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AN ANALYSIS OF CAUSALITY BETWEEN CRYPTOCURRENCIES AND USD/EUR EXCHANGE RATE

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KRİPTOPARALAR VE USD/EUR KURLARI ARASINDAKİ NEDENSELLİK İLİŞKİSİ ANALİZİ

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PREFACE

This study is submitted in fulfilment of the requirements of the Master's Degree of Financial Economics program in İstanbul Bilgi University.

Even before noone had ever call the name "money", its existance was felt throughout the history. At early mankind, people had used the barter system to get their needs. After the invention of money, people started to trade much more easier than the times of barter system.

Money has started to evolve as the time pass. After the Internet entered our lives, money has started to be evaluated in different dimensions.

As the development of humanity continues, new forms of money have emerged besides the known forms of money. One of the newest form of money is called as Cryptocurrencies. Cryptocurrencies have been started to use and became as popular as national currencies in recent history.

In this study, the causality relation between Dollar and Euro which have been accepted as global currencies for many years all over the world and Cryptocurrencies which is called the new generation of money will be analyzed.

I would like to signify my appreciation and thanks to my adviser Assoc. Prof. Serda Selin ÖZTÜRK for her encouragement and help during my study. I would like to thanks to my dear husband Barlas BURAK for his support and his patience throughout at every stage of process. My mother Tülinay ORHAN, my aunt Şenay ERENDOR and my father Osman ORHAN also supported me at all process.

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LIST OF ABBREVIATIONS

USD	United States Dollar
CPU	Central Processing Unit
BTC	Bitcoin
ETH	Ethereum
EUR	Euro Currency
VAR	Vector Autoregressive Model
LTC	Litecoin
XRP	Ripple
PKI	Public Key Infrastructure
DXY	USD Index Price
ADF	The Augmented Dickey-Fuller Test
PoW	Proof-of-Work
AIC	The Akaike Information Criterion
SC	The Schwarz Criterion
LR	Likelihood Ratio
FPE	The Final Prediction Error
HQ	The Hannan Quinn Information Criterion

LIST OF SYMBOLS

μ	Mean
σ^2	Variance
γ_k	Covariance
X_t, Y_t	Series
C	Constant
y, p, t, a, u, i	Parameters
$\hat{L}$	Maximum Value of the Model's Likelihood Function
k	Estimated Number of Parameters
n	Number of Observations
ε	Error
β	Coefficient
LNBTC/EUR	Logarithmic BTC in EUR Exchange Rate
LNETH/EUR	Logarithmic ETH in EUR Exchange Rate
LNEUR	Logarithmic EUR Index Exchange Rate
LNUSD	Logarithmic USD Index Exchange Rate
LNBTC/USD	Logarithmic BTC in USD Exchange Rate
LNETH/USD	Logarithmic ETH in USD Exchange Rate
D(LNBTC/EUR)	First Differantial of BTC in EUR Exchange Rate
D(LNETH/EUR)	First Differantial of ETH in EUR Exchange Rate
D(LNEUR)	First Differantial of EUR Index Exchange Rate
D(LNBTC/USD)	First Differantial of BTC in USD Exchange Rate
D(LNETH/USD)	First Differantial of ETH in USD Exchange Rate
D(LNUSD)	First Differantial of USD Index Exchange Rate
C	Constant

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ABSTRACT

Development of civilizations have been affected much more from invention of the money rather than barter system. Therefore, interactions between societies has developed which has caused the technological improvements.

As the use of technology in daily life has increased, money started to be more digitized. After money was begun to be used as digital money, it provided a basis for the invention of cryptocurrencies. This invention of cryptocurrencies has brought a new extent to the meaning of money.

An academic research about the relations between cryptocurrencies and traditional currencies becomes important as the popularity of cryptocurrencies has increased in recent years. As Bitcoin and other cryptocurrencies are started to be named as future of money, the existence of interaction between them and traditional currencies is questioned. It is wondered whether the values of cryptocurrencies is increased completely independently.

The present study, the Granger Causality Analysis was found to be the most appropriate method to research the causality relations between the two most used cryptocurrencies since the emerge of cryptocurrencies which are Bitcoin (BTC) & Ethereum (ETH) and the two most accepted national indexes which are United States Dollar (USD) Index and Europ Currency (EUR) Index.

In conclusion, the analysis of the Granger Causality between the two new generation currencies and the two traditional currencies is completed to research the Causality Analysis. After the results are examined, they showed that there are no causality between BTC/USD and USD Index or ETH/USD and USD Index. In addition to this there is also no causality between BTC/EUR and EUR Index or ETH/EUR and EUR Index.

Key Words: Bitcoin, Ethereum, The Granger Causality Analysis, Vector Autoregressive Model (VAR), Money, Cryptocurrency, Peer-to-Peer, USD Index, EUR Index, Traditional Money, The Augmented Dickey- Fuller

ÖZET

Medeniyetlerin gelişimi paranın bulunmasından takas sistemine nazaran daha çok etkilenmiştir. Bu sebeple, toplumlar arası etkileşim gelişmiş, bu da teknolojik gelişmelere sebep olmuştur.

Teknolojinin günlük hayattaki kullanımı arttıkça, para daha da dijitalleşmeye başlamıştır. Paranın dijital olarak kullanılmaya başlanması kripto paraların ortaya çıkmasına zemin hazırlamıştır. Bu buluş paranın anlamına yeni bir boyut getirmiştir.

Kripto paraların son yıllardaki popülerliğinin artması ile geleneksel para birimleri ile kripto paralar arasında bir ilişki olup olmadığının akademik olarak araştırılması önem kazanmıştır. Bitcoin ve diğer kripto paraların geleceğin parası olarak adlandırılması sebebiyle, geleneksel para birimleri ile aralarındaki etkileşimin varlığı sorgulanmaktadır. Kripto paraların değerlerinin tamamen bağımsız olarak mı arttığı merak edilmektedir.

Bu çalışmada ortaya çıkışından bu yana en çok kullanılan iki kriptopara olan Bitcoin (BTC) ve Ethereum (ETH) kullanılarak, geleneksel ve tüm dünyada en çok kabul gören iki döviz endeksi olan United States Dollar (USD) Index and European Currency (EUR) Index ile aralarında nedensellik olup olmadığının belirlenebilmesi için Granger Nedensellik Analizi kullanılabilecek en uygun yöntem olarak görülmüştür.

Sonuç olarak, bu iki yeni nesil para birimi ile iki geleneksel para birimi arasındaki nedensellik araştırması Granger nedensellik analizi yapılarak tamamlanmıştır. Sonuçlar incelendiğinde, BTC/USD ile USD İndeksi veya ETH/USD ile USD İndeksi arasında Granger Nedensellik Analizi anlamında bir nedensellik lişkisine rastlanmamıştır. Ayrıca BTC/EUR ile EUR İndeksi veya ETH/EUR ile EUR İndeksi arasında da Granger Nedensellik Analizi anlamında bir nedensellik ilişkisinin olmadığı görülmüştür.

Anahtar Kelimeler: Bitcoin (BTC), Ethereum (ETH), Granger Nedensellik Analizi, Vektör Otoregresyon Modeli (VAR), Para, Kriptopara, Eşler Arası, USD indeks, EUR indeks, Geleneksel Para.

INTRODUCTION

The history of money dates back to the early days of human history. Money has gone through many phases till its emergence and perhaps the greatest change of money has experienced with its digitalization.

First Cryptocurrency which is Bitcoin were invented 11 years ago. There are two reasons affected to emerged cryptocurrencies at the market. These are technological developments had to be advanced level and investors had to believe that they needed a new currency. Cryptocurrencies have increased their popularity and price from 0 in the last 11 years. After Bitcoin is invented, lots of cryptocurrencies and altcoins were invented. The number of cryptocurrencies and altcoins are still rising up.

It is intriguing whether the traditional currencies have an impact on the popularity of cryptocurrencies and the increase in their value. Because in general terms the traditional currencies are; regulated by the government, protected by certain rules, are only provided by third parties for transactions and have high transaction fees. On the other hand, there are cryptocurrencies which are; not regulated by any legal authority, open sourse, no need third parties for transactions, low or non-transaction fees and protected by cryptology and various mathematical algorithms.

Although cryptocurrencies and traditional currencies have different markets, whether they affect each other are among the topics of interest. Even though there are many academic researches for the relationship of these two types of money, there is so few researches about the analysis of causality between.

To find the answer about this issue, the Granger Causality Analysis should be used. The content of the data is Euro based Bitcoin (BTC/EUR), Euro based Ethereum (ETH/EUR), Dollar based Bitcoin (BTC/USD), Dollar based Ethereum (ETH/USD), Dollar Index and Euro Index.

This study is planned as follows: In the first chapter of the thesis, the definition of money is made with its historical development and what humanity were using before it. Then, functions of money are listed with their detailed explanations.

In the second chapter, the types of the money which are commodity money and fiat money are explained. Their different characteristics in terms of advantages and disadvantages and historical timeline are mentioned.

In the third chapter, what digital currency is and the affect of technological improvement on digital currency are clarified. Then, the meaning of cryptocurrency and the differences between cryptocurrency and currency are stated. With more detailly, they articulated in terms of structure, anonymity, transparent and transaction manipulation.

Cryptocurrency is the title of fourth chapter that is defined the following headings; the primary functions of cryptocurrency, the history of cryptocurrency, what blockchain is, what is Bitcoin - the first cryptocurrency, Proof of Work method, lightning network, why cryptocurrency is used and trading volume of cryptocurrencies.

Just before the most important chapter which is sixth chapter, the literature research for the thesis is reviewed in the fifth chapter.

With beginning the sixth chapter, transition to causality analysis is completed. Firstly, the data structures that were used are defined with their date range information and definitions of the list of currencies. Secondly, stationary analyse of the data is determined with The Augmented Dickey-Fuller Unit Root Test. Thirdly, the Lag Length Criterion test helped to find the lag length. Therefore, Vector Autoregressive model is used to control if the data is significant. Lastly, Granger Causality Analysis is applied to find out if there is any causality and the research would be completed.

CHAPTER 1

MONEY

In order to understand the cryptocurrencies, it is important to understand what the money is and what its nature. Understanding the real structure of money and its features that it should have will help to better understand the currency.

Money has been used by people in many forms and ways throughout their journey in history. And during this process it has been changed in terms of usage. After the industrial revolution, there have been important developments in financial and economic terms in the developing world in all fields.

The rate of participation in the circulation has also increased due to the rapid exchange of money. Afterwards, technological developments facilitating circulation increased.

1. What is the Money?

Money is a something that a society accepts to use in transactions as a measure of value or as a means of payment (Merriam-webster, 2019).

It represents the value of other things. The money used when purchasing may be used by the recipient to obtain another goods or services. However, it must be acceptance as an instrument of change by all. It is hard to define what money is, but it is simply what people accept for change.

In terms of money features;

- Suitable for easy carrying under the scale of weight and volume which makes it easier to trade from further distance.
- Due to the divisiveness character of money, it is possible to make payments in different amounts which also cause to be converted into other units.
- Resistance to external factors such as heat, moisture, wear, etc.

- It must be recognized and accepted by other countries.

1.1. History of Money

1.1.1. Before Money

In the years when humanity was developing, the barter method was used to get the needs. Bartering is a method of the needs of encountering of wants (Furnham & Argyle, 1998).

According to Robertson (2007), "Money gradually developed out of various different features of early societies, such as ceremonies and feasts or compensation for killing a man or a bride-price for marrying a woman". Gold, Silver and other shiny objects were being used in different types of ceremonies as their traditional activities. For example, sacrifices, gifts to gods and tax to the kings. While some archaeologists and anthropolocists think that money is at the heart of social cultural religion, some parties think that money was developed to help trade. Bartering objects under the environmental change and changing value measure could cause trouble for people. Therefore, ancient people started to think of solving the negative results of the burdensome, slow and time-consuming bartering method. This was the beginning of the idea of money (Robertson, 2007).

When humanity was involving in 9000 BC, people used different type of products for bartering. Some examples; camels, sheep, vegetables, grain etc. This situation could helped the evolution of farming in those years. Because ancient societies began to realize the trading options with using those times objects that are being used instead of money. In China and some parts of Africa, people started to use cowrie sheels for barter at around 1200 BC. The usege of cowrie sheels idea helped Chinese people to develop imitations of cowrie sheels from metals such as copper and bronze at around 1000 BC. This new money kind metals were offen used for tool exchance (Back & Pumfrey, 2011).

Some examples of other products which was being used for barter are listed below: Drums, wampum, feathers, gongs, hoes, ivory, leather, nails, pigs, amber, quartz, rice, cowries, salt, umiacs, zappozatsand eggs (Davies, 2002).

1.1.2. After Foundation of Money

The Lydians invented coins as money at around 700 BC. This invention had rapidly spread to other countries, thus all of them melted their own series of coins with different values. The converting metals into coins idea was perfect for easy trade, recycling if needs and durability throughout time. At the end, coins were suitable to compare the value of things that anyone wanted (Bellis, 2018).

Rebbeca Burn-Callander (2014), published a brief summary of the evolution of money in www.telegraph.co.uk web site:

- In 1250, Marco Polo journey to China, introduced the paper money to European Countries.
- In 1661, First bank notes were begun to use in Sweden.
- In 1860, Western Union, which was an industry giant also at that time, allowed money to be sent by telegraph.
- In 1946, the first credit card was invented. It name was “Charg – it Card”.
- In 1999, banks began to use telephone banking as cellphones were being popular.
- The first contactless card “Contactless Payment Card” in 2008 was released in UK.
- Satoshi Nakamoto sent an e-mail with a paper in 2008 which entitled; “Bitcoin: A Peer-To-Peer Electronic Cash System”.

- In 2014, Bitcoin entered the mainstream for being the first carried out decentralized cryptocurrency.

1.2. Functions of Money

Money can be used for buying and selling goods and services. Three most important functions and other three sub-functions can define money. Money serves as A Medium of Exchange, A Measure of Value, A Store of Value, are three main functions of money. The sub-functions are; The Basis of Credit, A Unit of Account and A Standard of Postponed Payment (Suman, 2014).

If these functions did not exist, the exchange of goods would be more difficult. It would be difficult to determine the value of products when bartering. But money, regulates the expenditure of people who want to make mutual purchases (Hermele, 2014).

1.2.1. Medium of Exchange

A medium of exchange is a tool or a system which helps to buy or sell and trade for products. It helps in facilitating. All trading processes are important, their amount is big or small does not change this fact.

Money should provide equality for market player in the market. The money must represent a standard of value for the use of the exchange tool function. This standard should be accepted by all parties (Chen, 2019).

Money desired good or service makes it easier to buy. The requested good or service can be obtained by making a bid. In order to ensure arrange and predictability in the market, offers can be given for the purchase of goods and services.

Producers can know how much debt they will pay for production and production through price predictability. This structure creates a stable pricing model. With the stable pricing model, consumers can also plan their own budgets appropriately.

The most important function of money is being a tool for medium of exchanges. Without money, the transactions are based on a barter system with direct change. The difficulty of the barter system is to give something other than the equivalent to the desired goods and services (Cliffsnotes, 2019) Money is a tool that can be used without any difficulties in the exchange process.

One of the main difficulty is getting together people whose needs and wants align at the same time and place. In order to solve this diffeculty, credit system and cash system was begun to use together. For historical researchs, there is no solid proof which one of these two systems had developed first that is not important for today's purposes of people (Narayanan et al., 2016).

1.2.2. Unit of Account

It is also necessary to consider the money as a result of the exchange. In short, money should be considered as an account unit. It allows to compare the prices of products in different sectors. This provides a sense of supply-demand balance for both the supplier and the owner, and the ease of decision-making (Cliffsnotes, 2019).

In other words, money is used to record and measure the cost of all products or services, regardless of time (Suman, 2014).

1.2.3. Store of Value (Purchasing Power)

Money is a liquid asset. Liquidity can be considered as easy disposable to obtain the desired goods and services. Since the value of money is an asset that is protected over time, it is suitable for accumulation.

Previously, the products used in the barter did not have much to do with storage / accumulation. This caused people to be economically deteriorated. Therefore, they were not considered sufficient as a storage medium (Suman, 2014).

In modern money, people are allowed to accumulate and to participate in them. Thus money can be used as a purchasing power store. Can be stored as much as

desired and available for the future. It can be used as a value store only if its value is stable (unless there is inflation or devaluation in the country concerned).

1.2.4. The Other Functions

Sanket Suman (2014) explained the other functions of money in the article as follow:

1.2.4.1. The Basis of Credit

Money is the source of loans. In case of need and in the absence of money, borrowers may have money through loans.

1.2.4.2. A Measure of Value

In the barter system, it is very difficult to measure the values of the goods and services. Because the products used in the purchase of goods and services to determine the exact equivalence of the variable is variable.

Money is a measurement tool. It provides the pricing and value of everything in a common denominator. For the goods and services people want to buy; different prices comparison and relative value differences are seen.

1.2.4.3. A Standard of Postponed Payment

A standard of postponed payment is an extension of the first function, medium of exchange. Money is again a means of exchange, but this time the payment is made by spreading over a certain period. With the deposit payment, the buyer buys the goods or services and the remaining amount is paid in installments. This type of payment in the barter system can create various troubles. In other words, the use of money permits postponement of spending from the present to some future occasion.

CHAPTER 2

TYPES OF THE MONEY

2. Types of the Money

2.1. Commodity Money

In commodity money, the value of the currency comes from the material from which it is made. Gold, silver, cereals, animals etc. other products have served as a commodity benefit in the past. Commodity allowance, regardless of any governing body, is a type of money that has its own value. That means the value of money itself. The longest and most popular commodity currency format is gold and silver coins. Their history dates back five thousand years (Herold, 2017).

2.2. Fiat Money

Fiat money is a currency that lacks intrinsic value and is established as a legal tender by government regulation.

As a result of such legal decrees of value, fiat currencies are also called "legal tender" which means they have to be accepted for payment of goods and services in their respective countries. That being said, you can now see that money as we know it today has value only because of its legal status, which is declared by governments (Quest, 2018).

The reason is one of the most basic principles of economics; supply and demand. To be more specific, this means that when the supply of an object is increased, the value of that object will tend to decrease assuming demand for that thing remains constant. Conversely, when the supply of an item is decreased, assuming constant demand, the value will increase (Quest, 2018).

2.2.1. History of Fiat Money

Fiat money, started to be used by Yuan, Tang, Song ve Ming Dynasties in 11th Century in China. Between 618 and 907 Centuries, the demand for precious metals

in the Tang Dynasty was too high and the supply did not meet the demand. The coin shortage, which was caused by the high demand, forced people to move from coins to banknotes. Due to this problem, the transition was easier. In Song Dynasty (between 960 and 1276 Centuries), in the Tchetchuan region, there was an explosion leading to a copper money shortage. Special notes of the investors about financial reserve was accepted as the first legal motion. Paper money usage was began in the 18th century in the west. At the beginning of the 20th century, the financial institutions had allowed to convert coins and notes to commodity money on demand. In 1971, America took a couple of economic measures, because of the declining gold reserve. These measures includes forbidding of the direct conversion of the dollar. Since then, many countries have started to use fiat coins for exchange between the main currencies (What is Fiat Currency?, 2019).

2.2.2. Fiat Money Working System

If a money is supported by a legal authority, the type of that money is fiat money. As another choice to the barter system and a storing purchasing power, the paper is used.

Ensures that the desired products and services are received without experiencing the difficulties due to the differences in the needs of the products or the inability to equalize the values of the products in the trade. People use money not only to trade but also to contribute to the development of their societies. Depending on their storage capability, people can follow the path to accumulate money for their future plans. A value of money which has a type of fiat money can be determined by the econonomical situations of country or countries that use the money or other countries economical situtation towards that money. These situation affect the interest rate of the money. If a country is in a bad economical situation, citizen of this country can not buy the goods and services as they needed because of the increase rate in prices (What is Fiat Currency?, 2019).

2.2.3. Advantages and Disadvantages of Fiat Currency

Fiat money; gold, silver etc. unlike commodity-based coins has a stable value. The most important feature is that. The fact that paper money can be printed and retained at a time when it is needed provides a significant advantage.

Fiat currency or fiat money is what a government declares as legal tender: any medium of payment recognized by the law to meet financial obligations, such as paying for goods and repaying debts (Bajpai, 2019).

Fiat is considered to have an intrinsic value since there is no physical commodity supporting the money. Since there is no physical commodity supporting it, it can be worthless in extreme inflation. The value of Fiat currencies is more stable than commodity currencies (What is Fiat Currency?, 2019).

2.2.4. The Difference Between Fiat Money and Cryptocurrency

As fiat money mentioned so far, without the confidence of society and governments' support, it has no value by itself. The regulations of goverments supply it so societs can pay the taxes. On the other hand, cryptocurrency is standing just the opposite side from the fiat currency. Cryptocurrency does not supportted by Central government, it is not legal tender and it is not centralized. Cryptocurrency does not been used by society to pay their taxes. However, cryptocurrency has its own regulations which is being controlled by its own algorithm. At the end, both fiat money and cryptocurrency are different forms of money and both can serve you to reach goods or services. They are both mediums of exchange; their value depends on various factors of their environment (What is Fiat Currency?, 2019).

CHAPTER 3

DIGITAL CURRENCY

3. Digital Currency

Digital money is a payment method which exists only in electronic form but outside of conventional banking system. This type of payment method does not officially acceptted by any countries. Digital money system usually has two common characteristics which are value transfer and accounting system in the Internet. Because of the less expensive transactional fees then conventional banking systems', this type of new world wide payment systems leap forward for personal financial activities (Mullan, 2014).

Digital money currently has a limited user. Moreover, the regulations are still evolving around. Work is underway for the infrastructure needed to develop digital money. The payments are not subject to legal regulations as they are directly related to users. In this way, extra payments can be terminated. In addition, they have a more transparent structure due to their infrastructure.

Digital money does not have any forms. They can't hold hands. Digital money includes virtual currencies and encrypted currencies. For financial services, existing companies are making transfers of digital money.

It does not have a certain shape like digital money banknotes or coins. Computer, smart mobile phone etc. It is possible to send via internet via technological tools.

Although digital money is useful and evolving, banks and government agencies do not accept these currencies. In addition, the number of investors investing in digital money is increasing every day.

Fiat money has opened the way for a kind of money digitalization. Money has highlighted the importance of digital and online currencies together with regulatory authorities and the internet. With these developments, they have become the main

method for processing. Along with this development, the physical money myths that are circulating in the world economy are getting narrower.

It is the responsibility of the central authorities to keep the continuous increase in digital money under control while the physical currency is decreasing. This is done by monitoring who has what.

Main motive of Central Bank to take an interest in retail payments is that ensuring stability of economic environment, providing secure and efficient financial regulations and establishing confidence to functional currencies in their market. Historically, in retail payments, several innovations have occured and this position is leading to trust and efficiency. Therefore, central banks are following this alterations closely. With appearance of digital currencies, it was acclaimed in reports of Committee on Payments and Market Infrastructures (CPMI) on innovations and non-banks in retail payments (BIS, 2015).

3.1. What is the Cryptocurrency?

In the case of Cryptocurrency, briefly refer to the digital crypto money;

- Used as exchange tool
- Has a high level of reliability in terms of reliability. This is because it was created using cryptorology.
- The process through the algorithm and protocols reaches the destination without any changes along the way.
- These algorithms and Blockchain system can be used without any legal control.

3.2. Differences Between Cryptocurrency and Currency

Although cryptocurrencies are counted as digital currencies, there are also basic differences.

In terms of structure;

- Crypto coins are used as digital centers and other currencies are managed by a financial institution and a central authority.
- Decentralized regulations can be made by most of the society and in other digital currencies, society cannot participate in regulations.

In terms of anonymity;

In order to trade in traditional digital currencies, the identity information must be registered. This is not necessary in crypto coins but this means that users do not have any information. Since the transactions are open source, users can be monitored by everyone.

In terms of being transparent;

Traditional digital currencies are not transparent. In addition, crypto currencies are transparent. Because all revenue streams are placed in a common chain, anyone can see any user's transactions.

Transaction manipulation;

Digital currencies have a central authority that deals with problems. He may cancel or suspend transactions at the request of the exhibitor or authorities or on suspicion of fraud or money laundering (Techopedia, 2018).

CHAPTER 4

CRYPTOCURRENCY

4. Cryrptocurrency

Every coin/token is a Cryptocurrency, but we want to stress an important distinction. Cryptocurrencies are coins/tokens which function as a substitution for fiat money (EUR, USD, etc.). Therefore, only currencies which are intended to be used as a payment method are listed in this category (Quest, 2018).

As the world wide use of technologies and importance of innovations become a major part of Global economy, thus it has changed the financial system all around the world (Romanôva &Kudinska, 2016).

The new technology has influenced investment decisions (Slimane, 2012).

Among the new technologies, the first cryptocurrency, bitcoin become a new digital currency. Transactions of Bitcoin impact highly on the transactions of the digital currency. Bitcoin is a cryptocurrency that is based on open source software. Bitcoin transactions run between two individuals that is called peer-to-peer. This type of transaction allows an irreversible payment in private. The mechanism in this transaction has no border, no limit and maybe a few charge for a all around world network system. The bitcoin transaction system is not also private but also anonymous. Therefore, it is offen used by users who want more privacy for their actions. The ledger of account for all bitcoin transactions is public and distributed (Simser, 2015). Yet, there is a low risk of deterioration in cryptocurrency.

4.1. Primary Functions of Cryptocurrencies

Dr. Garrick Hileman and Michel Rauchs, in their Global Cryptocurrency Benchmarking Study, published in 2017, have four functions that are necessary and prioritized for the use of cryptopsias; These are Exchanges, Wallets, Payments, Mining.

Figure 4.1. The Four Key Cryptocurrency Industry Sectors and Their Primary Function

Industry sectors	Primary function
Exchanges	Purchase, sale and trading of cryptocurrency
Wallets	Storage of cryptocurrency
Payments	Facilitating payments using cryptocurrency
Mining	Securing the global ledger ('blockchain') generally by computing large amounts of hashes to find a valid block that gets added to the blockchain

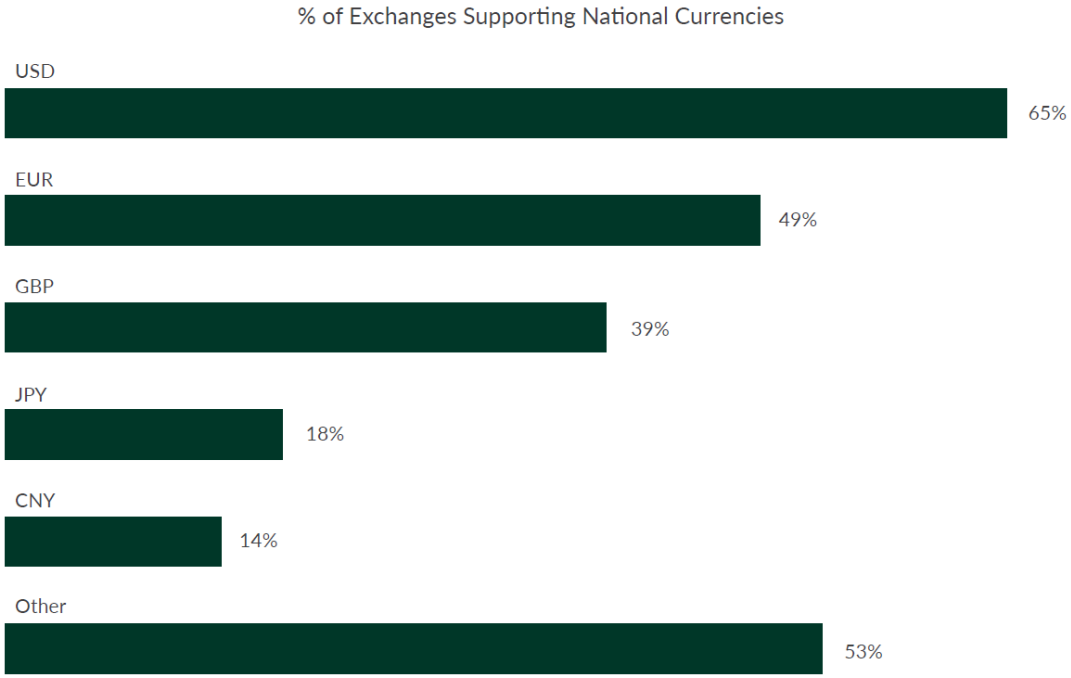
Source: Global Cryptocurrency Benchmarking Study, 2017

4.1.1. Exchanges

Exchanges provide a market place for cryptocurrencies and other digital assets. In these markets Global currencies can be traded with cryptocurrencies or cryptocurrencies can be traded with other cryptocurrencies. This opportunity helps to establish trading, liquidity, and price discovery for the cryptocurrency economy. The first exchange market place was founded in early 2010 as a project to enable early users to trade cryptocurrencies (Hileman & Rauchs, 2017).

Most known major exchanges; OKCoin, Bitfinex, Bitstamp, Coinbase, Kraken, BTCC and Huobi.

Figure 4.2. Most Widely Supported National Currencies



Source: Global Cryptocurrency Benchmarking Study, 2017

Explanation of the figure; USD is the most widely supported national currency on exchanges; many specialize in local currencies.

4.1.2. Wallets

Wallets have been created by using simple programming softwares to handle key management. Although wallet seems like a simple tool, it fulfils the needs of advanced applications which are variety of technical characteristics and extended services. These features surpass the primative storage requirement of cryptocurrency. Therefore, wallets are being used to store cryptocurrency securely and send and receive safely. The owners can easily manage their wallet accounts to use these features for their cryptographic keys (Hileman & Rauchs, 2017).

Cryptocurrency owners save their cryptocurrency coins such as bitcoins in the wallets which the users must secured and backup. The wallets have a connection

type of peer-to-peer with using internet networks which cause resistancy to central attacks (Grinberg, 2011).

A Cryptocurrency is an asset in a digital form, thus its private keys must be protected like protecting bank accounts. For digital assets, there are differents ways of protecting the private keys/PINS which are wallets.

There are varieties for the wallets where users have saved their cryptocurrencies. In her article (2017), described the wallet types as follows:

Online Wallet

Online wallets uses cloud storages, thus when ever there is internet connection, users can access their assets via different devices.

Mobile Wallet

Mobile wallets are designed for mobile phones or tablets. Their application technology allows their users to use their assets for a payment even in physical stores.

Desktop Wallets

Desktop wallets are being used at PC's or laptops. Although they are safer from online wallets, any fatal damage or virus attack to the device could cause the lose of users' assets.

Hardware Wallets

Hardware wallets are used to store private keys on a device which is a USB drive. To make online transactions they usually use web interfaces. When ever the users do not make transactions these wallets are offline, therefore they are more secured and this characteristic is one of the major benefits of hardware wallets. Also, the users' opportunity to carry the USB driver where ever they want and just plug in them to a device with internet connection are another major benefits.

Paper Wallets

Paper wallets is the safest wallet type for users to store the digital assets. A paper wallet is a printed sheet of paper which has the copy of user's generated keys. Users can make transactions with useing their public and private keys which are stored on the paper wallet.

4.1.3. Payments

Cryptocurrencies have an integrated payment network system to generate transactions. The companies generate gateways between users' transfer system and the outside economy which means these companies create bridges between national currencies and cryptocurrencies (Hileman & Rauchs, 2017).

Figure 4.3. Taxonomy of Main Cryptocurrency Payment Platform

Use case	Payment activity	Description
Payment rail ('national currency-focused')	Money transfer services	Services that primarily provide international money transfers for individuals denominated in national currencies. These include among others traditional remittances and bill payment services.
	B2B payments	Platforms that provide payments for businesses, denominated in national currencies, often times across borders.
Cryptocurrency payments ('cryptocurrency-focused')	Merchant services	Services that process payments for cryptocurrency-accepting merchants. May provide additional merchant services such as shopping cart integrations and point-of-sale terminals.
	General-purpose cryptocurrency platform	Platforms that perform a variety of cryptocurrency transfer services including instant payments to other users on the same platform using cryptocurrency and/or national currencies, payroll, and other services. In general, payments are denominated in cryptocurrency but can be easily exchanged to national currencies.

Source: Global Cryptocurrency Benchmarking Study, 2017

4.1.4. Mining

The security of values is the most important function for the users. For this reason, mining is used to maintain the security of the system. The integrity of system also helps to increase the level of security. Mining function is carried out by miners who

are already users in the system. Miners use their computers just like users to take action on mining (Grinberg, 2011).

At the beginning, as a hobby, miners used their computers to support the system. Afterwards, the sector has evolved really quickly into well funded and professional (Hileman & Rauchs, 2017).

4.1.5. Hash Function

Hash Function is the logic that protects cryptology. It is a mathematical function that has three properties. These are;

- The input of a hash function has any size with any string.
- The output of a hash function is a fixed-sized output.
- A hash functions is efficiently computable. Because, the amount of time needed for the output of a known input string can be calculated.

In addition to these main features, a hash function must have three additional characteristics which are collision resistance, hiding and puzzle friendliness (Narayanan et al., 2016):

- Collision resistance occurs when two different hash function inputs produce the same output.
- Hiding means after getting the output of a hash function, there is no way to find the input of it.
- Puzzle Friendliness means that if a hash function H is a puzzle friendly then its every possible output value (y) with a high min-entropy distribution value (k) brings out an infeasible result ($H(k \| x) = y$) to find the input (x) in less then 2^n time.

4.2. Cryptocurrency History

Quest (2018), started the process of historical development of cryptocurrencies.

In 1990, David Chaum created DigiCash, the first Online money in the Netherlands. The eCash product, which it has created technologically, produced a great response in the media. After Digicash, companies started to create alternative solutions and money systems on an internet basis. With these solutions, they made small but important changes on the systems. Paypal has become one of the most renowned companies who produce solutions and make new improvements.

Some factors come into prominence in the emergence of crypto currencies. One of the most important factors is the mortgage crisis that erupted in the United States in 2008. The United States' financial economy was the most affected by this crisis. But in other countries the economies have been exposed to the effects of the crisis. The crisis has led to an enlightenment in most of the world's major economies. After all, the blockchain, which is the basis of cryptocurrency, has emerged.

In 2009, a person or a group who called himself Satashi Nakamoto published an article describing the source code named Blockchain. Blockchain technology and explaining the concept of this article by sending an e-mail sent to all major people. With the Blockchain technology, the history of all existing cryptocurrencies has started.

With the Blockchain technology, all the traditional online data management protocols, including the centralization of the data, have taken a step towards change.

There are over 16 million cryptocurrency units circulating in the digital financial system. The total value of all crypto-units is approximately $ 50 billion. Cryptocurrencies began to attract the interest of economies with its technical support and acceptance. Some of the major countries such as Australia, Canada and Japan have started to regulate the cryptocurrencies according to taxes and laws.

The first cryptocurrency bitcoin generated by the Blockchain infrastructure. Bitcoin is currently the most traded cryptocurrency.

Bitcoin, along with its popularity and popularity, has emerged in other bitcoins. These are called altcoins. The total market value of all bitcoins and subcoins exceeds $ 177 billion. There are a total of 2.171 cryptocurrencies in the market.

The use of cryptocurrecy units by the people and learning by the people has also increased. With the increase in usage, it has started to create a new Global financial impact.

With the large developments in Blockchain technology, there will be an increase in the number of cryptocurrency in the market and this infrastructure will be used in new applications.

As more and more crypto currency platforms and exchanges begin to emerge, more people will be able to use blockchain-based applications and contribute to the growth of the industry.

All existing currencies are fraud, forgery and so on protection from these situations. For Fiat currencies, the relevant central banks receive protection measures.

The security system of cryptocurrencies must satisfy the users that they would not be frauded. Because of this, an intervention to the system or dublicated transactions can not be done with an circumstances. Cryptocurrencies are not ruled by a central authority like fiat currencies, they use highly unique tecknological cryptography which is used for encryption to keep the cryptocurrencies in safe. Cryptography endures advanced academical mathematical techniques that are highly complicated and hard to implement (Narayanan et al., 2016).

Cryptocurrencies can be introduced to the future by adopting developments in technological fields as well as finance and commerce.

4.3. Blockchain

Blockchain is a decentralized process and data management technology developed for the design process of cryptocurrencies.

It first emerged in 2008 and since then the interest in the blockchain has been growing exponentially. Not only for cryptocurrencyler but also for other areas are evolving.

The reason for the increased interest of Blockchain in some sources; eliminating the need for a third party during the execution of the transactions and thus reducing the costs. In this way, centralized transactions are removed. There is no need for a third party or the lack of a centralized system.

Trust in all areas of the world, in short, financial, personal. For Blockhain, trust is a top priority and among other priorities for honesty, accountability, consideration and transparency. The confidence provided by the abolition of these conditions is reinforced.

Distributed ledger technology is a solution for many financial services which are restricted by old institutions. By using blockchain the people who are connected to the Internet but can not use financial system because of financial prosedures have a financial activity opportunity which are buying, selling and establishing a prosperous life. The distiruted ledger starts to be shared by everone, then settlemtns would occor instantly for all to see (Tapscott & Tapscott, 2016).

Cryptocurrencies are often described as distributed ledger, because of the distribution system that they are based on. All or part of cryptocurrent information is not stored on a single computer. It is stored on multiple computers on the network. Most of the users use the public blockchain, thus it is usually the slowest. On the other hand, consertium blockchain that uses specific crossover points for validation has a faster process features for the council users who have access this type of blockchain. The third type of blockchain is entirely private blockchain. In this

system, transactions are validated by only dedicated validators. The creator can decide all of these procedures. This allows the blockchain a very fast processing time (Neuefeind & Kacperczyk, 2018).

Accourding to Neuefeind and Kacperczyk (2018), each block in blockchain can create a new code and carry existing information. Many cryptocurrencies are based on blockchain technology. The blokchain technology has 4 main characteristics. These are summarized at below:

- The Decentralisation means the data is saved on multiple computer or servers simultaneously. Because of that, it is impossible to change the blockchain once a transaction is confirmed.
- The Consensus means the validators of the blockchain system have to agree on what happens or what does not happen. The way to achieve this compromise is called "mining".
- The Transparency means all the transactions are visible and trackable.
- The Transfer of Value means blockchain system has a lot faster transfer time than current financial system. In addition to this, blockchain transfer time does not affected by the value size of transaction or its destination.

In the blockchain network, all the transactions conducted are verified, cleared, and stored in a block. These blocks are linked to another accourding to the preceding block, which means they create chains. Each block refers to the preceding block to be valid. This structure permanently time-stamps and stores exchanges of value, so the blockchain is a distributed ledger representing a network consensus of every transaction that has ever occurred (Tapscott & Tapscott, 2016).

4.3.1. Blockchain's 7 Design Principles

Don Tapscott and Alex Tapscott (2016), discusses the seven basic design principles of the blockchain on their book of "Blockchain Revolution". The principles are describe at below;

- Networked Integrity

- Distributed Power
- Value as Incentive
- Security
- Privacy
- Rights Preserved
- Inclusion

4.3.1.1. Network Integrity

Network contributors can exchange the value that is sent because, the network integrity is coded and distributed within entire process. In order to maintain this, double-spending problem should have to be solved first. Therefore, money can be taken from the source account to the target account safely. Blockchain technnology solves double-spending problem by using transactions that are being recorded by public users which is also cannot be undone. In blockchain technology, some type of ciphers which is also called as consensus mechanism solved the double-spending problem of the transactions. As a result of this, the network time-stamps the first transaction, so the owner spends the coin and then rejects subsequent spends of the coin. Therefore, double-spending situations has been eliminated (Tapscott & Tapscott, 2016).

4.3.1.2. Distributed Power

Blockchain does not have a single control point. It distributes power between spouses. No group can shut down the system. In case of any interruption, the system will continue to operate. If more than half of the network tries to be captured, everyone will realize it. Satoshi Nakamoto was inspired by Hashcash, the cryptographer Adam Back's solution to reduce spam and denial of service attacks. No operations are stored on a central server and cannot participate in third party transactions. Each process includes a link to all subsequent operations. The functioning of Blockchain is the best mass cooperation (Tapscott & Tapscott, 2016).

4.3.1.3. Value of Incentive

Rewarding for the transactions of the users who are involved in the system and ensuring their operation ensures the continuity of the system. Because data miners store their own bitcoins on this network, they also pay more attention to the reliability of the activities. It is also for the safety of owning the best equipment for the activities, for spending energy as efficiently as possible, and for protecting the ledger again for its safety in its bitcoins. Distributed user accounts are the most basic element of the cryptographic network infrastructure. Often, different miners will find two equally valid blocks of equal height and the rest of the miners should choose which block to build after. As a result of this process, the user who wins the transaction wins the bitcoin as a reward.

4.3.1.4. Security

Anyone who wants to join blockchain should use cryptography. Security measures are placed on the network without any open. If the required safety precautions are not followed, these users are removed from the network. The longest chain is generally the safest chain.

The majority of miners maintain the ledger, thus the ledgers of cryptocurrency can be more secured. Then, the miners have encouragement financially to do so (Barber et al., 2012).

An advanced form of “asymmetric” cryptography is used for public key infrastructure (PKI) to provide a secured platform. Participants used PKI to get two different keys that one is for encryption and the other one is for decryption. Hence, they are asymmetric. Digital currency is not stored by itself, A cryptographic hash function of indicated transactions represents it. Participants keep the cryptokeys for their own money and serve directly with one another. All in all, this type of securiy reveals the responsibility of saving the private keys in private (Tapscott & Tapscott, 2016).

4.3.1.5. Privacy

As of today, people should control their own data themselves. They should decide for themselves whether to share their personal information with others. In order to communicate with someone in Blockchain, the need to know the credentials is eliminated. There is no need for any credentials to join the network layer (Tapscott & Tapscott, 2016).

4.3.1.6. Rights Preserved

Everyone has rights. It was intended to enable more effective use of these rights when the digital age began. We can't trade on things that don't belong on our blockchain. No one can make a swap but his own (Tapscott & Tapscott, 2016).

4.3.1.7. Inclusion

The economy works best for everyone. Some people may still not use mobile payment systems. But in this case they cannot do online transactions. Blockchain can work without internet if necessary. In this case, without the need for information and mobile can be do without the need. “The potential of using the blockchain for property records in the emerging world, where that’s a huge issue related to poverty,” is significant, said Austin Hill (Tapscott & Tapscott, 2016).

4.4. Bitcoin (BTC)

Bitcoin is the first cryptocurrency. Built with Blockchain infrastructure. In 2008, a document by a person or a group known as Satoshi Nakamoto was introduced via mail. The document is called to “Peer to Peer”.

Satoshi Nakamoto, defined bitcoin as a decentralized technology. Cryptology is a technology created using. Each transaction is recorded. Since it is open source, everyone can be a participate.

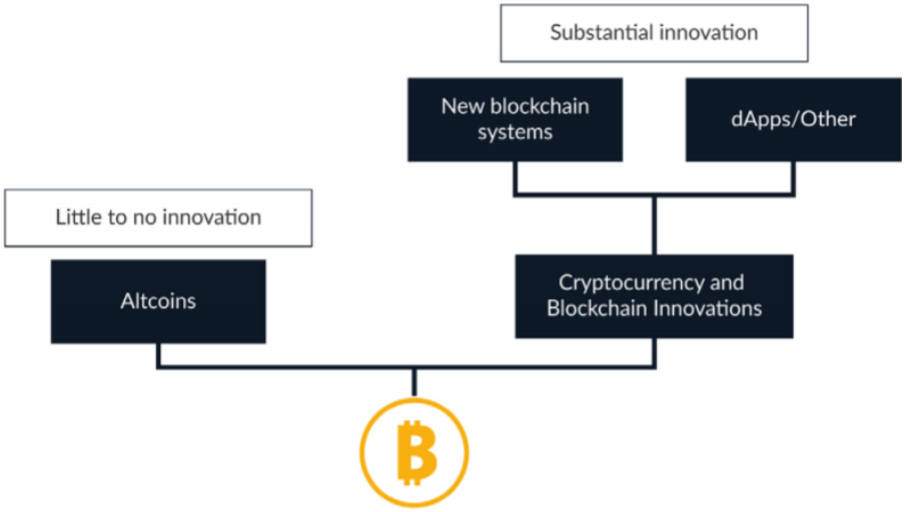
A purely peer-to-peer version of electronic cash would allow online payments to be sent directly from one party to another without going through a financial institution.

A double-spending problem arises because there is no third-party transaction provider. For this purpose, the use of a network between digital signatures and spouses provides protection. Protection solution of Bitcoin transaction is provided by digital signatures. In cases where a digital signatures are not sufficient, the advantage of the system is lost and the system needs to thirdparty (Nakamoto, 2008). Operations on Bitcoin are irreversible.

In the face of developing technology, financial institutions are constantly trying to make their customers satisfied and happy by finding new methods. They try to offer them unlimited possibilities to choose themselves. In such a recourse environment is completely different and foreign currencies are emerging from Bitcoin and other cryptocurrencies.

Bitcoin, a new solution, allows transactions to take place without the need for a central authority. Bitcoin is a worldwide currency created with encryption. Transactions are made directly between spouses (Reid & Harrigan, 2011).

Figure 4.4. The World of Cryptocurrencies Beyond Bitcoin



Source: Global Cryptocurrency Benchmarking Study, 2016

Grinberg (2011) notes that Bitcoin, a digital currency, competes with two product classes; internet-based trade facilitating products and gold backed money ie fiat money.

There are no states or central governments where Bitcoin has received support to be sustainable. In this case, another area in which it competes against the currencies being supported is the basis for being sustainable. Grinberg (2011), refers to the situations that might prevent Bitcoin from being sustainable.

Bitcoin Sustainale Confidence

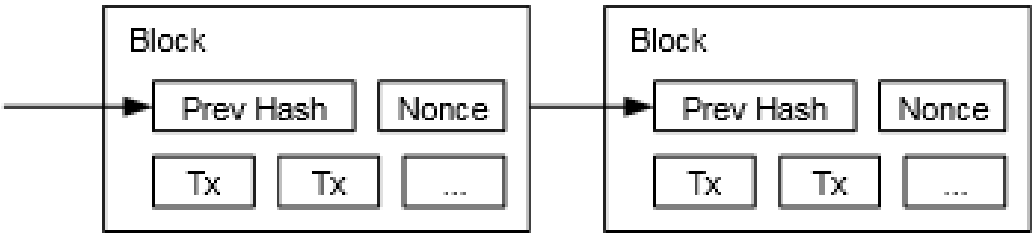
- The collapse of trust in Bitcoin
- Emergence of alternative and strong currencies
- Unexpected changes in inflation rate
- Government collapse
- The state imposes bans
- Technical problems
    - Endangering system anonymity
    - Loss of money
    - Theft of money
    - Abuse the Miner's duties and so on.

4.5. Proof of Work (PoW)

One of the best-known basis of blockchain is Proof of Work (PoW). Proof of Work is a way that a “miner” receive a reward for solving a cryptographic tasks which are complex calculations. The transactions which are saved on the blocks are approved by miners means they are made accurately. Althought the rewards per block are different from Cryptocurrency to Cryptocurrency, Proof of work method still being criticised. Because it is not only consumes lots of energy but also a time-consuming method. Therefore, these indicators make the method very expensive (Neuefeind & Kacperczyk, 2018).

In order to change the block, the work has to be redone, thus the required CPU effort should be expended again for the proof of work. When new blocks are connected to the chain, it is necessary to repeat the arrangement of all subsequent blocks (Nakamoto, 2008).

Figure 4.5. Mechanism of Proof- of -Work



Source: A Peer to Peer Electronic Cash System

4.6. Lightning Network

The lightning network is an advanced peer to peer application of existing Bitcoin Blockchain. Its system is named as “payment channels” which enables the transactions to surpass the blockchains without working. Two users can establish a payment channel to send and receive transaction. If both of the users who can determine the duration sing and end to close the channel, then the transaction is saved on the blockchain. Adjusting the duration of the channel enables the transactions that are made between the users do not have to be saved on the blockchain. Therefore, just opening and closing the operations are enough (Neuefeind & Kacperczyk, 2018).

4.7. Why to Use Cryptocurrency?

Martin Quest (2018) mentioned the reasons on his book “Cryptocurrency Master Bundle” for starting to use cryptocurrency as follows;

- **Repetition**
    - Blockchain is among the safest data transactions because it is not attacked
    - Any transaction that has been approved in a block is visible to everyone and cannot be modified
    - No matter where in the world, it will be approved day and night
    - Smart contracts are writable and manageable platforms
    - Its adaptability is endless and its market is expanding rapidly
- **Smart Contracts**

It is an agreement between two people which is not viewed and controlled by an intermediary, only the system. That means if a party breaches that contract, the blockchain automatically executes the arrangements (which were agreed before) or enforces any other obligation which has been added to the contract.

- **Market Liquidity**

The meaning of market liquidity is a description of how easy it can be to buy or cash the coin number. The high liquidity of a cryptocurrency allows the volume to be increased so well.

4.8. Cryptocurrencies Trading Volume

Bitcoin (BTC) and Ethereum (ETH) are the most commonly used cryptocurrencies for causality analysis. After Bitcoin and Ethereum, Litecoin (LTC) and Ripple (XRP) are the most preferred cryptocurrencies. “Market Capitalization”, “Volume” and “Closing Rates” graphs of these four cryptocurrencies are shown below. With the increase in supply and market capitalization, volume is one of the most obvious criteria in cryptocurrency to analyze.

These four cryptocurrencies “Market Capitalization”, “Volume” and “Closing Rates” graphs are showed below. With increasing supply and market capitalization, volume is one of the most obvious criteria in cryptocurrency.

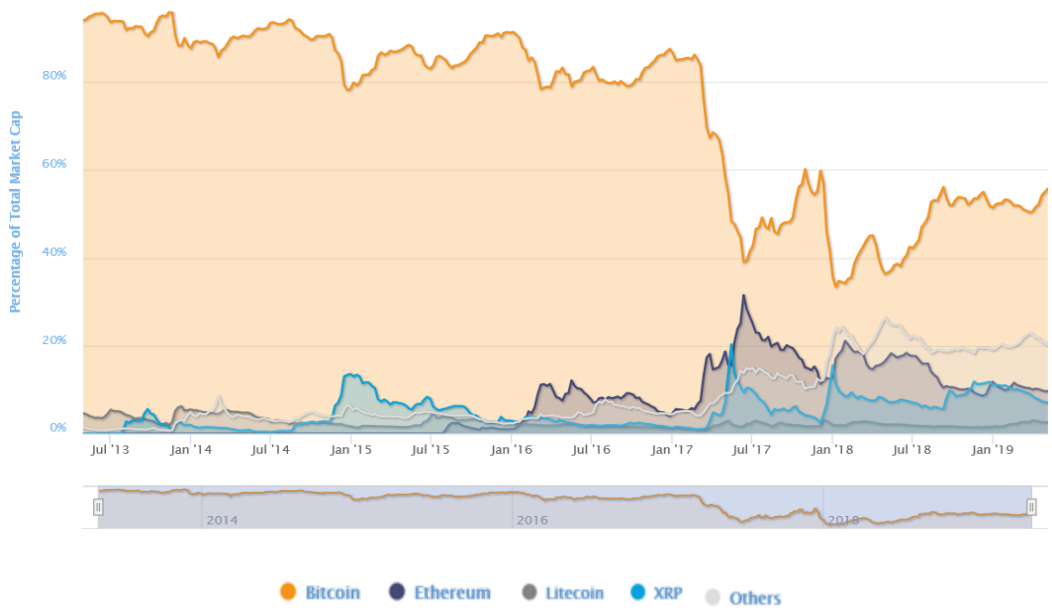
BTC has the hightest percentage when the total of market capitalization is analyzed. After comes ETH. Before July 2017, there is an huge increase at the total market capitalization rate of ETH and other cryptocurrencies because of the downfall of BTC. The values of the cryptocurrencies that are used for comparison in the graphs are on USD basis.

In total market capitalization, BTC has the highest percentage. Then the ETH comes. In July 2017, there is an increase in ETH and other cryptocurrencies in spite of the decrease in the price of BTC. The cryptocurrencies used in the comparisons were used in USD exchange rate.

From 2013 till 2019, there is an increase for the total market of all cryptocurrencies.

Figure 4.6. All Time Most Trade Cryptocurrencies Total Market Capitalization (%)

Percentage of Total Market Capitalization



Source: coinmarketcap.com, 28.04.2013 – 6.05.2019

Figure 4.7. All Time Total Market Capitalization

Total Market Capitalization (Logarithmic Scale)

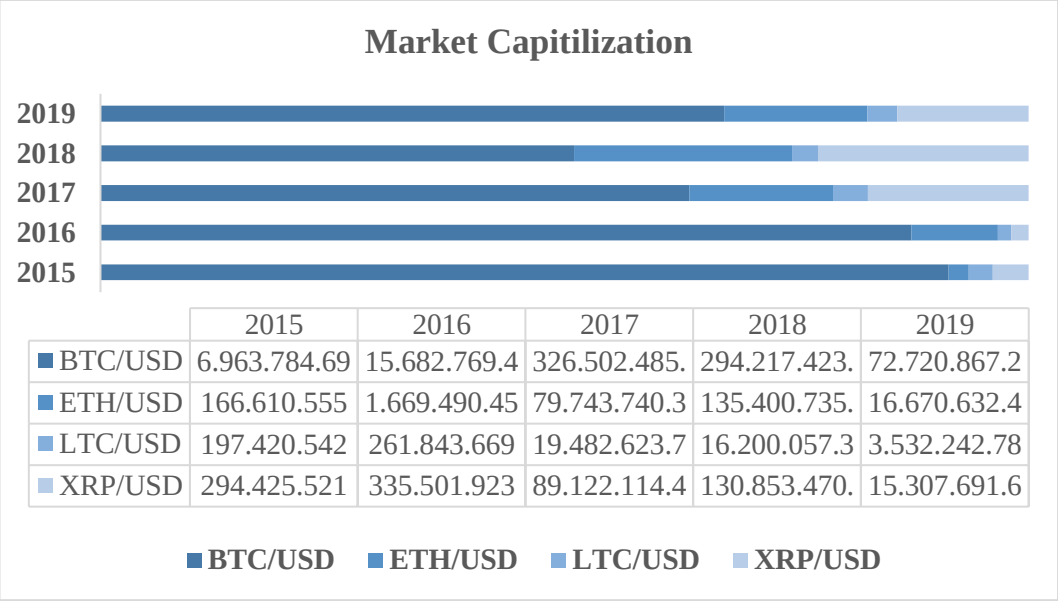
Source: coinmarketcap.com, 28.04.2013 – 6.05.2019

The graph of the Chart 4.1. shows that there is a large difference between BTC and the other cryptocurrencies in the scale of market capitalization. Because BTC is the first traded cryptocurrency and most well known. All cryptocurrencies who emerged with the development of the cryptocurrency market were affected by BTC

In 2017, the market capitalization rate of BTC reached its highest value. After that in 2018, BTC came up against a big decrease.

There is a limit at the number of Bitcoin that could possible produce. This number is foreseen as nearly 21 million.

Chart 4.1. Market Capitalization of BTC, ETH, LTC and XRP

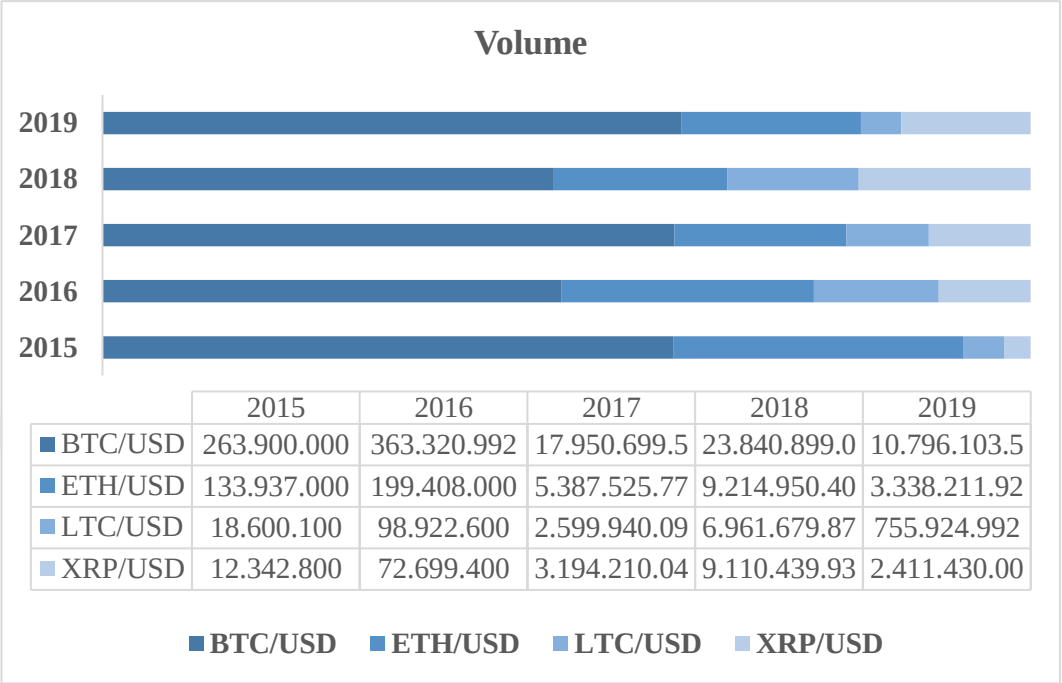


	2015	2016	2017	2018	2019
BTC/USD	6.963.784.69	15.682.769.4	326.502.485.	294.217.423.	72.720.867.2
ETH/USD	166.610.555	1.669.490.45	79.743.740.3	135.400.735.	16.670.632.4
LTC/USD	197.420.542	261.843.669	19.482.623.7	16.200.057.3	3.532.242.78
XRP/USD	294.425.521	335.501.923	89.122.114.4	130.853.470.	15.307.691.6

Source: https://finance.yahoo.com, 07.08.2015-11.03.2019

In terms of volume, BTC has the highest volume in the cryptocurrency market from the beginning. Unlike the market Capitalization graph, BTC reached its hightest at 2018.

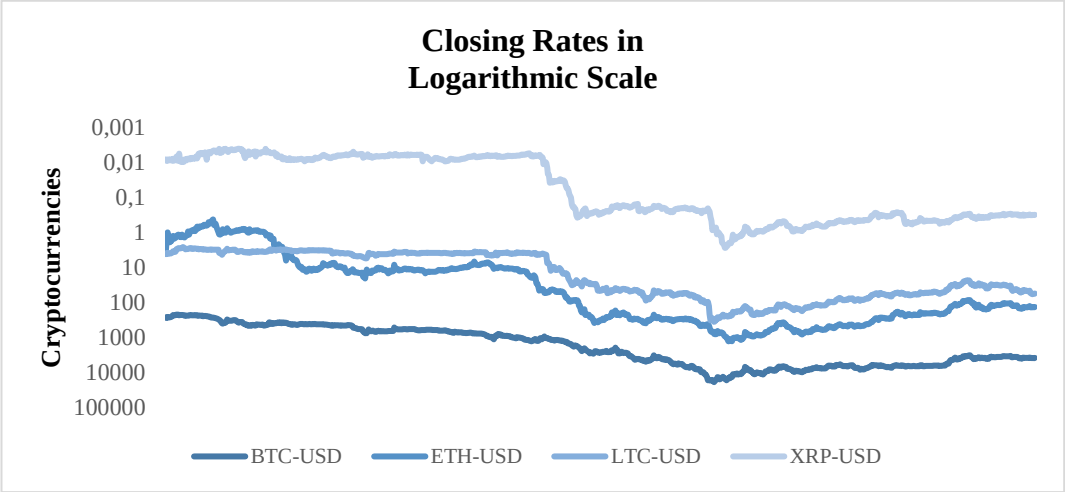
Chart 4.2. Volume of BTC, ETH, LTC and XRP



	2015	2016	2017	2018	2019
BTC/USD	263.900.000	363.320.992	17.950.699.5	23.840.899.0	10.796.103.5
ETH/USD	133.937.000	199.408.000	5.387.525.77	9.214.950.40	3.338.211.92
LTC/USD	18.600.100	98.922.600	2.599.940.09	6.961.679.87	755.924.992
XRP/USD	12.342.800	72.699.400	3.194.210.04	9.110.439.93	2.411.430.00

Source: https://finance.yahoo.com, 07.08.2015-11.03.2019

Chart 4.3. Closing Rates in Logarithmic Scale of BTC, ETH, LTC and XRP



Source: https://finance.yahoo.com, 07.08.2015-11.03.2019

CHAPTER 5

LITERATURE REVIEW

5. Literature Review

In the academic literature, there are many studies examining about cryptocurrency and also internet sites for research.

Furnham & Argyle (1998) wrote about barter system had been using before foundation of money.

Robetson (2007) mentioned at his article about precious metals such as gold and silver were used not only for bartering but also for other social events like religious rituals.

He also said that the things that were used before money for bartering system could cause confusion. Therefore, money had a big impact on social development thoughout history. Not only Robertson (2007), but also Back ve Pumfrey (2011) studied about the development of bartering system until the first metal money that was invented at China. Davies (2002) showed in the study of things that were used for bartering as follows leather, jade, wampum, cowries, drums, thimbles, eggs, feathers, hoes, ivory, kettles, mats, nails, amber, pigs, quartz, rice, salt, gongs, yarns etc.

Bellis (2018) wrote about spreading the money to other counties just after Lydians invented the money, because of its ease of use.

Rebbeca Burn – Callender (2014) described the stages of evolution of money. These were; journey of Chinese printed metal money to the Europe, invention of the money by Lydians, sending money via telegraphy, first use of credit-card, usage of contactless credit-card and lastly, launching the first cryptocurrency, Bitcoin to the market.

Hermele (2014) described three basic functions to define something as money. These are a medium of exchange, a measure of value, a store of value. In addition to this, Suman (2014) added three more function which are the basis of credit, a unit of account, a standard of postponed payment.

A medium of exchanges is described as a system or tool to help the people for buying or selling things. Chen (2019) said that this system allows the people to take place in the market. Medium of exchange is known as the most important function of the money. The functions of unit of account shows that money is measurable while the functions of store of value shows people can save money.

Herold (2017) wrote that the commodity money takes the value from its material and it has its own value.

Quest (2018) described another feature of money “fiat money” as a currency that has a legal tender by government regulation. This is the currency feature that we use now.

Fiat money emerged because of the lack of situations that specifing the real value of goods and services. Therefore, it is easy to define the real value of goods and services by using fiat money. In addition to this, Bajpai (2019) also mentioned about fiat money as how ease to carry, printable as requested and much more stable from commodity money.

In the web site, Blog.monetha.io the title; What is Fiat Money? (2019), the differences of cryptocurrency and fiat money mentioned as fiat money is supported by government regulation cause it to be more reliable while cryptocurrency is not supported. Fiat money is centrialized while cryptocurrency is decentrialized. At last, people can use fiat money to pay taxes but can not use cryptocurrency.

In the website Techopedia (2018), it is specified that with use useage of digital money, the boundaries of money come to an end. Digital money has no physical shape. Also, spreading of the Internet has a big impact on digitalization of money.

Quest (2018) argued that cryptocurrencies were invented to take place fiat money. Romanôva and Kudinska (2016) claimed that cryptocurrency has changed the financial system all around the world because of the development of worldwide use of technologies and importance of innovations become a major part of Global economy.

Slimane (2012) wrote about the development of new technologies have an impact on investment. This statement support Simser (2015). Accourding to Simser (2015), Bitcoin is one of the newly emerged currencies that came up with the technological improvements. Also he mentioned about Bitcoin's open-source speciality and peer-to-peer network system which has unique encryption methodology that execute no backward protocol for the payment operation. Therefore, there is no need for third-party companies to maintain the securety of these operations. The cost of each operastion is too low or zero and the ledgers that the transactions are kept is open public.

Hilleman and Rauchs (2017) explained the four important functions of Cryptocurrencies in "Global Benchmarking and Study" research. These essential functions are; "Exchanges", "Wallets", "Mining" and "Payments". They also explained Exchanges as it provide a market place for cryptocurrencies and other digital assets. In these markets global currencies can be traded with cryptocurrencies or cryptocurrencies can be traded with other cryptocurrencies. This opportunity helps to establish trading, liquidity, and price discovery for the cryptocurrency economy. They said about wallets are simple sowfware programming that use key cryptography. In addition to this, Grinberg (2011) said wallets are a tool for Bitcoins to store and keep in safe for their owners. Vaitkune (2017) detailed the wallets into 5 types which are Online Wallet, Mobil Wallet, Desktop Wallet, Hardware Wallet and Paper Wallet. He also mentioned that Hardware and Paper types of wallets have the highest security opportunity for owners.

Hilleman and Rauchs (2017) speak of companies that create bridges between national currencies and cryptocurrencies are used by users as a third party which usually cryptocurrencies have no need for third parties. They also said that mining had become a hobby in a short time and the system needs miners in order not to have a hitch.

As Narayanan et al. (2016) clarified why the Hash Function is the cryptology logic for security of the transactions while explaining the matematical dimension of it.

Quest (2018) detailly wrote about they are some previous researches of cryptocurrency before Satoshi Nakamoto (2008) which is for example David Chaum found the first online money that is called Digicash and more for internet based works. Lots of these researches were shortlived while the longest one is Paypal. The Mortgage Crisis in 2008 which had affected lots of countries financially was one of the causes to put Cryptocurrencies on the market. Therefore, cryptocurrency was launched with its blockchain system at 2009. As people discovered about cryptocurrency, it was started to be used much more. As mentioned above at Narayan et al. (2016), although fiat money is protected by govermental prosedures, cryptocurrencies have their own protections which are cryptography and algorithm for encryption.

Tapscott et al. (2016) said that “blockchain is a decentralized process and data management technology developed for the design process of cryptocurrencies” and they also explained the transaction which is used to borrow, sell, buy or something else between two users does not need a third-party company. These system could also free the entrepreneurs.

Neuefeind & Kacperczyk (2018) mentioned that system of blockchain as each block is recorded to the next block which provides safety and control of historic transactions.

The system is called as “Proof-of-Work”. Because of the system is decentrialized, special keys are generated for users for protection. At his paper, Nakamoto (2008)

used a number of ciphers in order to solve the double-spending problem of the transactions in the distributed network and it was called consensus mechanism. Thus he found the solution with digital signatures.

Barber et al. (2012) stated that the safety of cryptocurrencies rely on miners who are dependable. Reid and Harrigan (2013) wrote that Bitcoin is a world-wide cryptocurrency and a payment method while its source code is open and traceable in the nodes of blockchain. Nakamoto (2008) submitted the structure and how it is work of Bitcoin via e-mail. Grinberg (2011) cited that the sustainable development of Bitcoin could collapse if lose the trust, goverment intervention, technical problems or a more powerful product is shown up.

For the analysis, Augmented Dickey-Fuller Unite Root Test, VAR and Granger Causality should be explained. Takım (2010), the Augmented Dickey-Fuller (ADF) test is a unit root test. It controls the stationery of the series so that the most appropriate equation to be used in the analysis will be determined. Gujarati (2003), mentioned that unstable series contain unit roots. Moreover, the stability of the series is also understandable from the graphs. Akyüz (2018), mentioned that the most appropriate criterion for the determination of lag length is the examination of the Akaike Information Criterion. AIC has been seen as a model that will work in future predictions. Quenouille (1957) said that VAR model is used for the analysis of multiple time series. Lütkepohl (2007) also said that a linear VAR model make the model easy of use. Canova (2007) mentioned that there are some researches of Chris Sims about this topic for 25 years ago. Ivanov ve Kilian (2005) stated that Lag length criterion is very important to make the analysis. Işığıçok (1994), referred the causality is defined as making predictions about future with historical data. Lastly, Granger (1969) had studied about there is causality between unstationary series and then these studies became popular.

CHAPTER 6

GRANGER CAUSALITY

6. Data Structure

In this research, the causality analysis between cyrptocurrencies of Bitcoin (BTC) & Ethereum (ETH) and Dollar (USD) Index and Euro (EUR) Index were studied. The tradiotional currencies, Dollar (USD) is the currency of United State of America, Euro (EUR) is the currency of European Union. On the other site Bitcoin (BTC) is the first released cyrptocurrency that has the highest trading volume while Ethereum (ETH) has the second highest trading volume.

In the first analysis, historical data of BTC/EUR Index (value of BTC in EUR exchange rate) and historical data of ETH/EUR Index (value of ETH in EUR exchange rate) were used. The parameters of the data are;

- The source is www.investing.com
- The date range is from 08/10/2015 till 05/10/2019
- The type is instantaneous exchange rate
- The period is the weekdays
- The classification is price

In the second analysis, historical data of BTC/USD Index (value of BTC in USD exchange rate) and historical data of ETH/USD Index (value of ETH in USD exchange rate) were used. The parameters of the data are;

- The source is www.investing.com
- The date range is from 03/10/2015 till 05/10/2019
- The type is instantaneous exchange rate
- The period is the weekdays
- The classification is price

The main objective of the analysis is finding out that is there any causality between traditional currencies indexes (USD or EUR) and cryptocurrencies (BTC or ETH). After the tests are done, an interaction between each other is expected to be found. For detail, if one of the tradiotinal currencies is increasing while one of the cryptocurrencies is increasing or decreasing means there is a causality between each other.

To do the causality research, the most commonly used method "Granger Causality Test (1969)" was used. The analysis was performed via EViews and the arrangements were completed on Microsoft Office Excel.

6.1. Data Stationary Test Description

The Augmented Dickey Fuller Test (ADF) is unit root test for stationarity. The data need to be questioned if the time series that used are stationary or not. Therefore, the most suitable equation to be used in the analysis of the data can be determined. The reason for this are the stochastic tendency of the time series of the economic and the changing average by the time pass. Lastly, ignoring the problem can eliminate the validity of these hypotheses (Takım, 2010).

Darnell (1994) explained that "If a time series is stationary, its mean, variance and covariance do not change over time. The average of a time series, its variance and covariate over time is defined as poor stasis, and is also referred to as covariance stasis or second order"
Stochastic time series stationary conditions of any X_t series can be summerized as follows (Gujarati, 2003).

$$E(X_t) = \mu \rightarrow Mean \tag{6.1}$$

$$Var(X_t) = E(X_t - \mu)^2 = \sigma^2 \rightarrow Variance$$

$$Cov(X_t - X_{i+k}) = \gamma_k \rightarrow Covariance\ (For\ all\ t, k \neq 0\ )$$

The series is stationary when a time series' the mean (μ), variance (σ2) and covariance (γ_k) rest constant over time.

Non-stationary series contain unit roots. In order to determine whether a series is stationary or not, it is decided by looking at the graph of the series and the correlation of the autocorrelation function. If the series does not fluctuate in a balanced way around a given mean, the series is considered non-stationary (Gujarati, 2003).

The Augmented Dickey – Fuller (ADF) Unit Root Test is the best way to define for economic time series stationary analysis. For another way is determining visually is a series is stationary or not. The graphs at below that is titled as Chart 6.1. were prepared to look the stationary type visually (used logaritmic scale of each series).

6.2. Data Stationary Test

In the first ADF tests, data was used unlogarithmically. When the stationary test was performed on the data which had been used without any regulation, it became stationary at level. As a result of the first data stationary tests, it is considered appropriate to examine the data logarithmically because they are stationary before they turned the first difference.

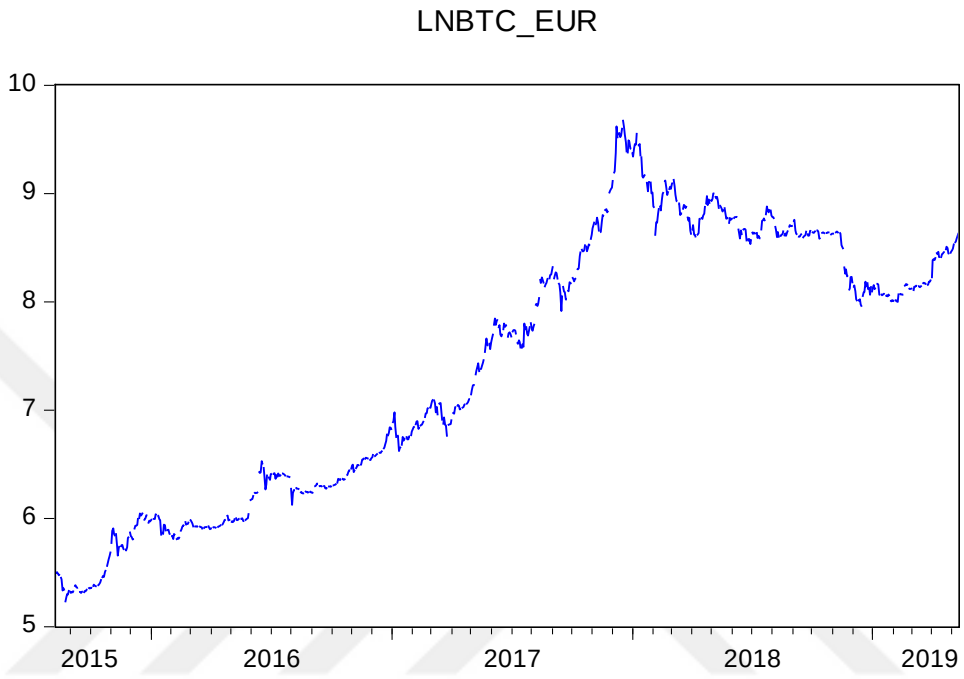
In ADF test, the series is expected to be stationary in the first difference. In order to achieve this, the logarithmic function of the data set was taken separately. Logarithmic studies were performed for BTC and ETH cryptocurrencies and EUR index. In order to VAR estimation and Granger Causality Analysis, the data is expected to be stationary at first difference.

6.2.1. The Augmented Dickey-Fuller Stationary Test for EUR Currency Basis

The graphs used for the determination of stationary are composed of working day data from 08/10/2015 to 5/10/2019.

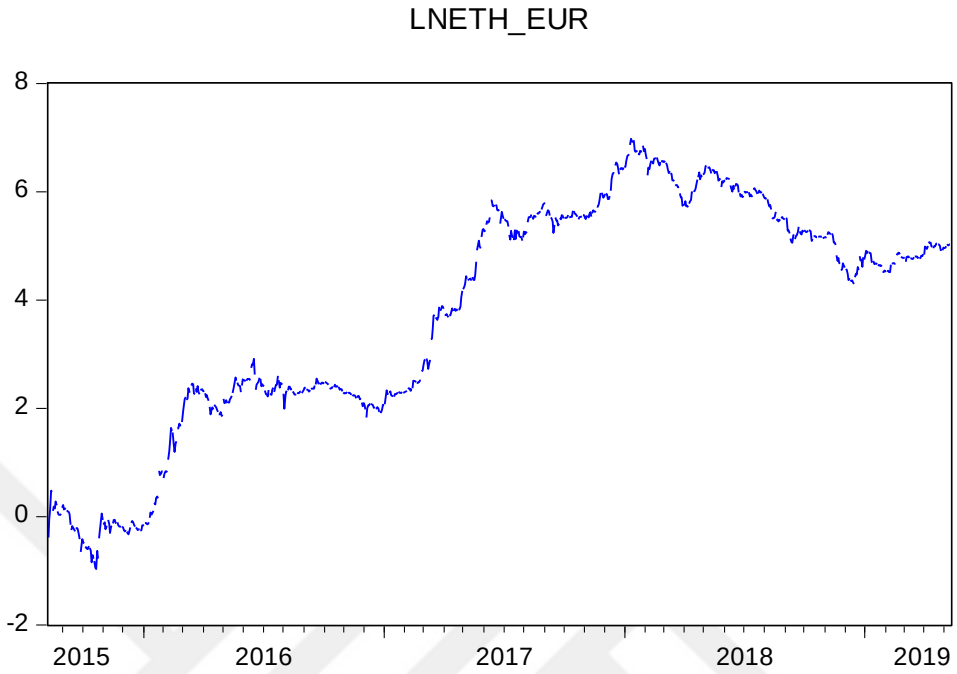
It is observed that BTC / EUR series is not visually stationary in the logarithmic graph. There is a fluctuation of the descent.

Chart 6.1. Logarithmic BTC/EUR Variance Graph



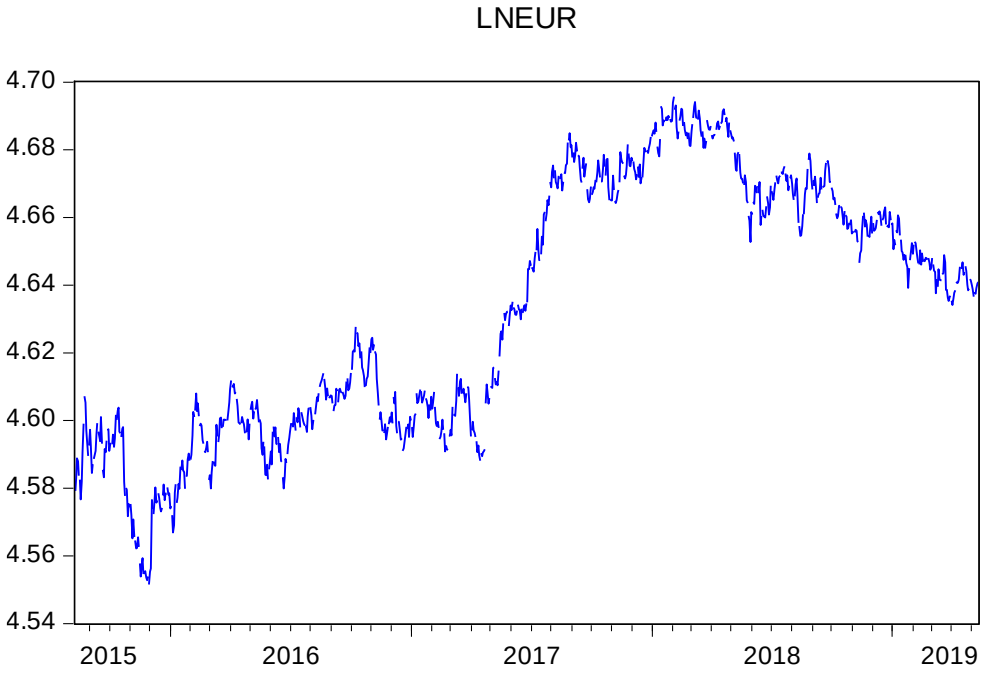
It was observed that it was not visually stationary for another cryptocurrency ETH / EUR based on the analysis.

Chart 6.2. Logarithmic ETC/EUR Variance Graph



It was observed that the first traditional currency which is the subject of causation, the EUR index, is not stationary and has a continuous fluctuation.

Chart 6.3. Logarithmic EUR Index Variance Graph



According to the Augmented Dickey-Fuller (ADF) Unit Root tests which were done by taking logarithmic results, the following results were reached.

Table 6.1. The Augmented Dickey-Fuller Unit Root Test in Level for Logarithmic BTC/EUR, ETH/EUR and EUR

		t-Statistic	Probability	Hypothesis
The Augmented Dickey-Fuller Test	**Level**	-1.232721	0.6621	Ho Not Reject
LNBTC	*1%*	-3.436809		
	5%	-2.86428		
	10%	-2.568281		
		-2.048169	0.2663	Ho Not Reject
LNETH	*1%*	-3.436809		
	5%	-2.86428		
	10%	-2.568281		
		-1.725488	0.4181	Ho Not Reject
LNEUR	*1%*	-3.436809		
	5%	-2.86428		
	10%	-2.568281		

The equivalence of ADF Unit Root test;

If $Ho \geq 5\%$, $Ho\ not\ reject$ else $Ho < 5\%$, $Ho\ Reject$ (6.2)

For BTC/EUR, ETH/EUR and EUR logarithmic series; the absolute value of the 5% significance level is greater than the critical value. Therefore, the hypothesis cannot be rejected. All series are non-stationary at level because probability is greater than 5%.

Table 6.2. The Augmented Dickey-Fuller Unit Root Test in First Difference for Logarithmic BTC/EUR, ETH/EUR and EUR

		t-Statistic	Probability	Hypothesis
The Augmented Dickey-Fuller Test	**Level**	-31.24104	0.0000	Ho Reject
D(LNBTC)	*1%*	-3.436816		
	5%	-2.864283		
	10%	-2.568283		
		-29.97468	0.0000	Ho Reject
D(LNETH)	*1%*	-3.436816		
	5%	-2.864283		
	10%	-2.568283		
		-31.84818	0.0000	Ho Reject
D(LNEUR)	*1%*	-3.436816		
	5%	-2.864283		
	10%	-2.568283		

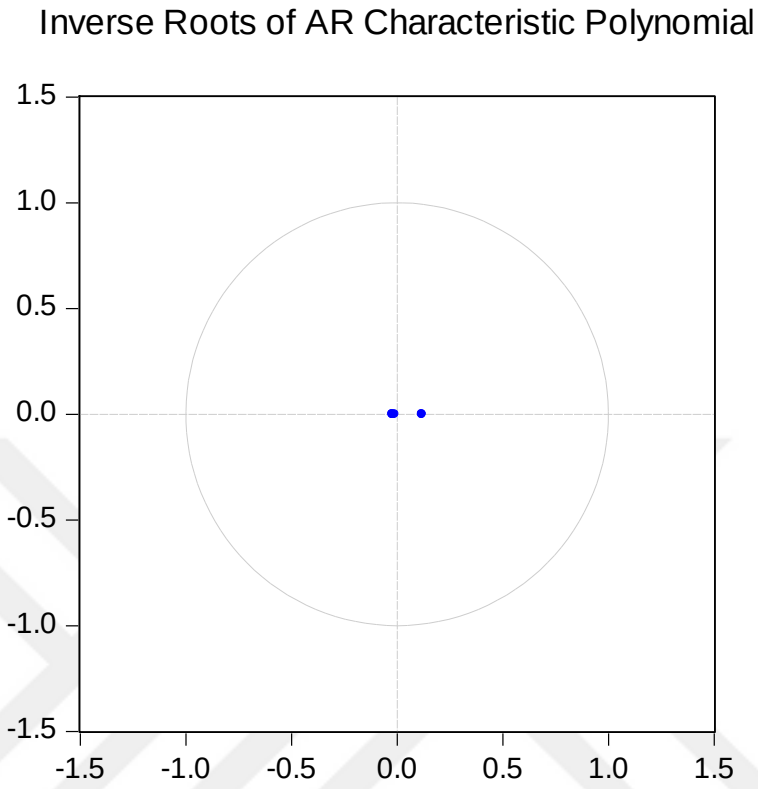
For BTC/EUR, ETH/EUR and EUR index logarithmic series; the absolute value of at the 5% significance level is smaller than the critical value. Therefore, the hypothesis is rejected.

All series are stationary at first differance because probability is 0%. The first difference of the stationary export series at the level has become stationary.

It indicates the level at which the variables become non-stationary at 5% significance level.

In order to be able to understand more clearly, it is possible to observe the series with the AR Characteristic Polynomial test applied in the first differential.

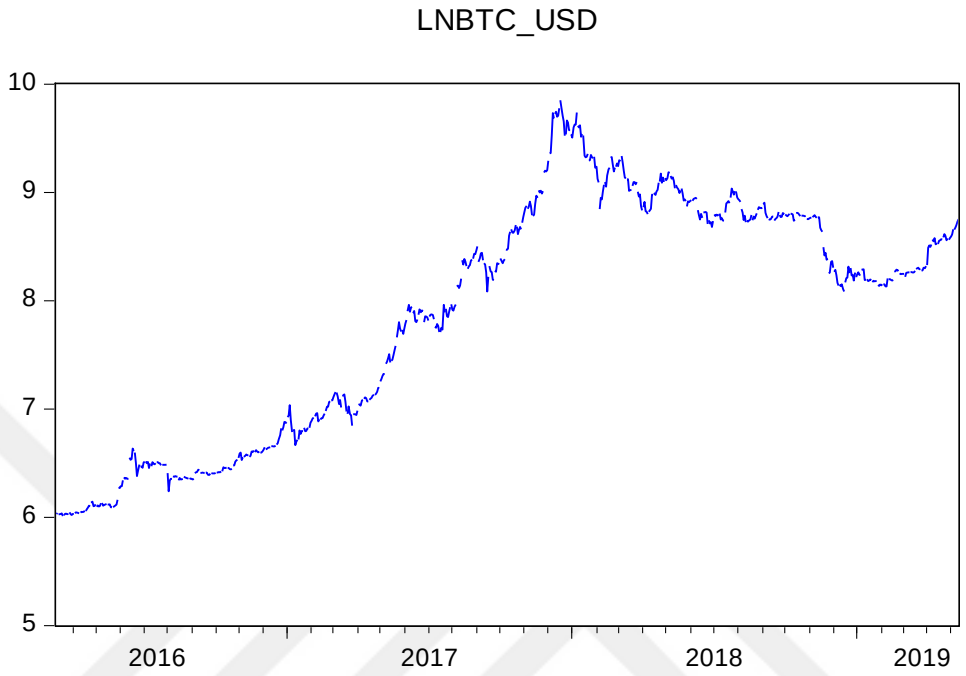
Figure 6.1. AR Characteristic Polynomial Test View



6.2.2. The Augmented Dickey-Fuller Stationary Test for USD Currency Basis

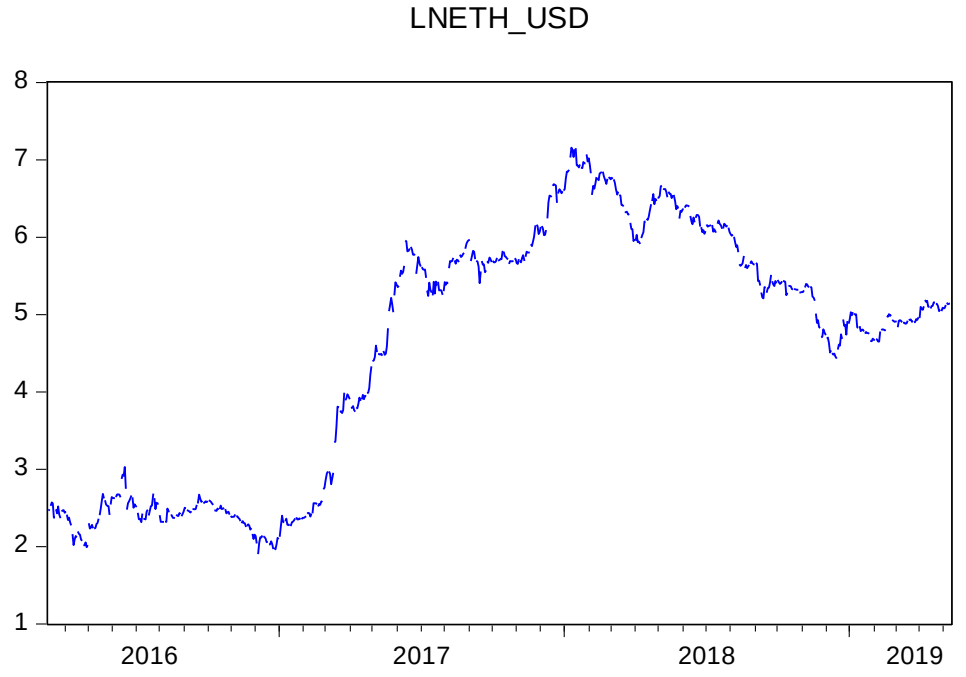
USD is the second traditional currency selected for analysis. The assessment of the stability test results according to the USD is evaluated. The graphs used for the determination of stationary are composed of working day data from 03/10/2016 to 5/10/2019.

Chart 6.4. Logarithmic BTC/USD Variance Graph



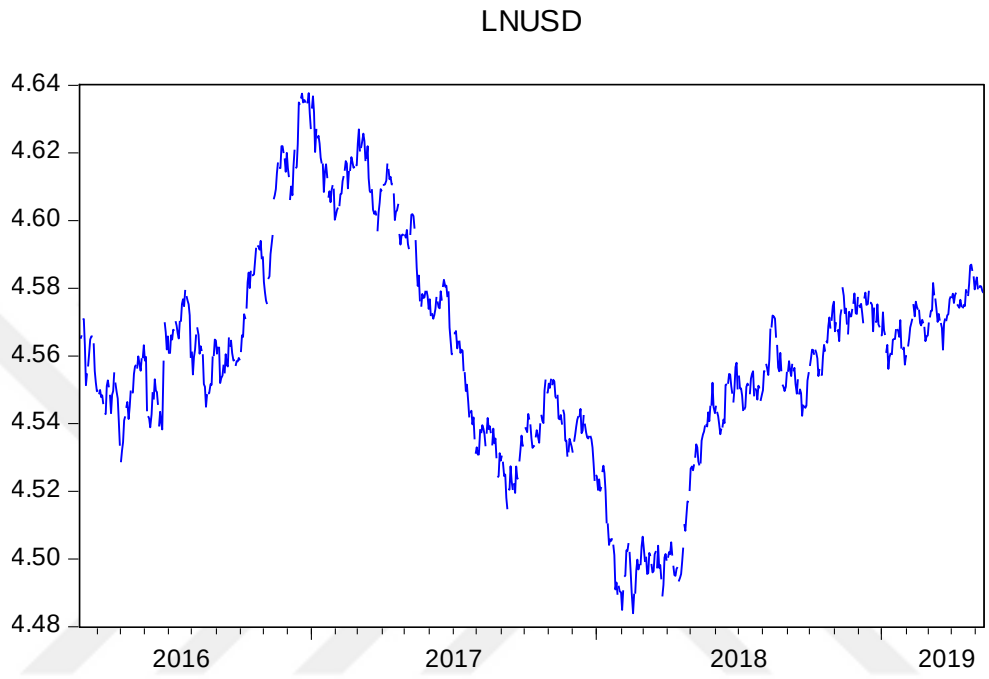
It is observed that BTC / USD series is not visually stationary in the logarithmic graph. There is a fluctuation of the descent.

Chart 6.5. Logarithmic ETH/USD Variance Graph



It was observed that it was not visually stationary for another cryptocurrency ETH/ USD based on the analysis.

Chart 6.6. Logarithmic USD Index Variance Graph



It was observed that the first traditional currency which is the subject of causation, the USD index, is not stationary and has a continuous fluctuation.

According to the Augmented Dickey-Fuller (ADF) Unit Root tests which were done by taking logarithmic results, the following results were reached.

Table 6.3. The Augmented Dickey-Fuller Unit Root Test in Level for Logarithmic BTC/USD, ETH/USD and USD

		t-Statistic	Probability	Hypothesis
The Augmented Dickey-Fuller Test	**Level**	-1.521456	0.5224	Ho Not Reject
LNBTC	*1%*	-3.438033		
	5%	-2.864821		
	10%	-2.568571		
		-1.255444	0.6518	Ho Not Reject
LNETH	*1%*	-3.438033		
	5%	-2.864821		
	10%	-2.568571		
		-1.677035	0.4426	Ho Not Reject
LNUSD	*1%*	-3.438033		
	5%	-2.864821		
	10%	-2.568571		

For this test; the equivalence of ADF Unit Root test;

If $Ho \geq 5\%$, $Ho\ not\ reject$ else $Ho < 5\%,\ Ho\ Reject$ (6.3)

For BTC/USD, ETH/USD and USD index series; the absolute value of the 5% significance level is greater than the critical value. Therefore, the hypothesis cannot be rejected. All series are non-stationary at level because probability is greater than 5%.

Table 6.4. The Augmented Dickey-Fuller Unit Root Test in First Difference for BTC/EUR, ETH/EUR and EUR

		t-Statistic	Probability	Hypothesis
The Augmented Dickey-Fuller Test	**Level**	-28.46113	0.0000	Ho Reject
D(LNBTC)	*1%*	-3.438042		
	5%	-2.864825		
	10%	-2.568573		
		-27.5261	0.0000	Ho Reject
D(LNETH)	*1%*	-3.438042		
	5%	-2.864825		
	10%	-2.568573		
		-29.15554	0.0000	Ho Reject
D(LNUSD)	*1%*	-3.438042		
	5%	-2.868250		
	10%	-2.568573		

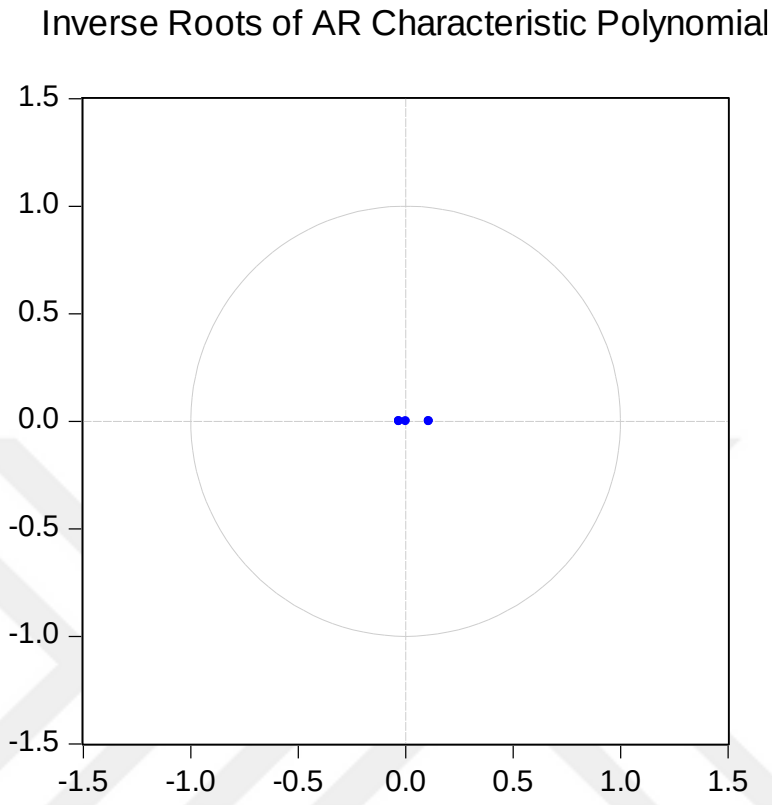
For BTC/USD, ETH/USD and USD logarithmic series; the absolute value of at the 5% significance level is smaller than the critical value. Therefore, the hypothesis is rejected.

All series are stationary at first differance because probability is 0%. The first difference of the stationary export series at the level has become stationary.

It indicates the level at which the variables become non-stationary at 5% significance level.

In order to be able to understand more clearly, it is possible to observe the series with the AR Characteristic Polynomial test applied in the first differential.

Figure 6.2. AR Characteristic Polynomial Test View



6.3. Vector Autoregressive (VAR) Model Description

VAR analysis estimation is the next stage of ADF tests. Thus, it can be determined whether there is a relationship between the variables. The relationship of the variables examined daily can be found with the VAR test. The finding of the relationship allows the transition to the next stage, Granger Causality analysis.

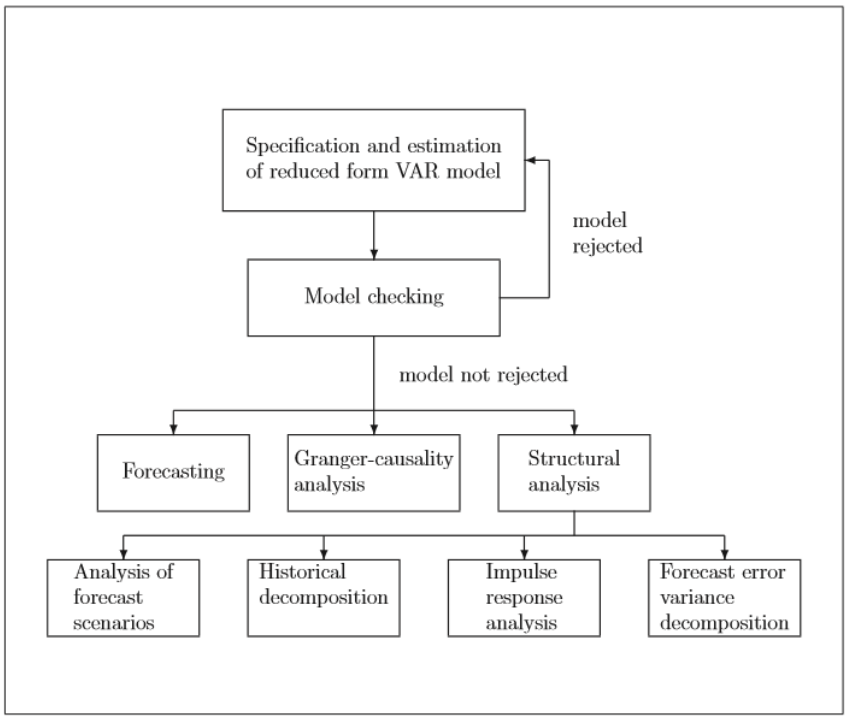
Vector Autoregressive (VAR) models have a long tradition as tools for multiple time series analysis (Qunouille, 2017).

Being linear models, they are relatively easy to work with both in theory and pratice. Although the related computations are relatively straight-foward, they are suffciently involved to make applied work cumberstone before powerful computers were in widespread use. VAR models become popular for economic analysis when

Sims (1980) advocated them as alternatives to simultaneous equations models (Lutkepohl, 2007).

VAR models, pioneered by Chris Sims about 25 years ago, have acquired a permanent place in the toolkit of applied macroeconomists both to summarize the information contained in the data and to conduct certain types of policy experiments (Canova, 2007).

Figure 6.38. Vector Autoregressive Model Analysis



Source: Vector Autoregressive Model, 2011

Luetkepohl (2007) describe VAR model and relation between VAR and Granger-causality as follows (econometric analysis with vector autoreg models); "VAR model also open up the possibility for analyzing the relation between the variables involved. Analyzing the casual relations is of particular interest. Granger (1969) presented a definition of causality in the time series context which has become quite popular in applied work. He called a variable y_{1t} casual for a variable y_{2t} if the information in y_{1t} is helpful for improving teh forecasts of y_{2t}. Because this is a

special concept of causality, it is often referred to as Granger- causality." In a bivariate VAR(p) setting,

$$\begin{pmatrix} y_{1t} \\ y_{2t} \end{pmatrix} = \sum_{i=1}^{p} \begin{bmatrix} a_{11,i} & a_{12,i} \\ a_{21,i} & a_{22,i} \end{bmatrix} \begin{pmatrix} y_{1,t-i} \\ y_{2,t-i} \end{pmatrix} + u_t, \tag{6.4}$$

it turns out that y_{1t} is not Granger – causal for variable y_{2t} if and only if

$$a_{21,i} = 0 \qquad i = 1, 2, \dots, p,$$

that is, if it does not appear in the y_{2t} equation of the model.

In order to build VAR model and do the Granger Causality Test, the Lag Length should be determined. Therefore, the accuracy rate of the test would be better.

6.3.1. VAR Lag Order Selection

Choosing VAR models to maintain estimates of impulse responses in experimental macroeconomics is generally used. Selecting the Var lag order is one of the most important steps for this type estimations. Selecting the order of the autoregression is another one of the most important steps for the same used data to construct the impulse response estimates. Usually, selecting the lag-order by some pre-specified criterion and conditioning on this estimate in constructing the impulse response estimates are the general strategy in empirical studies (Ivanov & Kilian, 2005).

AIC is a powerful model selection criterion used to compare different sized models. This criterion is also a sample loss of accuracy resulting from the use of parameter measurement estimations for different samples.

Smallest AIC model is the best model when a is the maximum value of the model's likelihood function and k is the estimated number of parameters. AIC is not only selected sample size but also selected sample size valid for future forecasting. Akaike (1978) defined AIC information criterion as follows (Akyüz, 2018).

$$AIC = -2\ln(\hat{L}) + 2k \tag{6.5}$$

$\hat{L}$; Maximum value of the model's likelihood function

k; Estimated number of parameters

Definition of Schwarz Information Criterion (SIC);

$$SIC = -2\ln(\hat{L}) + \ln(n)\,k \tag{6.6}$$

n; Number of observation

The SIC is more careful edited in assessing the situation than AIC when new variables are added to the model (Akyüz, 2018).

The tests would be done with using lag lenght 1 and lag lenght 8 while AIC and SC criterions will be taken into consideration, because these are the most efficient criterions for determining lag lenght. Even though, the other criterions are verified, the main ones are always AIC and SC.

For the variables taken into consideration in EUR, two tests were performed to determine the length of the lag as a result of the analysis performed in EViews. Firstly, lag length was considered to be 1 and secondly, lag length was taken as 8.

When lag length is set to 1; LR, FPE, AIC, SC and HQ were determined in all criteria. It is the AIC (Akaike Information Criterion) with the lowest and most suitable value. In this respect, it is appropriate to carry out the tests in lag 1. Total number of observation is 972.

Table 6.5. Lag Order Section for EUR Currency Basis – 1 Lag Length

Lag	SC	AIC	LR	FPE	HQ
0	-0.564217	-0.579191	NA	1.12E-04	-0.573494
1	**-14.36432***	**-14.42422***	13516.83*	1.09E-10*	-14.40143*

To be sure, the lag length is 8; again, the most appropriate criteria values are provided at lag 1. FPE, AIC, SC and HQ criteria have the lowest values. Especially, the AIC has the lowest value at lag 1. Total number of observation is 972.

Table 6.6. Lag Order Section for EUR Currency Basis – 8 Lag Length

Lag	SC	AIC	LR	FPE	HQ
0	-0.567199	-0.582259	NA	0.000112	-0.576527
1	**-14.44205***	**-14.50229***	13492.52	1.01E-10*	-14.47937*
2	-14.39531	- 14.50073	16.35884	1.01E-10	-14.46061
3	-14.33905	- 14.48964	7.151479	1.02E-10	-14.43233
4	-14.28105	- 14.47683	5.469570	1.04E-10	-14.40232
5	-14.23114	- 14.47209	13.177890	1.04E-10	-14.38039
6	-14.17715	- 14.46329	9.253890	1.05E-10	-14.35438
7	-14.13269	- 14.46400	18.27131	1.05E-10	-14.33790
8	-14.09068	- 14.46718	20.54737*	1.05E-10	-14.32389

For the variables in EUR, the most suitable lag length criteria is 1.

In the second stage, lag length should be determined for the variables in USD. Similarly, the results were firstly given to the lag criterion 1. When the results are considered, it is seen that the lowest values are provided in LR, FPE, AIC, SC and HQ. In order to determine the lag criteria correctly, lag value is given as 8 and the results will be examined. Total number of observation is 827.

Table 6.7. Lag Order Section for USD Currency Basis – 1 Lag Length

Lag	SC	AIC	LR	FPE	HQ
0	-0.226985	-0.244099	NA	0.000157	-0.237535
1	**-14.28840***	**-14.35686***	11632.72*	1.17E-10*	-14.33060*

As a result of the lag value of 8; It was seen that the most suitable criteria is provided by the first lag. Total number of observation is 820.

Table 6.8. Lag Order Section for USD Currency Basis – 8 Lag Length

Lag	SC	AIC	LR	FPE	HQ
0	-0.241048	-0.24278	NA	0.000155	-0.251667
1	**-14.30022***	**-14.36914***	11532.37*	1.15E-10*	-14.34269*
2	-14.24300	- 14.36361	13.35043	1.16E-10	-14.31733
3	-14.18550	- 14.35779	13.06905	1.17E-10	-14.29168
4	-14.12526	- 14.34924	10.81162	1.18E-10	-14.26329
5	-14.07157	- 14.34724	16.04288	1.18E-10	-14.24146
6	-14.00469	- 14.33204	5.409212	1.20E-10	-14.20643
7	-13.95152	- 14.33056	16.33904	1.20E-10	-14.18512
8	-13.89172	- 14.32245	10.99780	1.21E-10	-14.15717

As a result of the analysis in USD, lag length criteria will be used as 1. For both the EUR and USD exchange variables, the lag length will be 1 and the VAR estimation will be made.

6.3.2. VAR Series Equation Estimation

If we accept that Y is a dependent variable; we can write the connection formula with the X independent variable as follows:

$$Y = \beta_0 + \beta_1 X_1 + \cdots + \beta_i X_i + \varepsilon \tag{6.7}$$

ε; Error

β; Coefficient

$H_0 \leq 5\%$; H_0 reject, H_a accept (6.8)

Dependent variable is D(LNBTC/EUR) and independent variables are D(LNEUR) and C; for D(LNEUR) probability is 0.0099 and less than 5%; we reject H_0 and we accept H_a. Our hypothesis is significant at 1%. F-statistic probability and R-squared coefficient values are small.

When one unit increase in D(LNEUR), we expected D(LNBTC/EUR) to increase by -1.137. Another explanation for this situation; one unit increase in D(LNEUR) is expected to increase by -113% in D(LNBTC/EUR). And C is another constant. One unit increase in C is expected to increase by 0.33% in D(LNBTC/EUR).

Table 6.9. Least Squares Test for D(LNBTC/EUR) with D(LNEUR)

Variable	Coefficient	t-Statistic	Std. Error	Prob.	Hypothesis
C	0.003289	2.304994	0.001427	0.0214	Ho not reject
D(LNEUR)	-1.137881	-2.58506	4.40E-01	0.0099	Ho not reject
Prob. (F-Statistic)	0.009880				
F- Statistic	6.682536				
R- squared	0.006793				

Dependent variable is D(LNETH/EUR) and independent variables are D(LNEUR) and C; for D(LNEUR), the probability is 0.6908 which is greater than 5%, so we do not reject H_0. The probability of C is 0.0295 which is less than 5%, so we reject H_0 and we accept H_a. Our hypothesis is significant at 6% because F-statistic probability and R- squared coefficient values are small.

Table 6.10. Least Squares Test for D(LNETH/EUR) with D(LNEUR)

Variable	Coefficient	t-Statistic	Std. Error	Prob.	Hypothesis
C	0.005567	2.179983	0.002554	0.0295	Ho not reject
D(LNEUR)	-0.313446	-0.397863	7.88E-01	0.6908	Ho reject
Prob. (F-Statistic)	0.690818				
F- Statistic	0.158295				
R- squared	0.000162				

Dependent variable is D(LNBTC/USD) and independent variables are D(LNUSD) and C; for D(LNUSD), the probability is 0.8357 which is greater than 5%, so we do not reject H_0. the probability of C is 0.0383 which is less than 5%, so we reject H_0 and we accept H_a. Our hypothesis is significant at 8% because F-statistic probability and R- squared coefficient values are small.

Table 6.11. Least Squares Test for D(LNBTC/USD) with D(LNUSD)

Variable	Coefficient	t-Statistic	Std. Error	Prob.	Hypothesis
C	0.003292	2.0744767	0.001586	0.0383	Ho not reject
D(LNUSD)	0.085402	0.207408	4.12E-01	0.8357	Ho not reject
Prob. (F-Statistic)	0.835743				
F- Statistic	0.043018				
R- squared	0.000052				

Dependent variable is D(LNETH/USD) and independent variables are D(LNUSD) and C; for D(LNUSD), the probability is 0.5093 which is greater than 5%; so we do not reject H_0. The probability of C is 0.0383 which is less than 5%; so we reject H_0 and we accept H_a. Our hypothesis is significant at 5% because F-statistic probability and R- squared coefficient values are small.

Table 6.12. Least Squares Test for D(LNETH/USD) with D(LNUSD)

Variable	Coefficient	t-Statistic	Std. Error	Prob.	Hypothesis
C	0.003261	1.31355	0.002482	0.1894	Ho not reject
D(LNUSD)	-0.425313	-0.66014	6.44E-01	0.5093	Ho not reject
Prob. (F-Statistic)	0.509347				
F- Statistic	0.435787				
R- squared	0.000528				

6.3.3. Data VAR Estimation

It is the model used to reveal the interactions of variables that are thought to be in mutual relation with each other. The priority is to establish the VAR model in EViews according to the specified lag length.

For the EUR model, there are two models which are D(LNBTC / EUR) and D(LNETH / EUR), on the other hand, for the USD model, there are also two models which are D(LNBTC / USD) and D(LNETH / USD). These 4 models will be examined in 1 lag lengths.

The values that are shown with in the sembols "[ ]" are t-statistic values. When the Critical value is taken between -1.96 and 1.96, the other values would be significant

at 5%. However, because of the values of t-statistic is not with these interval, they are not significant.

Table 6.13. D(LNBTC/EUR) and D(LNEUR) VAR Estimates Results Table

Independent Variables	Dependent Variables	
	DBTC	**DEUR**
DBTC (-1)	-0.00087 (0.03214) [-0.02707]	-1.59E-03 (0.00233) [-0.68341]
DEUR (-1)	-0.131321 (0.44360) [-0.29603]	-2.05E-02 (0.03210) [-0.68341]
C	0.003214 (0.00144) [2.23583]	6.58E-05 (0.00010) [0.63216]
R- squared	0.000090	0.000827

Number of total observations is 978. We could not find any significant effect of EUR on BTC/EUR.

Table 6.14. D(ETH/EUR) and D(EUR) VAR Estimates Results Table

Independent Variables	Dependent Variables	
	DETH	**DEUR**
DETH (-1)	0.049846 (0.03170) [-1.57225]	1.53E-03 (0.00130) [1.17481]
DEUR (-1)	-0.468156 (0.78074) [-0.59963]	-1.82E-02 (0.03198) [-0.56810]
C	0.004965 (0.00254) [1.95623]	5.21E-05 (0.00010) [0.50127]
R- squared	0.002921	0.001761

Number of total observations is 978. We could not find any significant effect of EUR on ETH/EUR.

Table 6.15. D(BTC/USD) and D(USD) VAR Estimates Results Table

Independent Variables	Dependent Variables	
	DBTC	**DUSD**
DBTC (-1)	0.008373 (0.03486) [0.24019]	4.43E-03 (0.00294) [1.50969]
DUSD (-1)	0.115137 (0.41225) [0.27929]	-1.59E-02 (0.03481) [-0.45728]
C	0.003258 (0.00159) [2.04478]	8.83E-07 (0.00013) [0.00656]
R- squared	0.000166	0.003002

Number of total observations is 826. We could not find any significant effect of USD on BTC/USD.

Table 6.16. D(ETH/USD) and D(USD) VAR Estimates Results Table

Independent Variables	Dependent Variables	
	DETH	**DUSD**
DETH (-1)	0.04194 (0.03483) [1.19823]	-9.32E-04 (0.00188) [-0.49507]
DUSD (-1)	-0.156816 (0.64480) [-0.24320]	-1.59E-02 (0.03486) [-0.45696]
C	0.003105 (0.00249) [1.24797]	1.08E-02 (0.00013) [0.13705]
R- squared	0.001830	0.000539

Number of total observations is 826. We could not find any significant effect of USD on ETH/USD.

6.4. Granger Causality Analysis Description

Statistically, causality is the future estimated values of a time series variable are obtained by being influenced by the past values of itself or another related time series variable. Two deterministic processes are not enough to determine the causality. There needs to be a group of stochastic processes to determine the causality (Işığıçok, 1994).

In the meaning of Granger, the causality is expressed as a variable X, another Y variable, both X and Y information, while the Y variable is expressed in the sense of Granger only if it is estimated by the use of historical values of X. In other words, if the knowledge of the past values of the variable X allows for more precise predictions of Y, then the variable X is the reason for Granger Y variable (Takım, 2010).

The context of linear regression models is used to analyze the Granger Causality. For instance, consider a bivariate linear autoregressive model of two variables X_1 and X_2:

$$X_1(t) = \sum_{j=1}^{p} A_{11,j} X_1(t-j) + \sum_{j=1}^{p} A_{12,j} X_2(t-j) + E_1(t) \tag{6.7}$$

$$X_2(t) = \sum_{j=1}^{p} A_{21,j} X_1(t-j) + \sum_{j=1}^{p} A_{22,j} X_2(t-j) + E_2(t) \tag{6.8}$$

p; The maximum number of lagged observations included in the model (the model order)

A; Contains the coefficients of the model

E_1, E_2; Residuals (prediction errors) for each time series

If the variance of E_1 (or E_2) is reduced by the inclusion of the X_2 (or X_1) terms in the first (or second) equation, then it is said that X_2 (or X_1) Granger-(G)-

causes X_1 (or X_2). In other words, X_2 G-causes X_1 if the coefficients in A_{12} are jointly significantly different from zero (Seth, 2007).

Granger's definition of causality is based on the following two assumptions (Gayaker, 2015).

- The cause of the past can not be the future. When the past causes the future or present, it is possible to have a certain or full causality
- For the reason of a group of stochastic processes can only determine causality, the causality between deterministic processes can not be decided.

In the Granger Causality Analysis, causality can be from X to Y and from Y to X. In the equation (6.7), the causality from X to Y is indicated by the causality from (6.8) and the causality from Y to X.

6.4.1. Granger Causality Analysis

The hypothesis we have established for Granger Causality Analysis is as follows;

X_t and Y_t are variables; if prediction successful made with $X_t = (X_{t-1}, Y_{t-1})$ is better than prediction success made with $X = f(X_{x-1})$, we can say Y_t is the cause of X_t. The Granger Causality Test Hypothesis as follows;

H_0; Y_t is not cause of X_t

H_a; Y_t is cause of X_t

If $H_0: \sum_{i=}^{n} X_t < 5\%$ Y_t is not cause of X_t (6.9)

$H_a: \sum_{i=}^{n} X_t > 5\%$ Y_t is cause of X_t

Table 6.17. D(LNBTC/EUR)-D(LNEUR) Granger Causality Analysis

Null Hypothesis	Obs	F-Statistic	Probability	Hypothesis
D(LNEUR)-D(LNBTC/EUR)	978	0.08763	0.7673	Ho not reject
D(LNBTC/EUR)-D(LNEUR)		0.46705	0.4945	Ho not reject

If the currency type is EUR and the lag length is 1; probability value of 0.7673 is greater than 5%, so Ho can not be rejected. In this case, we can say D(LNEUR) is not the cause of D(LNBTC/EUR).

If the currency type is EUR and the lag length is 1; probability value of 0.4945 is greater than 5%, so Ho can not be rejected. In this case, we can say D(LNBTC/EUR) is not the cause of the D(LNEUR).

Table 6.18. D(LNETH/EUR)-D(LNEUR) Granger Causality Analysis

Null Hypothesis	Obs	F-Statistic	Probability	Hypothesis
D(LNEUR)-D(LNETH/EUR)	978	0.35955	0.5489	Ho not reject
D(LNETH/EUR)-D(LNEUR)		1.38017	0.2404	Ho not reject

If the currency type is EUR and the lag length is 1; probability value of 0.5489 is greater than 5%, so Ho can not be rejected. In this case, we can say D(LNEUR) is not the cause of D(LNETH/EUR).

If the currency type is EUR and the lag length is 1; probability value of 0.2404 is greater than 5%, so Ho can not be rejected. In this case, we can say D(LNETH/EUR) is not the cause of D(LNEUR).

Table 6.19. D(LNBTC/USD)-D(LNUSD) Granger Causality Analysis

Null Hypothesis	Obs	F-Statistic	Probability	Hypothesis
D(LNUSD)-D(LNBTC/USD)	826	0.07800	0.7801	Ho not reject
D(LNBTC/USD)-D(LNUSD)		2.27915	0.1315	Ho not reject

If the currency type is USD and the lag length is 1; probability value of 0.7801 is greater than 5%, so Ho can not be rejected. In this case, we can say D(LNUSD) is not the cause of D(LNBTC/USD).

If the currency type is USD and the lag length is 1; probability value of 0.1315 is greater than 5%, so Ho can not be rejected. In this case, we can say D(LNBTC/USD) is not the cause of D(LNUSD).

Table 6.19. D(LNETH/USD)-D(LNUSD) Granger Causality Analysis

Null Hypothesis	Obs	F-Statistic	Probability	Hypothesis
D(LNUSD)-D(LNETH/USD)	826	0.05915	0.8079	Ho not reject
D(LNETH/USD)-D(LNUSD)		0.24509	0.6207	Ho not reject

If the currency type is USD and the lag length is 1; probability value of 0.8079 is greater than 5%, so Ho can not be rejected. In this case, we can say D(LNUSD) is not the cause of D(LNETH/USD).

If the currency type is USD and the lag length is 1; probability value of 0.6207 is greater than 5%, so Ho can not be rejected. In this case, we can say D(LNETH/USD) is not the cause of D(LNUSD).

CHAPTER 7

CONCLUSION

In conclusion, investigation of a causality relationship between the USD Index and the EUR Index with Bitcoin (BTC) and Ethereum (ETH) is the main outline of this study. Firstly, data controls were made to determine causality. At the first test of the Augmented Dickey-Fuller (1976), all data turned to stationary at the Level Stage. Yet, I was expecting that the data would turn to stationary at First Differance Stage. Therefore, logarithmic types of the data were used with expecting the data would be stationary at First Differance. As I expected, logarithmic BTC / EUR, ETH / EUR, EUR index, BTC / USD, ETH / USD and USD index data sets were stationary in the First Difference of my test. Under these conditions the analysis was continued through the first differances of the data.

Another step for the VAR analysis and Granger Causality analysis is to determine the lag length to be used in the tests. AIC and SC criterias are most acceptable and important criterias to determine the lag length. When a value of 1 is given in EUR and USD; The AIC criterion and SC criterion values yielded the lowest and appropriate results. The most suitable lag length was found to be 1 in four of the results.

In order to find out the significant values of the data, I used “Least Squares” analysis. After the tests, the values that are between independent variables and dependent variable are detected.

With the predetermined lag length which is 1 and significant range of -1.96 to +1.96 for the Vector Autoregressive Estimation are used to find t-statistic values. Since t-statistic values were out of this range, no significant effect was found in any estimation. This situation shows that there is no significance between them.

Granger Causality Analysis (1969) is the main factor in the investigation of the desired causality relationship. During the analysis, it was observed that there was

no single or bidirectional causality relationship with BTC and ETH cryptocurrencies as a result of the tests carried out in EUR and USD.

First of all, starting with what money is, the historical development has reached to the cryptocurrencies and then the causality of the determined data by the analysis is investigated. The research shows that these two different types of currencies which are cryptocurrencies and traditional currencies are not connected and not interrelated. It is determined that the cryptocurrencies, which are called the money of the new age, act completely apart and does not have a causal relationship between other currencies.

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APPENDIX

APPENDIX A

Figure A.1. Price of United States Dollar (USD) Index for 5 Years

Source: investing.com

Figure A.2. Price of Euro Currency (EUR) Index for 5 Years

Source: investing.com

Figure A.3. Price of Bitcoin/USD (BTC/USD) Index for 5 Years

Source: investing.com

Figure A.4. Price of Ethereum/USD (ETH/USD) Index for All Times

Source: investing.com

Figure A.5. Price of Bitcoin/EUR (BTC/EUR) Index for 5 Years

Source: investing.com

Figure A.6. Price of Ethereum/EUR (ETH/EUR) Index for All Times

Source: investing.com

APPENDIX B

Figure B.1. Least Squares for BTC/EUR Currency Basis EViews Output

Dependent Variable: DLNBTC_EUR
Method: Least Squares
Date: 05/14/19 Time: 00:57
Sample (adjusted): 8/11/2015 5/10/2019
Included observations: 979 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
DLNEUR	-1.137881	0.440176	-2.585060	0.0099
C	0.003289	0.001427	2.304994	0.0214

R-squared	0.006793	Mean dependent var	0.003217
Adjusted R-squared	0.005777	S.D. dependent var	0.044764
S.E. of regression	0.044635	Akaike info criterion	-3.378556
Sum squared resid	1.946462	Schwarz criterion	-3.368573
Log likelihood	1655.803	Hannan-Quinn criter.	-3.374758
F-statistic	6.682536	Durbin-Watson stat	2.004922
Prob(F-statistic)	0.009880		

Figure B.2. Least Squares for BTC/USD Currency Basis EViews Output

Dependent Variable: DLNBTC_USD
Method: Least Squares
Date: 05/14/19 Time: 11:10
Sample (adjusted): 3/11/2016 5/10/2019
Included observations: 827 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
DLNUSD	0.085402	0.411758	0.207408	0.8357
C	0.003292	0.001586	2.074767	0.0383

R-squared	0.000052	Mean dependent var	0.003293
Adjusted R-squared	-0.001160	S.D. dependent var	0.045596
S.E. of regression	0.045623	Akaike info criterion	-3.334405
Sum squared resid	1.717184	Schwarz criterion	-3.322996
Log likelihood	1380.776	Hannan-Quinn criter.	-3.330029
F-statistic	0.043018	Durbin-Watson stat	1.983786
Prob(F-statistic)	0.835743		

Figure B.3. Least Squares for ETH/USD Currency Basis EViews Output

Dependent Variable: DLNETH_USD
Method: Least Squares
Date: 05/14/19 Time: 11:10
Sample (adjusted): 3/11/2016 5/10/2019
Included observations: 827 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
DLNUSD	-0.425313	0.644275	-0.660141	0.5093
C	0.003261	0.002482	1.313552	0.1894

R-squared	0.000528	Mean dependent var	0.003254
Adjusted R-squared	-0.000684	S.D. dependent var	0.071361
S.E. of regression	0.071386	Akaike info criterion	-2.439028
Sum squared resid	4.204113	Schwarz criterion	-2.427618
Log likelihood	1010.538	Hannan-Quinn criter.	-2.434652
F-statistic	0.435787	Durbin-Watson stat	1.917242
Prob(F-statistic)	0.509347		

Figure B.3. Least Squares for ETH/EUR Currency Basis EViews Output

Dependent Variable: DLNETH_EUR
Method: Least Squares
Date: 05/14/19 Time: 00:59
Sample (adjusted): 8/11/2015 5/10/2019
Included observations: 979 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
DLNEUR	-0.313446	0.787823	-0.397863	0.6908
C	0.005567	0.002554	2.179983	0.0295

R-squared	0.000162	Mean dependent var	0.005547
Adjusted R-squared	-0.000861	S.D. dependent var	0.079853
S.E. of regression	0.079887	Akaike info criterion	-2.214359
Sum squared resid	6.235198	Schwarz criterion	-2.204376
Log likelihood	1085.928	Hannan-Quinn criter.	-2.210560
F-statistic	0.158295	Durbin-Watson stat	1.881848
Prob(F-statistic)	0.690818		

APPENDIX C

Figure C.1. Lag Order Section Criteria for EUR Currency Basis 1 Lag EViews Output

VAR Lag Order Selection Criteria
Endogenous variables: LNBTC EUR LNETH EUR LNEUR
Exogenous variables: C
Date: 05/12/19 Time: 14:53
Sample: 8/10/2015 5/10/2019
Included observations: 979

Lag	LogL	LR	FPE	AIC	SC	HQ
0	286.5138	NA	0.000112	-0.579191	-0.564217	-0.573494
1	7072.654	13516.83*	1.09e-10*	-14.42422*	-14.36432*	-14.40143*

* indicates lag order selected by the criterion
LR: sequential modified LR test statistic (each test at 5% level)
FPE: Final prediction error
AIC: Akaike information criterion
SC: Schwarz information criterion
HQ: Hannan-Quinn information criterion

Figure C.2. Lag Order Section Criteria for EUR Currency Basis 8 Lags EViews Output

VAR Lag Order Selection Criteria
Endogenous variables: LNBTC EUR LNETH EUR LNEUR
Exogenous variables: C
Date: 05/12/19 Time: 14:53
Sample: 8/10/2015 5/10/2019
Included observations: 972

Lag	LogL	LR	FPE	AIC	SC	HQ
0	285.9777	NA	0.000112	-0.582259	-0.567199	-0.576527
1	7060.115	13492.52	1.01e-10*	-14.50229*	-14.44205*	-14.47937*
2	7068.353	16.35884	1.01e-10	-14.50073	-14.39531	-14.46061
3	7071.966	7.151479	1.02e-10	-14.48964	-14.33905	-14.43233
4	7074.738	5.469570	1.04e-10	-14.47683	-14.28105	-14.40232
5	7081.437	13.17789	1.04e-10	-14.47209	-14.23114	-14.38039
6	7086.157	9.253890	1.05e-10	-14.46329	-14.17715	-14.35438
7	7095.504	18.27131	1.05e-10	-14.46400	-14.13269	-14.33790
8	7106.049	20.54737*	1.05e-10	-14.46718	-14.09068	-14.32389

* indicates lag order selected by the criterion
LR: sequential modified LR test statistic (each test at 5% level)
FPE: Final prediction error
AIC: Akaike information criterion
SC: Schwarz information criterion
HQ: Hannan-Quinn information criterion

Figure C.3. Lag Order Section Criteria for USD Currency Basis 8 Lags EViews Output

VAR Lag Order Selection Criteria
Endogenous variables: LNBTC_USD LNETH_USD LNUSD
Exogenous variables: C
Date: 05/12/19 Time: 14:27
Sample: 3/10/2016 5/10/2019
Included observations: 820

Lag	LogL	LR	FPE	AIC	SC	HQ
0	108.8938	NA	0.000155	-0.258278	-0.241048	-0.251667
1	5903.346	11532.37*	1.15e-10*	-14.36914*	-14.30022*	-14.34269*
2	5910.078	13.35043	1.16e-10	-14.36361	-14.24300	-14.31733
3	5916.694	13.06905	1.17e-10	-14.35779	-14.18550	-14.29168
4	5922.186	10.81162	1.18e-10	-14.34924	-14.12526	-14.26329
5	5930.368	16.04288	1.18e-10	-14.34724	-14.07157	-14.24146
6	5933.136	5.409212	1.20e-10	-14.33204	-14.00469	-14.20643
7	5941.531	16.33904	1.20e-10	-14.33056	-13.95152	-14.18512
8	5947.203	10.99780	1.21e-10	-14.32245	-13.89172	-14.15717

* indicates lag order selected by the criterion
LR: sequential modified LR test statistic (each test at 5% level)
FPE: Final prediction error
AIC: Akaike information criterion
SC: Schwarz information criterion
HQ: Hannan-Quinn information criterion

Figure C.4. Lag Order Section Criteria for EUR Currency Basis 1 Lag EViews Output

VAR Lag Order Selection Criteria
Endogenous variables: LNBTC_EUR LNETH_EUR LNEUR
Exogenous variables: C
Date: 05/12/19 Time: 14:53
Sample: 8/10/2015 5/10/2019
Included observations: 979

Lag	LogL	LR	FPE	AIC	SC	HQ
0	286.5138	NA	0.000112	-0.579191	-0.564217	-0.573494
1	7072.654	13516.83*	1.09e-10*	-14.42422*	-14.36432*	-14.40143*

* indicates lag order selected by the criterion
LR: sequential modified LR test statistic (each test at 5% level)
FPE: Final prediction error
AIC: Akaike information criterion
SC: Schwarz information criterion
HQ: Hannan-Quinn information criterion

APPENDIX D

Figure D.1. BTC/EUR and EUR, VAR Estimates EViews Output

Vector Autoregression Estimates
Date: 05/10/19 Time: 21:16
Sample (adjusted): 8/12/2015 5/10/2019
Included observations: 978 after adjustments
Standard errors in ( ) & t-statistics in [ ]

	DBTC	DEUR
DBTC(-1)	-0.000870	-0.001589
	(0.03214)	(0.00233)
	[-0.02707]	[-0.68341]
DEUR(-1)	-0.131321	-0.020457
	(0.44360)	(0.03210)
	[-0.29603]	[-0.63724]
C	0.003214	6.58E-05
	(0.00144)	(0.00010)
	[2.23583]	[0.63216]
R-squared	0.000090	0.000827
Adj. R-squared	-0.001961	-0.001223
Sum sq. resids	1.959414	0.010262
S.E. equation	0.044829	0.003244
F-statistic	0.043821	0.403383
Log likelihood	1650.369	4218.593
Akaike AIC	-3.368852	-8.620845
Schwarz SC	-3.353866	-8.605859
Mean dependent	0.003203	5.94E-05
S.D. dependent	0.044785	0.003242

Determinant resid covariance (dof adj.)	2.10E-08
Determinant resid covariance	2.09E-08
Log likelihood	5872.346
Akaike information criterion	-11.99662
Schwarz criterion	-11.96665
Number of coefficients	6

Figure D.2. BTC/USD and USD, VAR Estimates EViews Output

Vector Autoregression Estimates
Date: 05/10/19 Time: 21:34
Sample (adjusted): 3/14/2016 5/10/2019
Included observations: 826 after adjustments
Standard errors in ( ) & t-statistics in [ ]

	DBTC	DUSD
DBTC(-1)	0.008373	0.004443
	(0.03486)	(0.00294)
	[0.24019]	[1.50969]
DUSD(-1)	0.115137	-0.015916
	(0.41225)	(0.03481)
	[0.27929]	[-0.45728]
C	0.003258	8.83E-07
	(0.00159)	(0.00013)
	[2.04478]	[0.00656]
R-squared	0.000166	0.003002
Adj. R-squared	-0.002264	0.000579
Sum sq. resids	1.716967	0.012239
S.E. equation	0.045675	0.003856
F-statistic	0.068340	1.239153
Log likelihood	1378.659	3420.413
Akaike AIC	-3.330894	-8.274607
Schwarz SC	-3.313764	-8.257476
Mean dependent	0.003287	1.51E-05
S.D. dependent	0.045624	0.003857

Determinant resid covariance (dof adj.)	3.10E-08
Determinant resid covariance	3.08E-08
Log likelihood	4799.092
Akaike information criterion	-11.60555
Schwarz criterion	-11.57129
Number of coefficients	6

Figure D.3. ETH/USD and USD, VAR Estimates EViews Output

Vector Autoregression Estimates
Date: 05/10/19 Time: 21:35
Sample (adjusted): 3/14/2016 5/10/2019
Included observations: 826 after adjustments
Standard errors in ( ) & t-statistics in [ ]

	DETH	DUSD
DETH(-1)	0.041740	-0.000932
	(0.03483)	(0.00188)
	[1.19823]	[-0.49507]
DUSD(-1)	-0.156816	-0.015928
	(0.64480)	(0.03486)
	[-0.24320]	[-0.45696]
C	0.003105	1.84E-05
	(0.00249)	(0.00013)
	[1.24797]	[0.13705]
R-squared	0.001830	0.000539
Adj. R-squared	-0.000595	-0.001890
Sum sq. resids	4.198449	0.012269
S.E. equation	0.071424	0.003861
F-statistic	0.754539	0.221877
Log likelihood	1009.373	3419.393
Akaike AIC	-2.436739	-8.272139
Schwarz SC	-2.419608	-8.255008
Mean dependent	0.003237	1.51E-05
S.D. dependent	0.071403	0.003857

Determinant resid covariance (dof adj.)	7.60E-08
Determinant resid covariance	7.55E-08
Log likelihood	4428.975
Akaike information criterion	-10.70938
Schwarz criterion	-10.67512
Number of coefficients	6

Figure D.4. ETH/EUR and EUR, VAR Estimates EViews Output

Vector Autoregression Estimates
Date: 05/10/19 Time: 21:20
Sample (adjusted): 8/12/2015 5/10/2019
Included observations: 978 after adjustments
Standard errors in ( ) & t-statistics in [ ]

	DETH	DEUR
DETH(-1)	0.049846	0.001526
	(0.03170)	(0.00130)
	[1.57225]	[1.17481]
DEUR(-1)	-0.468156	-0.018168
	(0.78074)	(0.03198)
	[-0.59963]	[-0.56810]
C	0.004965	5.21E-05
	(0.00254)	(0.00010)
	[1.95623]	[0.50127]
R-squared	0.002921	0.001761
Adj. R-squared	0.000875	-0.000286
Sum sq. resids	6.110075	0.010252
S.E. equation	0.079163	0.003243
F-statistic	1.428015	0.860106
Log likelihood	1094.232	4219.051
Akaike AIC	-2.231559	-8.621781
Schwarz SC	-2.216572	-8.606795
Mean dependent	0.005211	5.94E-05
S.D. dependent	0.079197	0.003242

Determinant resid covariance (dof adj.)	6.59E-08
Determinant resid covariance	6.55E-08
Log likelihood	5313.474
Akaike information criterion	-10.85373
Schwarz criterion	-10.82376
Number of coefficients	6

APPENDIX E

Figure E.1. BTC/EUR and EUR, VAR Estimates EViews Output

Pairwise Granger Causality Tests
Date: 05/10/19 Time: 21:22
Sample: 8/10/2015 5/10/2019
Lags: 1

Null Hypothesis:	Obs	F-Statistic	Prob.
DEUR does not Granger Cause DBTC	978	0.08763	0.7673
DBTC does not Granger Cause DEUR		0.46705	0.4945

Figure E.2. BTC/USD and USD, VAR Estimates EViews Output

Pairwise Granger Causality Tests
Date: 05/10/19 Time: 21:34
Sample: 3/10/2016 5/10/2019
Lags: 1

Null Hypothesis:	Obs	F-Statistic	Prob.
DUSD does not Granger Cause DBTC	826	0.07800	0.7801
DBTC does not Granger Cause DUSD		2.27915	0.1315

Figure E.3. ETH/USD and USD, VAR Estimates EViews Output

Pairwise Granger Causality Tests
Date: 05/10/19 Time: 21:35
Sample: 3/10/2016 5/10/2019
Lags: 1

Null Hypothesis:	Obs	F-Statistic	Prob.
DUSD does not Granger Cause DETH	826	0.05915	0.8079
DETH does not Granger Cause DUSD		0.24509	0.6207

Figure E.4. ETH/EUR and EUR, VAR Estimates EViews Output

Pairwise Granger Causality Tests
Date: 05/10/19 Time: 21:20
Sample: 8/10/2015 5/10/2019
Lags: 1

Null Hypothesis:	Obs	F-Statistic	Prob.
DEUR does not Granger Cause DETH	978	0.35955	0.5489
DETH does not Granger Cause DEUR		1.38017	0.2404