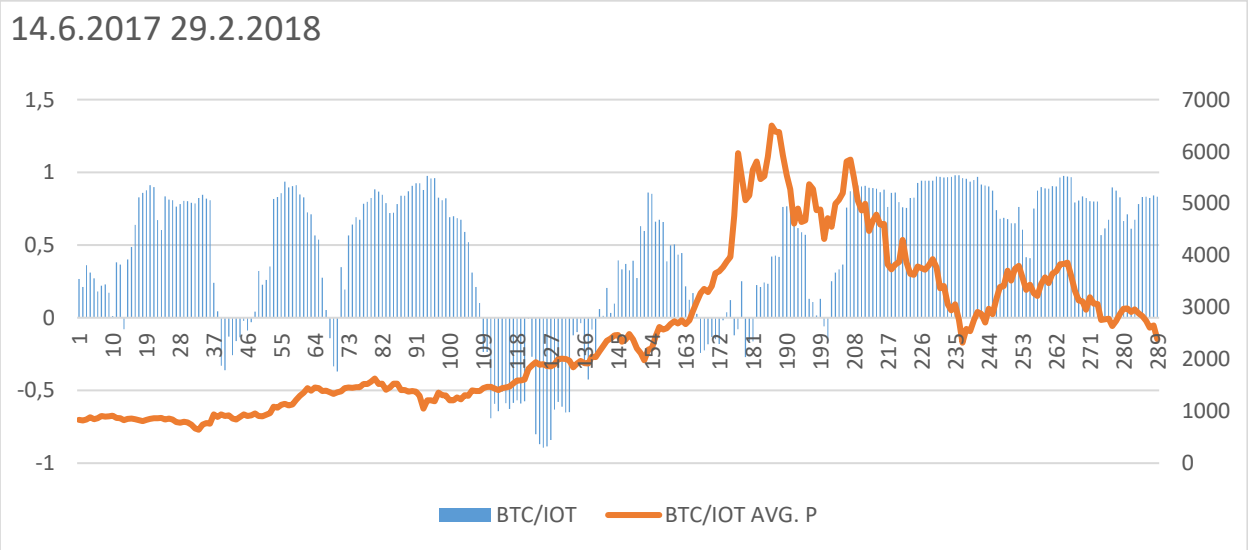
Appendix 11. Graph 5, Correlation of BTC/ETH (blue) and BTC/IOT 13.11.2017-05.02.2018



Source: www.coinmarketcap.com

Made by: Author

Appendix 12. Graph 6, Correlation BTC/IOT and Average price of BTC/IOT 14.6.2017 29.2.2018



Source: www.coinmarketcap.com

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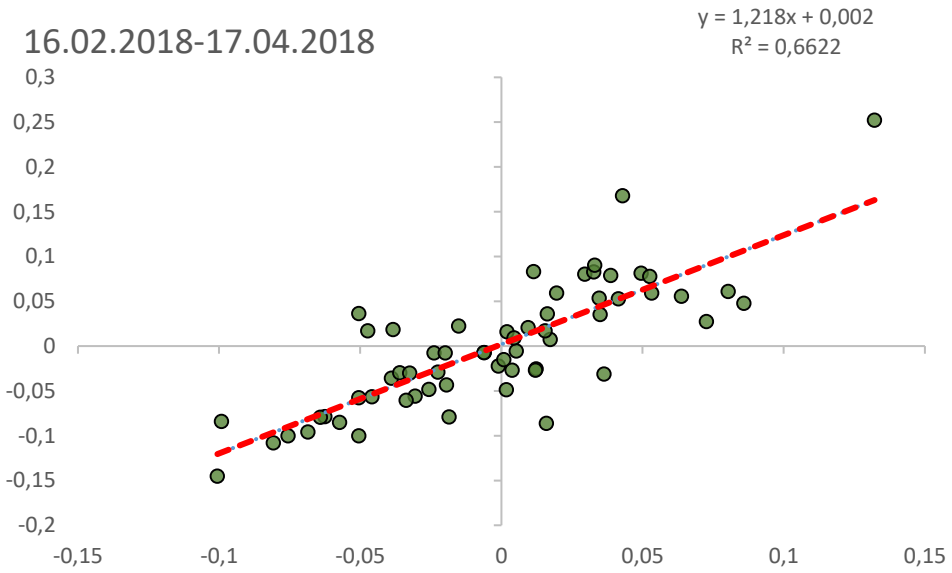
Appendix 13. Graph 7, Scatterplot of Correlation between IOTA and Bitcoin



Source: www.coinmarketcap.com

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Appendix 14. Table 3, Correlation matrix of eight selected cryptocurrencies

	BITCOIN	IOTA	ETHEREUM	RIPPLE	NEXT	FUNFAIR	DAI (MAKER)	STEEM
BITCOIN	1	0,457184698	0,52549285	0,25786877	0,52294887	0,387922001	-0,0204227	0,56745533
IOTA	0,4571847	1	0,45286059	0,258178552	0,30878692	0,412064859	0,077393751	0,36142674
ETHEREUM	0,52549285	0,45286059	1	0,463277249	0,40259545	0,505290619	0,080119807	0,58078683
RIPPLE	0,25786877	0,258178552	0,46327725	1	0,1718529	0,353883308	0,043188091	0,34227028

NEXT	0,52294887	0,308786922	0,40259545	0,171852896	1	0,292519251	0,014955474	0,49546155
FUNFAIR	0,387922	0,412064859	0,50529062	0,353883308	0,29251925	1	0,028598533	0,25442988
DAI (MAKER)	-0,020422	0,077393751	0,08011981	0,043188091	0,01495547	0,028598533	1	0,25442988
STEEM	0,56745533	0,361426742	0,58078683	0,342270278	0,49546155	0,254429882	0,25442988 2	1

Source: www.coinmarketcap.com

Made by: Author